JOURNAL OF CRITICAL REVIEWS
ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

PERFORMANCE ANALYSIS OF PV BASED DC-AC CONVERTER FOR DIELECTRIC HEATING

S. D. Sundarsingh Jebaseelan[1], K.Vasanth[2], S. Jayaprakash[3], G.Ezhilarasi[4], C.N.Ravi[5], D.Lakshmi[6]

[1]School of EEE,Sathyabama Institute of Science and Technology,Chennai
[2]Department of E.C.E,Vidya Jyothi Institute of Technology,Hyderabad, Telengana
[3]School of EEE,Sathyabama Institute of Science and Technology,Chennai
[4]Asst.Professor / EEE,Sri Sairam Institute of Technology,Chennai, India.
[5]Department of E.E.E, Vidya Jyothi Institute of Technology,Hyderabad, Teleng
[6]Asso Professor /EEE,AMET Deemed to be an University, Chennai, India.

E-mail: sundargifta@gmail.com[1], vkbece@vjit.ac.in[2], jakash2109@gmail.com[3]
ezhilarasi.eee@sairamit.edu.in4, lakshmiee@gmail.com[5]

ABSTRACT: This paper proposes a new PV based DC/AC converter for a dielectric application which consists of a solar panel, SEPIC DC/DC converter, resonant inverter and a dielectric application such as dielectric heating. The output of the solar panel is low voltage hence SEPIC DC/DC converter is used to boost the voltage which is later fed to the resonant inverter to converter the DC/AC and the converted AC voltage is utilized for dielectric heating. This system is used for high power applications and provides a better performance in terms of rise, time settling. The comparison between open loop with and closed loop system along with and without disturbance is presented in this paper.

KEYWORDS: Dielectric heating, PV source, resonant inverter and SEPIC converter.

I. INTRODUCTION

Solar energy is considered has one of the most effective and promising source of energy due to its infinite power and availability. Even though fossil fuels as been the primary source of energy, their availability is limited on earth. Also, they deplete the environment. When it comes to cleanliness and safety solar energy is always the right choice. Now-a-days, most of the applications use AC power. Hence power conversion interface has become a basic need as solar panel that generates DC power output. Here, the generated solar power is utilized for the dielectric heating which is a high frequency load. Over the years many power circuits were proposed for these PV based configurations. Jinn chang wu et al[1] proposed a solar generation system which consists of solar cell array, DC-DC boost converter, transformer to split the boosted dc voltage which is then fed to capacitor section where the voltage is converted to three level voltage. This voltage is applied to full inverter circuit where it is converted to seven level. Soft switching is not available in this system hence the switching losses is more also this system not suitable for high frequency applications. Surya Kumari et al [2] proposed a PV energy conversion system with MPPT to track the maximum power point in which total harmonic distortion is measured. Samer Alsadi et al[3] proposed a MPPT simulation for PV based system using perturb and observe under different climatic conditions to verify the accuracy. It is observed that the maximum power point varies slightly with respect to the climatic condition which reduces the performance of the system. Shen et al[4] proposed grid connected power converter with negative grounding of PV generation system without transformer. More number of electronic switches is used and hence switching losses are high. Lekshmy Rajan et al[5] proposed a PV based system with cuk and PWM inverter using MPPT algorithm. This system also consists of high switching losses and has low efficiency.

Sowmya Smitha Raj et al[6] proposed a MPPT based zeta converter fed from PV cell array with a PWM inverter. The number of cycles used in PWM inverter to control the voltage is more so the performance of the system is affected. Mastramauro et al[7] proposed a PV system with power quality conditioner functionality with maximum power point tracking to control the phase of the PV inverter voltage. This system cannot be used for high power applications. Kumaresh et al[8] proposed a literature review on solar MPPT system which clearly explains the importance of MPPT in solar based system. Esram et al. [9] proposed incremental conductance method based MPPT technique to get the maximum power poin at all conditions. Jitty Abraham et al [10] proposed a pwm modulated and power factor correction of zeta converter for open loop and closed loop. It is to be noted that the performance of open loop system is poor compared to closed to system. Christo shijith et al[11] proposed speed control and power factor correction of BLDC motor using zeta converter. Swati et al.

[12] in order to obtain maximum power point, used current feedback with PI controller. The above literature does not deal with the comparison between open loop and closed loop controlled system. This work deals with modeling and comparison of open loop with and without disturbance and closed loop system. The paper is sectioned as follows: The section 1 deals with the introduction of the proposed system. The section 2 deals with the system configuration which includes the various components of the circuit. The section 3 deals with the various modes of operation. The section 4 deals with the simulation results and section 5 deals with the conclusion of the proposed system.

