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Performance Analysis of PI controlled DC-DC Zeta Converter for Grid connected PV System

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Abstract

There are so many topologies of DC-DC converters are used in Grid connected PV system among all those topologies the PI controlled dc-dc Zeta converter with soft switching provides the best result among all and which is more suitable for both IC and P & O algorithm. This topology is also suitable for switching between two different MPPT algorithms. In this paper the MATLAB simulation performance analysis of combination of PI control and soft switching techniques. This performance analysis of this combination of techniques of a grid connected PV system finds the better suitable converter which can give the output with maximum power from the PV module and can have reliability to connect it to the GRID. **.**

Keywords*: Solar PV, Grid, Efficiency, MATLAB simulation, , zeta converter, PI controller*

1. Introduction

As we know there are so many process are taking place to deliver the electrical energy to the consumer to satisfy their demand. The significance of saving one unit of electricity has been discussed in [1] according to that, there is a need to generate two units of electrical energy in order to deliver one unit of electrical energy. This many losses are taking place due to the different kinds of processing losses. These processing losses involved starting from the electricity generating station to the consumer end. The power system network not only facing technical loss problem and also it has issues of environmental pollution in it [2]. Therefore there is a thrust to decline towards renewable energy generation which has numerous advantages because it does not require fuel, it require very less maintenance and it has environmental benefits etc. [3]. Even though the renewable energy generation has its own benefits it less conversion efficiency due to lacking in technical developments in the renewable energy generation and also the availability of source for renewable energy are not constant throughout the year. The researchers are focusing to improve the efficiency in different aspect for example the efficiency of the solar power plant is highly dependent upon the solar radiation, location of the plant to get maximum radiation etc., such kind of parameters are highly depends on environmental condition which never be controlled manually[4]. The challenge is not stopped just after improving the efficiency of the renewable energy generation plant it extends to the process of storing of the generated electrical energy. The large amount of electrical energy which is generated has to be stored because the energy generated form the renewable energy is not suitable to directly connect it to the grid. The generated energy either has to be stored or connected to the utility grid. In both the cases it is very difficult due to the technical limitations. [5-8]. Hence in this paper we are going to discuss

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the performance analysis of combination of PI controlled dc-dc zeta converter with soft switching grid connected PV which can help the energy which is generated from the solar PV to connect it to the grid efficiently with more reliability

2. Performance Analysis of Zeta Converter Topology

The DC-DC Zeta converter works under two modes they are Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM). This zeta converter consist of components such as switches, diodes etc., hence the zeta converter is the nonlinear circuit [9]. The first step to design a converter is modeling of the circuit therefore the modeling technology is carried out first. This modeling technique needs the averaging and linearization of the circuit. The linearization and averaging is the difficult portion of the modeling zone and due to this reason the Laplace transform under transient condition approach is followed in this paper [10]. The entire circuit is made in ON state and OFF state condition and those two stages is combined by state space analysis to get the transfer function. After deriving the transfer function and checking its stability and simulation is carried out to see its performance. The simulation results are displayed. [11-13]

2.1 Modeling of Converter with ON and OFF States

Designing a model with PI controlled Zeta converter. In this process, by applying signal flow graph technique transfer function is obtained. Then, the frequency domain responses are obtained form of Bode plot. Proper tuned PI controller is designed. At last, the simulation results based on the presented modeling and controlling methods are displayed to prove the efficient and reliable performance and behavior of proposed converter. Let we see the circuit diagram of the Dc-Dc zeta converter with CCM mode of operation with both ON state and OFF states.

The Figure (1) and (2) are shows the circuit diagram of ON and OFF state if zeta converter. By applying KVL and KCL and Transient analysis the transfer function is derives from those circuits. Here we use state space analysis to obtain the transfer function. The stability is checked by using bode plot. Let we see the modeling of the above circuits,

