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# A Single-Stage Transformer-Less Grid Connected Pv System To Improve Power Quality

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***Abstract:***
***Background/Objectives:*** *This paper analysis single-stage Z-source inverter (ZSI) Based Photo Voltaic (PV) system for power quality improvement in a grid. The grid connected PV system with transformer provides isolation and grounding for PV array. But the transformer will increase cost and size of the system. The proposed work uses transformer-less single-stage conversion by using the maximum power point tracking and interfacial PV grid.*
***Methods/Statistical analysis:*** *The maximum power point tracking (MPPT) is implemented by incremental conduction algorithm. The ZSI provides the injecting current to the grid by using hysteresis current control method. It can improves the power quality. An Z-Source Inverter consists of both Voltage Source Inverter and Current Source Inverter properties. This also improves the dynamic performance of the system.*
***Findings:*** *The simulation results of Current Source Inverter (CSI) inverter and ZSI inverter are obtained. The ZSI provides the better Total Harmonic Distortion (THD, power factor and active power of the system.*
*Application/Improvements: In this wide range of applications like Sub Stations, Distribution Stations, Transmission Stations.*
***Keywords:*** *Z source inverter (ZSI), grid connected PV system, maximum power point tracking (MPPT), hysteresis current control method.*

## I. Introduction

Now a days among all the renewable energy sources the PV systems is well known promising technology. The PV system has wide range of applications [1,2]. Like commercial, distribution, generation and transmission. The main factors are low cost and high efficiency. The output voltage is non sinusoidal for distribution, generation Applications[16]. The PV system operates two modes. One is grid connected mode and other one Islanded mode. The operation can take two key forms one standard alone generator is not connected to grid and the other one generator connected to the electrical grid in parallel, so grid connected mode is good for PV. There are single-stage and two-stage grid connected PV systems[1] These techniques are used for extracting the maximum power from PV systems. The grid connected PV with transformer provides isolation grounding for PV array. In this case cost& size of system may increases [3] For renewable energy applications current source inverter (CSI) having some limits, give justification so Z-source inverter could be alternating technology for PV systems.

It is a type of inverter a circuit that converts DC-AC. Because of the unique circuit topology, Z-source inverter having both voltage and current source properties. The Z-source inverter (ZSI) looks into grid connected PV system have been proposed [4] In general the PV panel output power and efficiency depends on irradiation, climatic condition and isolation level. For effective results of PV panel many authors are presented different techniques based Maximum Power Point Tracking (MPPT)[14,15]. We can achieve MPPT in two ways Electrical tracking and Mechanical tracking. In mechanical tracking by changing the direction of solar panel expose to the sun. In this way will obtain Maximum solar power output. The electrical tracking achieved by the different algorithms like.
Incremental conductance (ICT)
Perturb and observations (P&O)
Constant reference and voltage/current.

Among these algorithms ICT and P&O algorithms having good dynamic response and that can track maximum power from PV [9].

In this paper, a single-stage transformer less grid connected PV system for power quality improvement based on the ZSI (z-source inverter) proposed. In ZSI inverter inductors are connected in series and capacitors

are in diagonal. That looks like 'X' shape. We are using MPPT (maximum power point tracking) is obtain maximum power by using ICT technology. The ZSI provides the injecting current to the grid by using hysteresis current control method. To know the improved power quality of the proposed grid connected system simulation results are obtained using Simulink.

## II. IZ- Sourse Inverter Topology

From the (Figure 1)shows the topology of ZSI to inject current into the grid. In this arrangement grid is considered as source and load connected in series to the grid. PV panel is providing input supply to the ZSI[10]. Compare with the conventional (CSI) current source inverter Z-source inverter (ZSI) have more advantages. It will increas-e output voltage of the system by boosting the DC voltage.