II. SYSTEM CONFIGURATION

The aim of the proposed system is to provide continuous constant output to the load which is obtained by use of maximum power point tracking algorithm. Here, constant reference voltage method is used in which the solar panel output voltage is compared with a reference voltage in order to maintain constant output. initially the open loop is presented below in figure 1. In the proposed system, low DC output voltage is generated by the solar panel. In order to boost the DC output voltage at desired voltage, the SEPIC DC/DC converter is used which performs both buck and boost operation as per the requirement. The boosted DC voltage is then applied to the resonant inverter to convert the DC voltage to AC voltage which is suitable for dielectric heating. Block Diagram of the proposed DC/AC converter for dielectric heating is shown in figure1.

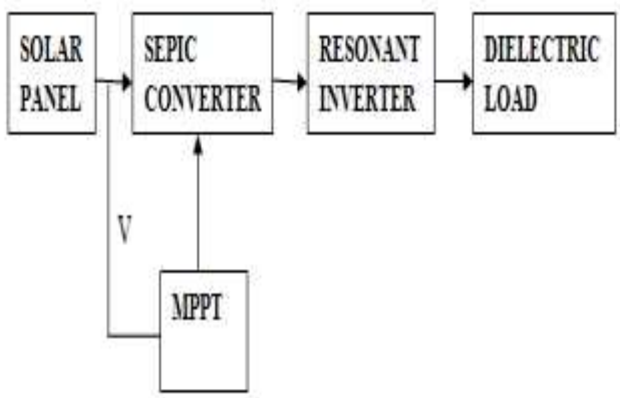


Figure.1. Block diagram of the proposed PV based DC/AC converter for dielectric application.

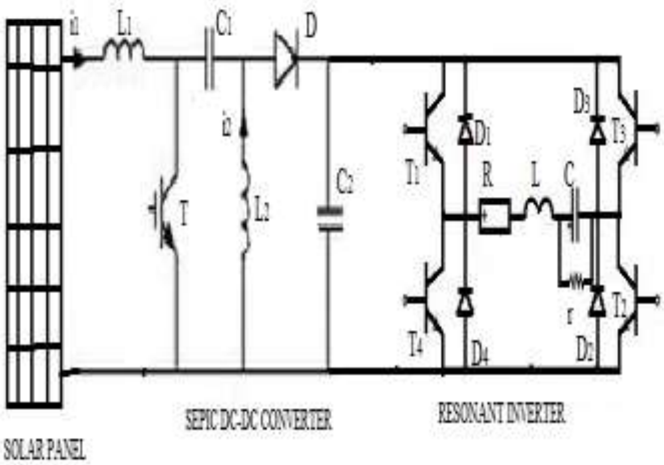


Figure 2. Configuration of the proposed DC/AC converter for dielectric heating.

The proposed PV system consists of a solar cell array, SEPIC converter and a resonant inverter and dielectric load. The resonant inverter consists of only four semiconductor switches, which simplifies the circuit configuration. Since dielectric heating is a high frequency application resonant inverter is used in the power conversion interface as shown in figure 2. The various sub units of the proposed block diagram is presented under different subdivisions.

A. Solar Panel

PV panel is used to generate electricity by using the solar energy from sun. The V-I characteristics is non linear and highly depends on the weather condition and sun's radiation. Solar cell developed in recent year has a high conversion efficiency of 31-35%. Variation in the sun's position will affect the output of the system hence in the proposed system; maximum power point tracking method (MPPT) is used to track the maximum power point in order to obtain the constant and maximum power output. In this system, sixteen solar cells have been used to generate electricity. The Fig.3 shows the Simulink model of solar panel. Equations 1, 2, 3, 4 gives the design equations pertaining to solar panel design.

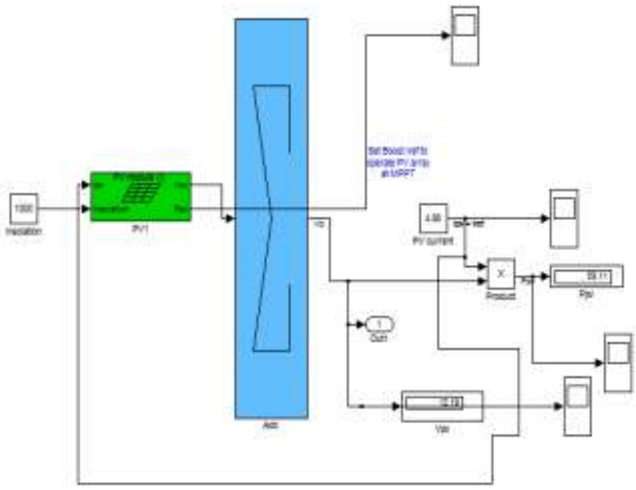


Fig.3. Simulink model of solar panel.