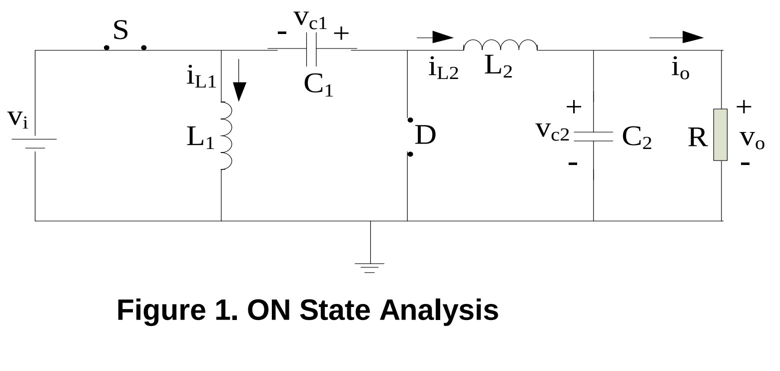

Figure 1. ON State Analysis

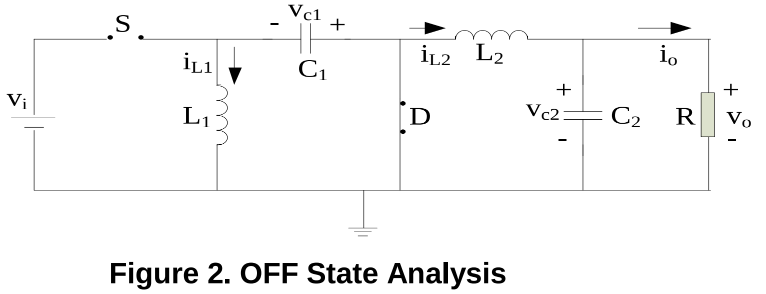

Figure 2. OFF State Analysis

$L_1 (di_{L1} / dt) = v_i$ (1)

$L_2 (di_{L2} / dt) = v_i + v_C + v_o$ (2)

$C_1 (dv_{C1} / dt) = i_{L2}$ (3)

$v_o = v_{C2}$ (4)

$C_2 (dv_{C2} / dt) = i_{L2} - (v_o/R)$ (5)

Substituting equation (4) in (5) we get,

$C_2 (dv_o / dt) = i_{L2} - (v_o/R)$ (6)

If, $x_1 = i_{L1}$, , $x_2 = i_{L2}$, $x_3 = v_{C1}$, $x_4 = v_{C2}$ state space equation can be written as below,

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1/L_2 & -1/L_2 \\ 0 & -1/C_1 & 0 & 0 \\ 0 & 1/C_2 & 0 & -1/RC_2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 1/L_1 \\ 1/L_2 \\ 0 \\ 0 \end{bmatrix} v_i \quad (7)$$

The above equation (7) is the state space equation of ON state and now we will see the OFF state equation as follows,

$L_1 (di_{L1} / dt) = -v_{c1}$ (8)

$L_2 (di_{L2} / dt) = -v_{c2}$ (9)

$C_1 (dv_{C1} / dt) =- i_{L1}$ (10)

$v_o = v_{C2}$ (11)

$C_2 (dv_{C2} / dt) = i_{L2} - (v_o/R)$ (12)

Substituting equation (4) in (5) we get,

$C_2 (dv_o / dt) = i_{L2} - (v_o/R)$ (13)

The above equations of OFF state analysis can be written in state space,

$$A_1 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1/L_2 & -1/L_2 \\ 0 & -1/C_1 & 0 & 0 \\ 0 & 1/C_2 & 0 & -1/RC_2 \end{bmatrix}, A_2 = \begin{bmatrix} 0 & 0 & -1/L_1 & 0 \\ 0 & 0 & 0 & -1/L_2 \\ 1/C_1 & 0 & 0 & 0 \\ 0 & 1/C_2 & 0 & -1/RC_2 \end{bmatrix}, B_1 = \begin{bmatrix} 1/L_1 \\ 1/L_2 \\ 0 \\ 0 \end{bmatrix}, B_2 = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (14)$$

In these above equations (7) and (14) the values of equilibrium is found, substituted and Laplace transform is applied to obtain the transfer function of the converter.

The final transfer function of the converter is given as,

$$G_0(s) = G_{vd}(s)\, G_{dc}(s)\, H(s) = G_{vd}(s) * (1/V_{oc}) * (V_{ref}/V_{dc}) \quad (15)$$

After substituting the designing parameters of the desired circuit the actual transfer function as follows,

$$G_0(s) = \frac{(1.814*10^{-6}s^2 - 8.67*10^{-3}s + 697)}{(3.054*10^{-11}s^4 + 2.44*10^{-10}s^3 + 1.25*10^{-2}s^2 + 1.005s + 1)} \quad (16)$$

3. Proposed PI control scheme design

A PI controller is designed for the stability of the Zeta converter in closed loop control system and the transfer function of the this network is derived as,

$$G_C(s) = (1+sR_1C_3) / (sR_2((C_3+C_4) + (sR_1C_3C_4)) \quad (17)$$

$$R_3 = ((R_2V_{ref}) / (V_{dc} - V_{ref})) \quad (18)$$

$$R_4 = ((R_2V_{ref}) / (V_{osc} - V_{ref})) \quad (19)$$

$$f_0 = ((1 / (2 \pi (L_2C_2)^{1/2}) \quad (20)$$

$$f_z = .75f_0 \quad (21)$$

Therefore the PI controller transfer function is,

$$Gc(s) = ((7.6 * 10^{-3}s+1) / (3.45 * 10^{-3}s^2 + 1.86s)) \quad (22)$$

Where $L_1 = L_2 = 40mH$, $C_2 = 833\mu F$, $f_s = 50kHz$, $V_{dc} = 60V$, V_{OSC} =4.5Volt, $V_{ref} = 1.05V$ (from IC datasheet), $\Delta V_{ovp} = 3V$(from IC datasheet), BW = 20Hz. After combining the transfer function of converter and PI controller the stability can be checked by using Bode Plot which is shown in Figure (3)

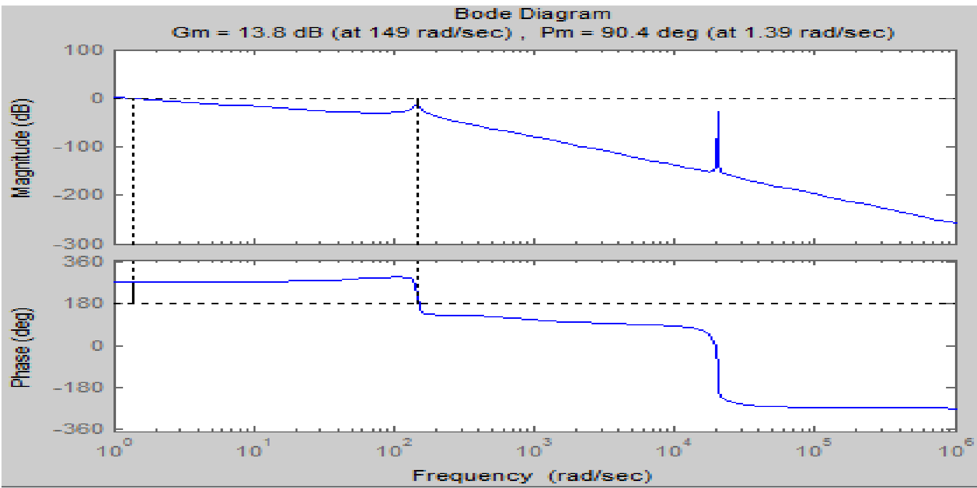

Figure 3. Bode Plot of Stability Check

From Figure (3) it is obvious that the PI controller make the zeta converter more stable as compared to basic converter.

4. MATLAB Simulation of the Proposed System with the Results

The Figure (6) is the MATLAB simulation of DC-DC zeta converter with PI control technique which helps to increase the stability and reliable which is coming out from the PV panel to connect it to the grid. The MATLAB simulation of the Entire system is also realized in Figure (5) where the zeta converter with PI controller used as a sub system to get the output with good quality which can be directly connected to the grid with less harmonics.