The fill factor can be calculated from the equation (1):

$$\text{Fill Factor} = V_{mp}\ I_{mp} / V_{oc}\ Isc \quad (1)$$

The maximum power can be calculated from the equation (2):

$$\text{Maximum Power } (P_{max}) = V_{mp}.\ I_{mp} \quad (2)$$

The number of cells and array can be calculated from the equation (3):

$$\text{Number of cell to get 12V} = V / V_{mp} \quad (3)$$

$$\text{Number of array} = I / I_{mp} \quad (4)$$

Where, V_{mp} - Solar cell array output voltage, I_{mp} – Solar cell array output current.

B. Maximum Power Point Tracking segment (MPPT)

The solar panel output varies drastically with respect to the change in weather condition and radiation of sun. In order to maintain constant and maximum power from the solar panel, the Maximum power point tracking algorithm is used. The constant reference voltage method is used here which has the advantage of simple operation, reduced cost and time saving. It is a very common method among the other techniques. The MPPT has the ability to increase the energy transferred from solar panel to the dielectric application. In the constant reference voltage method, the output voltage of the solar panel is compared with a reference voltage. If the solar panel output voltage is greater than the reference voltage then the pulse width is reduced. If the solar panel voltage is less than the reference voltage then the pulse width is increased. There is no change in the pulse width, if the solar panel output voltage and the reference voltage is same. Here the reference voltage is set as 30V. Fig.4 shows the flow chart of the MPPT algorithm.

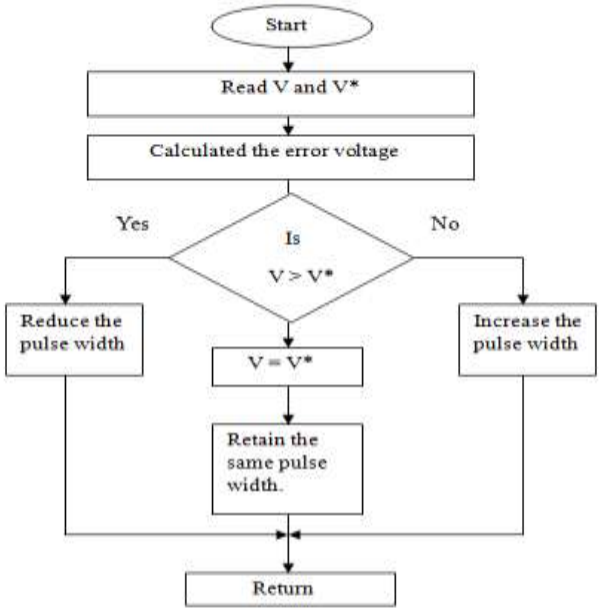


Fig.4. Flow chart for MPPT algorithm.

C. SEPIC Converter

The sepic converter is used for both buck and boost operation. It consists of a series connected inductor (L_1) and capacitor (C_1), parallel connected inductor (L_2) and capacitor (C_2), switch (T) and a diode (D). It has advantage of minimal active components with reduced noise. In the common conduction mode, the duty cycle is given by

Duty Cycle= (Vout/(vout+vin)) (5)

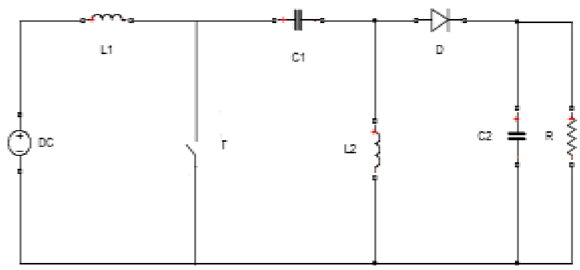


Fig.5.Sepic converter circuit diagram

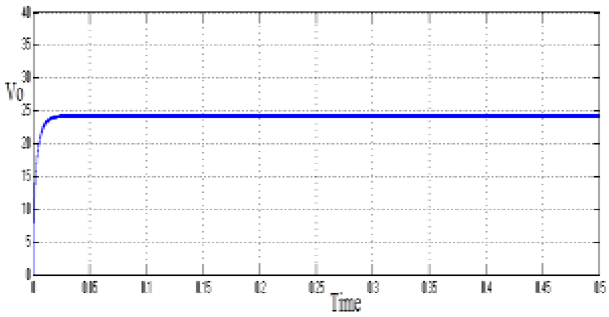


Fig.6.Sepic converter boosted output voltage

The circuit diagram of the SEPIC converter is given in figure 5 and the open loop simulation of the proposed technique is given in figure 6.

D. Dielectric Heating

Dielectric heating is a special method of converting electric energy to heat. It is a method of heating non-

JOURNAL OF CRITICAL REVIEWS
ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

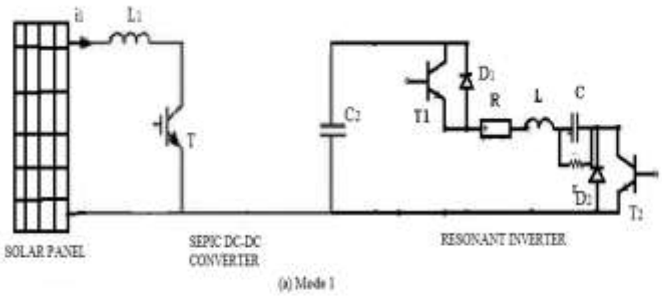
conductive materials. This method is often used in welding. The high frequency energy is connected to two electrodes between which the material to be heated is placed. The dielectric heating is also called as capacitive heating, electronic heating, RF heating, high frequency heating etc. For the dielectric heating, the generated power density per volume is given by the equation (6)

$$Q = W.\, \mathcal{E}_r\, .\mathcal{E}_0\, .E^2 \qquad (6)$$

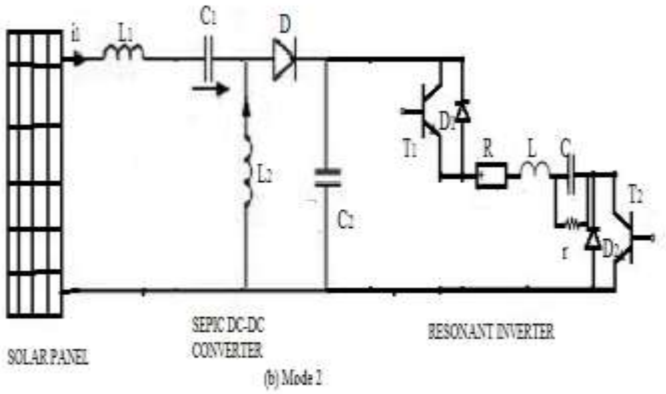
Where, W is the angular frequency of the excavating radiation, $\mathcal{E}_r$ is the imaginary part of the complex relative permittivity of the absorbing material, $\mathcal{E}_0$ is the permittivity of free space, E is the electric field strength.

III. PROPOSED POWER CIRCUIT CONFIGURATIONS

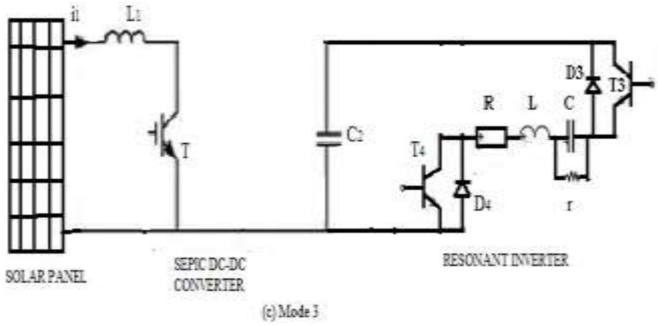
In this section the various modes of operation is explained using the Fig.7. There are four modes of operation and the operation of power converter interface is divided into negative half cycle and positive half cycle. The first two modes are mode 1and mode 2 for the positive half cycle and mode 3 and mode4 represent the negative half cycle of the inverter.