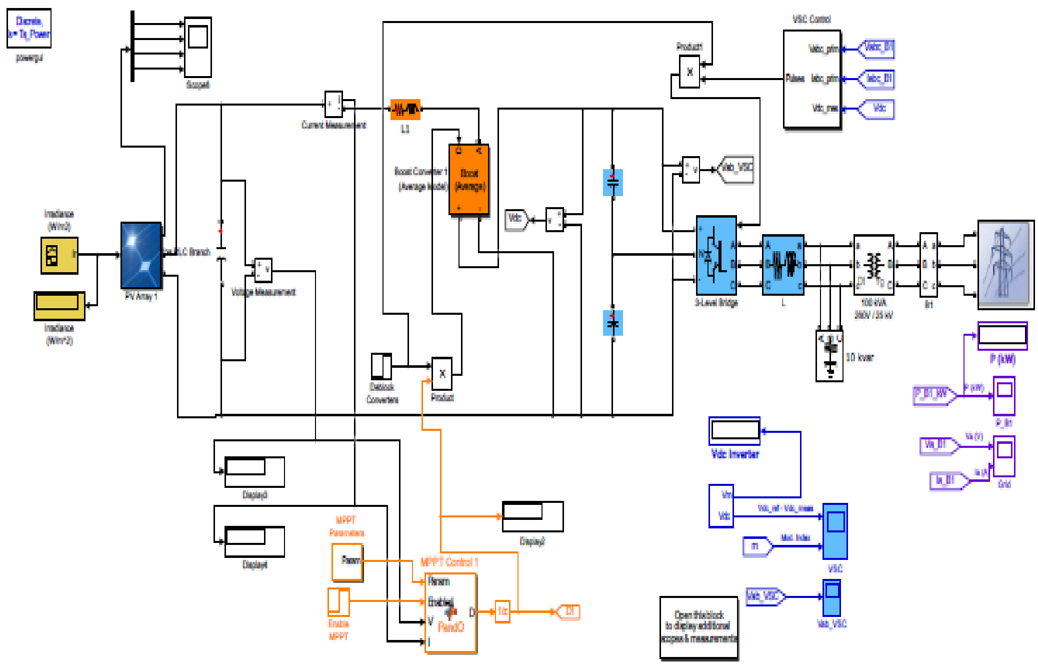

Figure 4. MATLAB Simulation of Entire PV System Connected to Grid

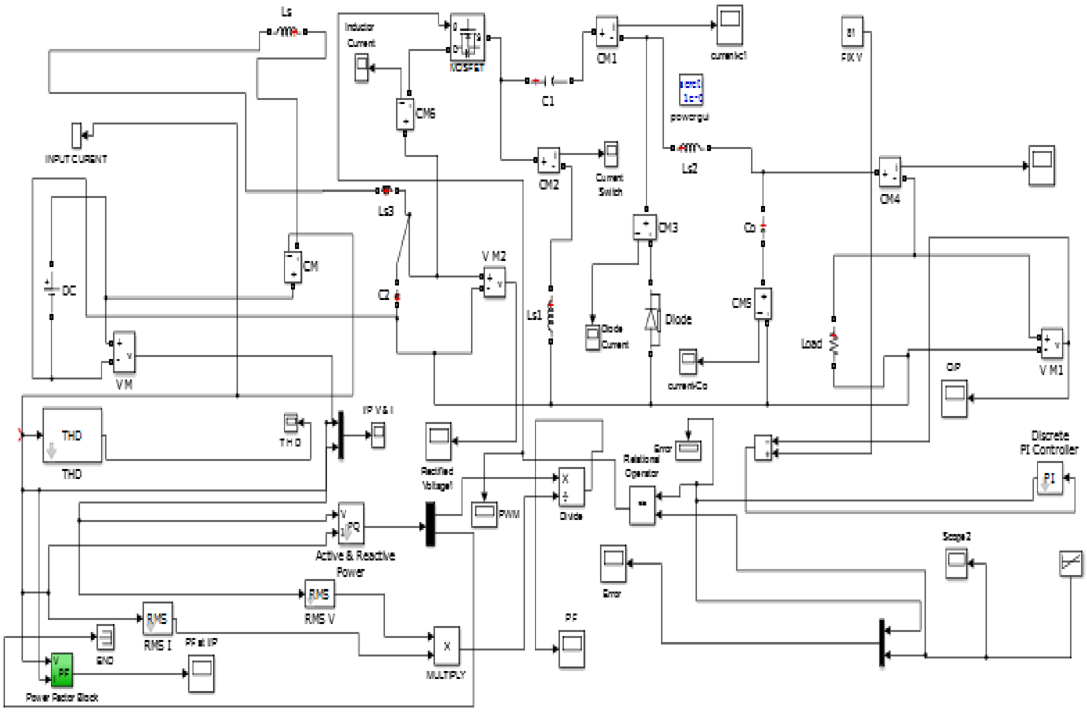

Figure 5. MATLAB Simulation Proposed Zeta Converter with PI Control Technology

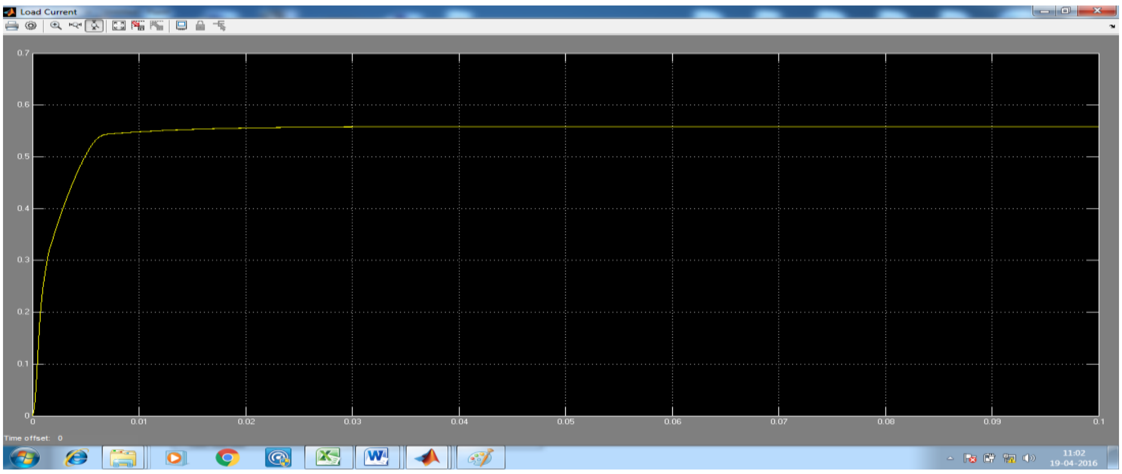

Figure 6. Load Current of ZETA Converter

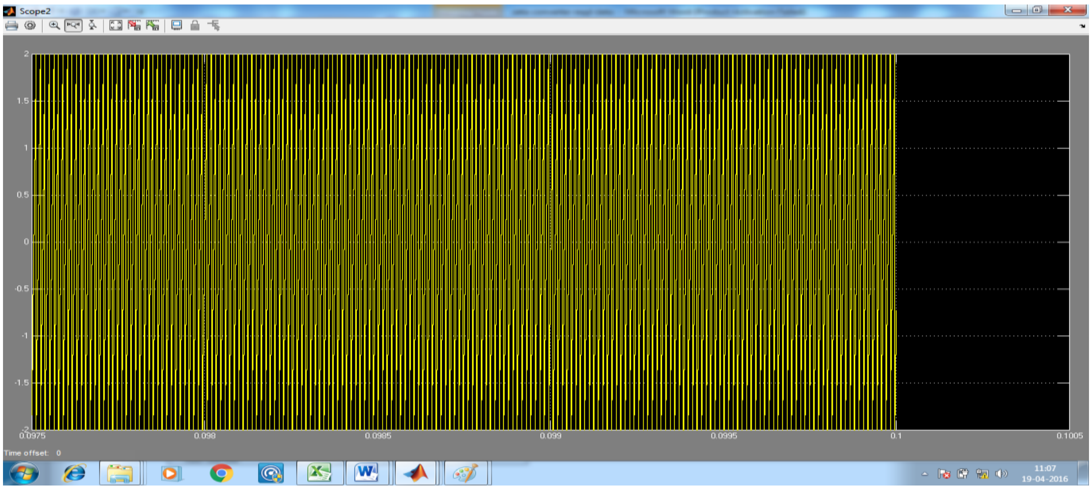

Figure 7. PI Controller Output

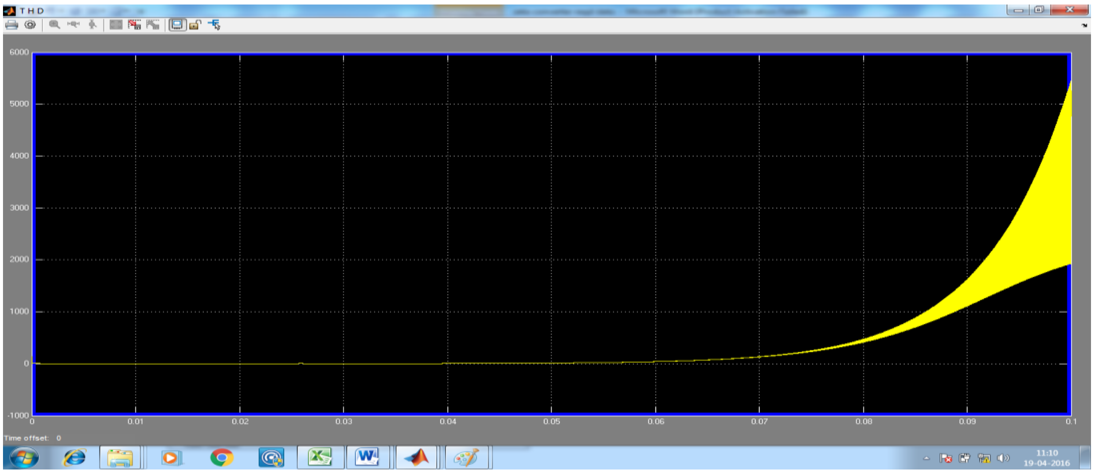

Figure 8. THD Level of the Converter

Figure 9. PWM Signal

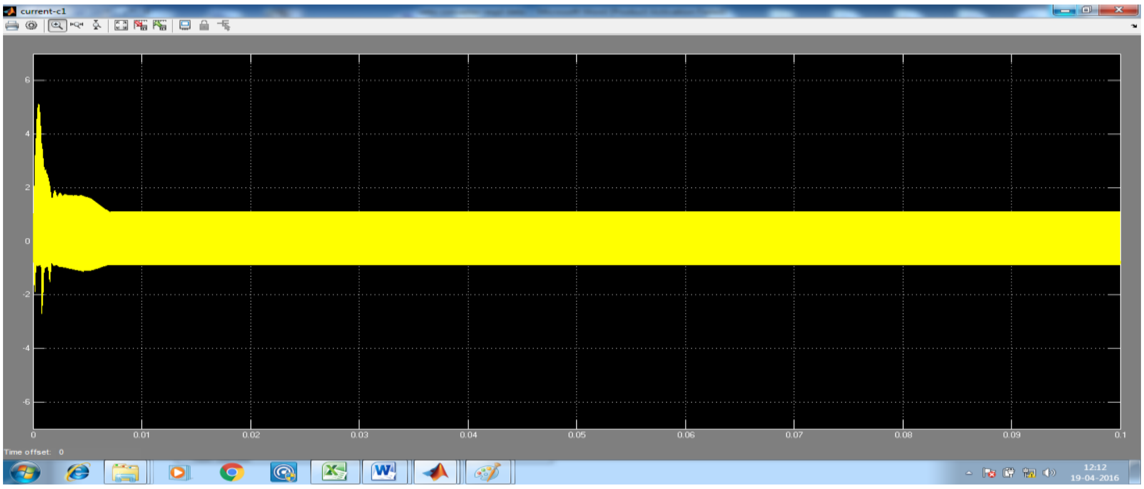

Figure 10. Capacitor Current

From the Figure (6) to (10) we can see the simulation performance graph of PI controlled Zeta converter. It obvious from the Figure (7) that it has very much better THD level which makes the output more stable and reliable.

5. Conclusion

This paper presents the most important basic requirements of PV system which are connected to the commercial grid is being discussed. The basic traditional dc- dc converter may be used to maintain the constant output before it is given to the inverter circuit but due its instability, less efficiency and more harmonics. Hence here we modelled and designed dc-dc zeta converter with PI controller which gives better THD level which increases the quality of the power which is fed to the utility grid. And also we can use soft switching circuit in addition with PI controller with zeta converter to improve the efficiency. Hence the dc-dc zeta converter with PI controller technique provides better results which are more reliable to connect it to the grid.

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