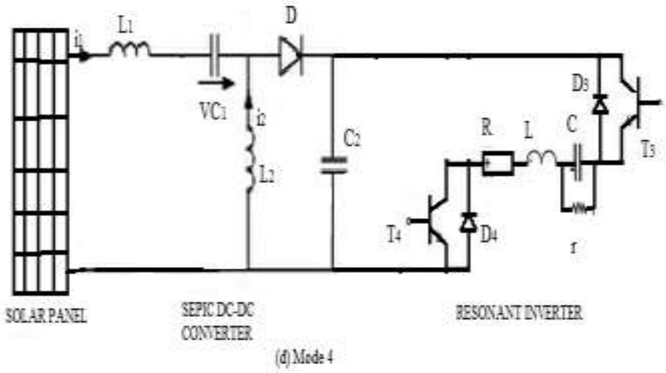
(a) Mode 1



(b) Mode 2



(c) Mode 3



(d) Mode 4

Fig.7. The modes of operation of the resonant inverter.
(a) Mode 1 (b) Mode 2 (c) Mode 3 (d) Mode 4.

Mode 1: The operation of mode 1 is shown in Fig.7 (a). In this mode, the switch (T) in the sepic DC/DC converter circuit is fired and the current i_1 starts flowing within the loop L1 and the switch (T). The stored charge in C_2 discharges through T1, load(R, L and C) and T2.

Mode 2: The operation of mode 2 is shown in Fig.7 (b). In this mode, the switch(T) in the sepic DC/DC converter circuit is turned off and the current i_1 now flows through L_1, C_1, diode, T_1, load and T_2 and capacitor is also charged.

Mode 3: The operation of mode 3 is shown in Fig.4(c). In this mode, the switch(T) in the sepic DC/DC converter is turned on and the current (i_1) flow through the closed loop L_1 and the switch. The stored charge in C_2 is discharged through T_3, load and T_4.

Mode 4: The operation of mode 4 is shown in Fig.4 (d). In this mode, the switch (T) is turned off and the current i_1 flow through L_1, C_1, diode, T_3, load and T_4.

IV. SYSTEM DESIGN EQUATIONS

The design equation for various components used in the circuit are discussed below where V_{pp} = 0.7, V_i = 12V, V_0 = 30V, F=20KHZ, L_0 = 50 micro Henry, I = 5A, R= 0.06%, n= V_i / V_0 = 0.4.

$$\text{Inductance (L)} = \frac{n2\,(1-D)^2.R}{2F} \quad (7)$$

$$= \frac{0.4^2\,(1 - 0.5)^2.\,5}{2 \times 20 \times 10^3} = 5\mu h$$

$$\text{Capacitance } (C_1) = \frac{D.\,V_0}{F.R.V_{pp}} \quad (8)$$

$$= \frac{0.5 \times 30}{20000 \times 5 \times 0.7} = 220 \times 10^{-6} = 220\mu f$$

$$\text{Ripple (R)} = \frac{1}{4\sqrt{3}.F.C_2.R} \quad (9)$$

$$6 \times 10^{-4} = \frac{1}{4\sqrt{3} \times 20 \times 10\sqrt{3} \times C2 \times 5}$$

$$C_2 = 2200\ \mu h$$

Where, F is Frequency in Hertz, C_1 is the Capacitance connected in series on the input side, C_2 is the Capacitance connected in parallel on the input side.

Let us assume,

Fifth harmonics (F5) = 5 F

$$F5 = \frac{1}{2\pi\sqrt{L_0 C_0}} \quad (10)$$

$$250 = \frac{1}{2\pi\sqrt{50\times 10^{6}\times C_0}}$$

$C_0 = 13\ \mu F$

$$\text{Loss in chokes } (W_c) = 2I^2 R_L \quad (11)$$

$$= 2\times5^2\times0.05 = 2.5W$$

$$\text{Loss in MOSFET } (W_m) = 3V_{ds}.I_{ds} \quad (12)$$

$$= 3\times0.1\times5 = 1.5W$$

$$\text{Loss in diode } (W_d) = V_d.I_d \quad (13)$$

$$= 0.7\times5 = 3.5W$$

$$\text{Efficiency} = \frac{P_0}{P_0+W_c+W_m+W_d}\times 100 \quad (14)$$

$$= 95.2\%$$

V. EXPERIMENTAL RESULTS & DISCUSSIONS

The simulation circuit for the open loop with and without disturbance and closed loop system are simulated using the MATLAB software and the computer used is of the specification intel(R) core(TM) i3-4005U CPU @1.70 GHz 1.70 GHz, 4GB installed memory and 64 bit operating system.

Fig.8.1 shows the simulink model of the open loop system for dielectric heating and the obtained output voltage, output current and output power for open loop system with and without disturbance is shown in the Fig.8.2 and Fig.8.3. The closed loop system simulink model is shown in Fig.9.1 and the obtained output voltage, output current and output power is shown in the Fig.9.2.

In this paper, the open loop system with and without disturbance and closed loop system is compared. From the output waveforms of open loop system with disturbance and closed loop system, it is observed that the settling time of the closed loop system is less compared to other systems hence it provides better performance and constant output.

MATLAB/SIMULINK OPEN LOOP MODEL OF THE PV BASED DC-AC CONVERTER FOR DIELECTRIC APPLICATION

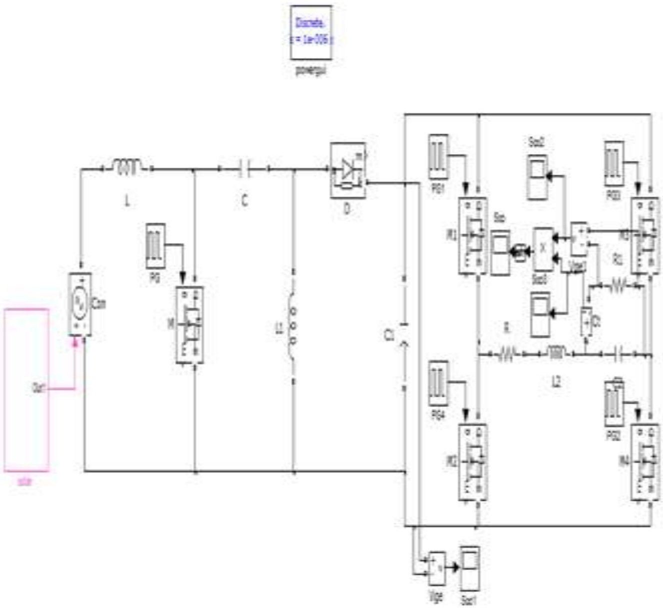


Fig.8.1. Simulink model of the open loop system for dielectric application.

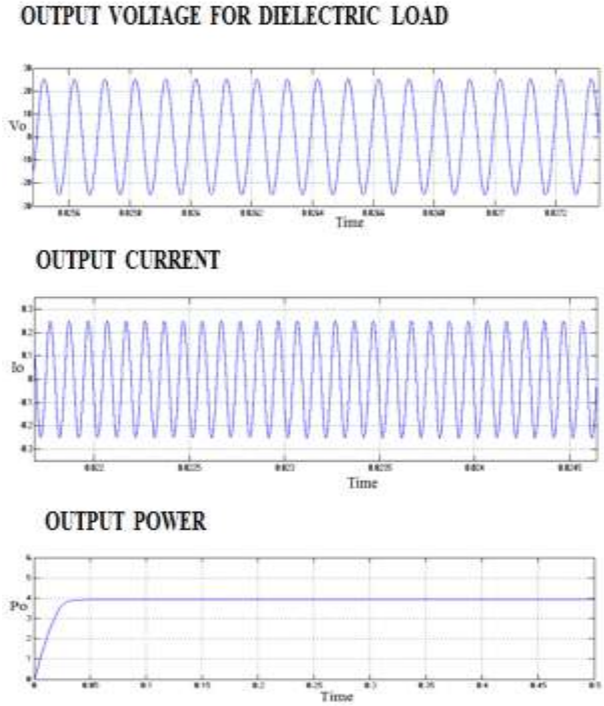


Fig.8.2. Open loop output voltage, current and power for dielectric load.

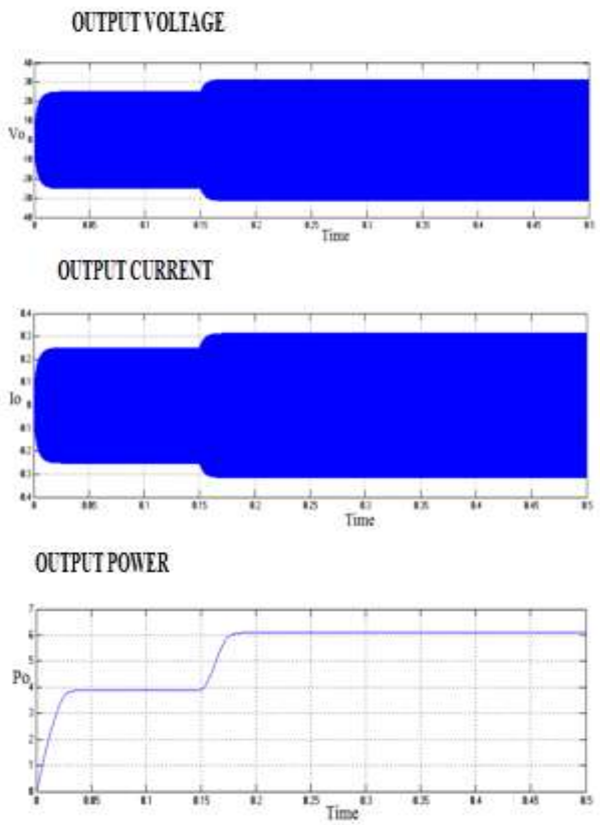


Fig.8.3. Open loop output voltage, current and power with disturbance for dielectric load.

MATLAB/SIMULINK CLOSED LOOP MODEL OF THE PV BASED DC-AC CONVERTER WITH PI CONTROLLER FOR DIELECTRIC APPLICATION

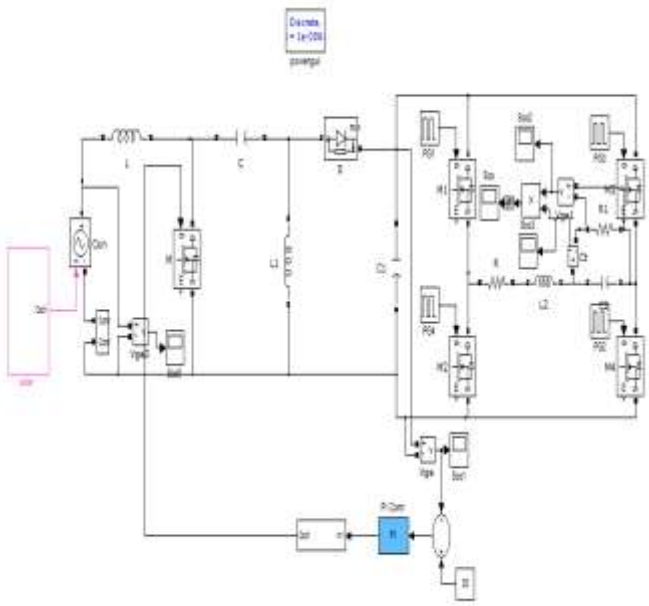


Fig.9.closed loop system simulation model.

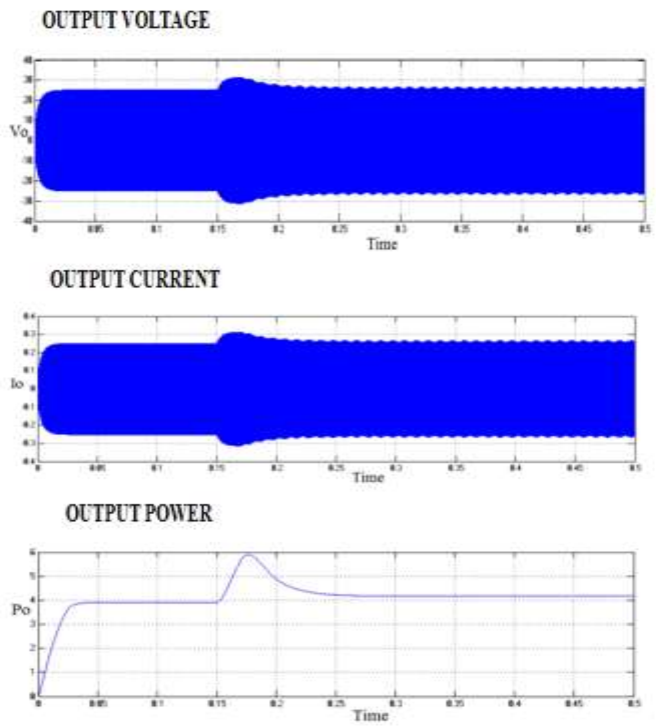


Fig.9.2. closed loop output voltage, current and output power with disturbance for dielectric load.

TABLE I
INPUT VOLTAGE, OUTPUT VOLTAGE, OUTPUT CURRENT AND OUTPUT POWER OF OPEN LOOP WITH AND WITH DISTURBANCE AND CLOSED LOOP SYSTEM

SYSTEM	Input voltage in volts	Output voltage in volts	Output current in amps	Output power in watts
OPEN LOOP	12	25	0.25	4
OPEN LOOP WITH DISTURBANCE	12	30	3	6
CLOSED LOOP	12	25	0.25	4

TABLE II
Rise time , Settling Time, Peak Time, Peak Voltage and Estimated Steady state.

SYSTEM	Raise Time in ms T_r	Settling Time in ms T_s	Peak Time in ms T_p	Peak Voltage in volts V_p	Estimated steady state E_{ss}
OPEN LOOP	0.023	0.27	0.16	6	0.45
CLOSED LOOP	0.015	0.24	0.15	2.6	0.4

Table I, describes the input voltage, output voltage, output current and output power for open loop with and without disturbance and closed loop. When 12V input is applied to open loop system without disturbance, the observed output voltage is 25V, output current is 0.25A and output power is 4W but when step disturbance is applied at the input side, it is observed that there is sudden change in the output voltage, current and power

which affects the system stability. The main aim of the proposed system is to provide constant output. In case of the closed loop system, it is observed that the output is not affected with respect to the disturbance.
Further, we can see from Table II that the raise time, settling time, peak time, peak voltage and the estimated settling ratio of the closed loop is less compared to open loop system which increases the performance of the closed loop system and constant output power is achieved.

The gain of the proportionality (K_p) and gain of the voltage integrated (K_v) are given by the equation below:

$$K_p = \frac{1}{E_{ss}} - 1 = \frac{1- 0.4}{0.4}$$

$$K_v = \frac{1}{0.4} = 2.5$$

VI.CONCLUSION

This paper proposes a PV based DC/AC converter for a dielectric load. It is composed of the following components: (1) Solar cell array (2) Sepic converter (3) Resonant inverter (4) Dielectric heating. Since the output voltage of the solar cell array is low, it is boosted using the sepic DC/DC boost converter and then it is fed to the high frequency resonant inverter to convert the DC to AC and it is applied to the dielectric application. A battery can also be used on the dc side to store the excess power generated. The main idea of this paper is to achieve constant output and reduce the steady state error hence PI controller is used in the closed loop system. Here, the performance of the open loop with and without disturbance and closed loop system is compared.

VII. REFERENCES

[1] Jinn-chang wu and Chia-wei chou,“A solar power generation system with a seven level inverter” IEEE transactions on power electronics, vol. 29, no.7, july 2014.
[2] J.Surya kumari and CH.Saibabu,”Maximum Power Point Tracking Algorithms for GridConnected Photovoltaic Energy Conversion System,” International Journal of Power Electronics and Drive System (IJPEDS) Vol. 3, No. 4, December 2014.
[3] Samer Alsadi, Basim Alsayid, “Maximum power point tracking algorithm for grid connected pv energy conversion system,” International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 6, December 2012.
[4] J.-M. Shen, H. L. Jou, and J. C. Wu, “Novel transformer-less gridconnected power converter with negative grounding for photovoltaic generation system,” IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1818– 1829, Apr. 2012.
[5] Lekshmy Rajan and R.Pradeep,” Performance analysis of maximum power tracking based photovoltaic mdule with cuk converter for electric application,” International Electrical Engineering Journal (IEEJ) Vol. 4 (2013) No. 1, pp. 992-999.
[6] N.Sowmya Smitha Raj and B. Urmila,” PV fed zeta converter,” International Journal of Engineering Research and Applications (IJERA) Vol. 3, Issue 4, Jul-Aug 2013, pp.2692-2696.
[7] R. A. Mastromauro, M. Liserre, and A. Dell’Aquila, “Control issues in,”single-stage photovoltaic systems: MPPT, current and voltage control,” IEEE Trans. Ind. Informat., vol. 8, no. 2, pp. 241–254, May. 2012.
[8] Kumaresh.V, Mridul Malhotra, Ramakrishna N and SaravanaPrabu.R,” Literature Review on Solar MPPT Systems,” Advance in Electronic and Electric Engineering, Research India Publications Volume 4, Number 3 (2014), pp. 285-296.
[9] T. Esram, and P.L. Chapman, Comparison of photovoltaic array maximum power point tracking techniques, IEEE Transactions on Energy Conversions, Vol. 55, No. 7, July 2008, pp. 2622-2628.
[10] Jitty Abraham and K.Vasanth,” Design and Simulation of Pulse-Width Modulated Zeta Converter with Power Factor Correction,” International Journal of Advanced Trends in Computer Science and Engineering Vol.2 , No.2, Pages : 232- 238 (2013).
[11] C. Christo Shijith and C. Christo Shijith,” PFC and speed control of BLDC motor using zeta converter,” International Journal of Advanced Research in Electrical and Electronics Engineering Volume: 2 Issue: 2 08-Apr-2014.
[12] Swati Bhasme, and A.P. Revankar, Modeling and analysis of single phase grid connected photovoltaic system,International Journal of Power System operation and Energy Management, Vol. 1, Issue. 4, 2012, pp. 52-58.