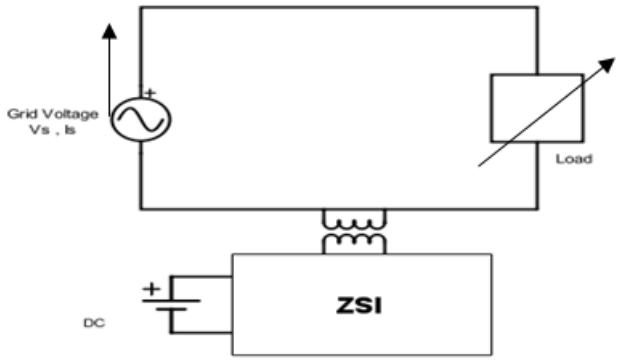


**Figure.1** Z-source inverter topology

In this configureuration two inductors can be arranged on same core. It minimizes the size and weight of the system. The ZSI has two independent control variables are Modulation index and Shoot through duty ratio [5] In ZSI misfiring of switches sometimes acceptable, and both buck and boost operations also possible, main circuits are interchangeable, less effected EMI, harmonic distortion and power losses low and very high efficiency [5] If the ZSI is treated as a single stage buck/boost converter. It gets voltage modeling in single stage without implementing more switching device. The ZSI deals with input voltage function in wide range, which is generally accomplished by a two stage chopper cascaded by inverter structure. A dynamic modeling and transient analysis of Z-source network are discussed by using state space average. For ZSI control closed loop control is proposed [7] The Characteristics of discontinuous mode of ZSI with low power factor are discussed. For distribution, generation applications from the original ZSI a new set of quasi Z-source inverter have been developed. The ZSI for grid connected PV systems has been illustrated in some surveys, they reveal that number of components and the system volume, loss are get reduced [4 ,11] If we go with dissimilar transformer-less inverter topology we can reduce the problem of leakage current in proposed PV array system [9] The main drawbacks of these topology is PV connected to grid without isolation. It leads voltage difference among the PV frame and solar cell, to reduce the electric shock and it should be grounded. The 3-phase inverters are not applicable for transformer-less PV applications. Because of propagation of high leakage current due to PWM (pulse width modulation) this problem avoided by keeping the CMV(common mode voltage) as a constant value in dc-dc converters [4].

## III. Incremental Conductance

The atmospheric condition is varied from time to time in a day. During this condition it is very difficult to track the power. This is overcome by adopting the incremental conductance method. The ICT technique halts at the operating point when maximum power point is reached.

If not, then the MPPT operating point can be calculated with in dI/dV and I/V the power and voltage on the MPPT. When MPPT is right, the dP/dV is negative and MPPT is left the dP/dV is positive. The ICT algorithm gives better result than P&O technique. ICT has the capability of tracking irradiance condition of power when it increases and decreases rapidly. It increases the complexity of the system. This is only the system disadvantage of ICT. In MPPT we have three types of techniques which is used to adjust the terminal voltage from the arrays. The voltage variation depends up on its behavior. Incremental conductance method is used to control the initial voltage on the array. The voltage depends on the instantaneous conduction of the PV module. From this below (Figure 2) shows the power curve zero at maximum.

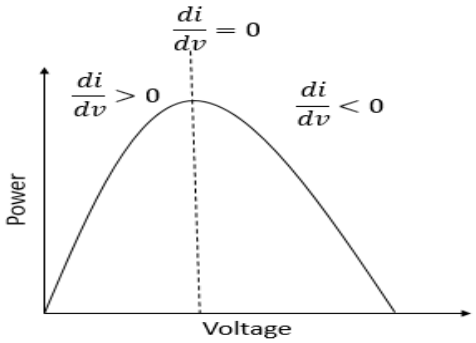


**Figure.2** Incremental conduction.

The maximum power point is decreasing on right hand side and increase on left hand side. Then the basic equations are

$$\frac{di}{dv} = -\frac{I}{V} \qquad (1)$$

$$\frac{di}{dv} > -\frac{I}{V} \qquad (2)$$

$$\frac{di}{dv} < -\frac{I}{V} \qquad (3)$$

I and V are the PV array output current and voltage respectively .where discontinuous conduction represents right hand side and incremental conduction represents left hand side [6] and [7,8] from (figure 3)

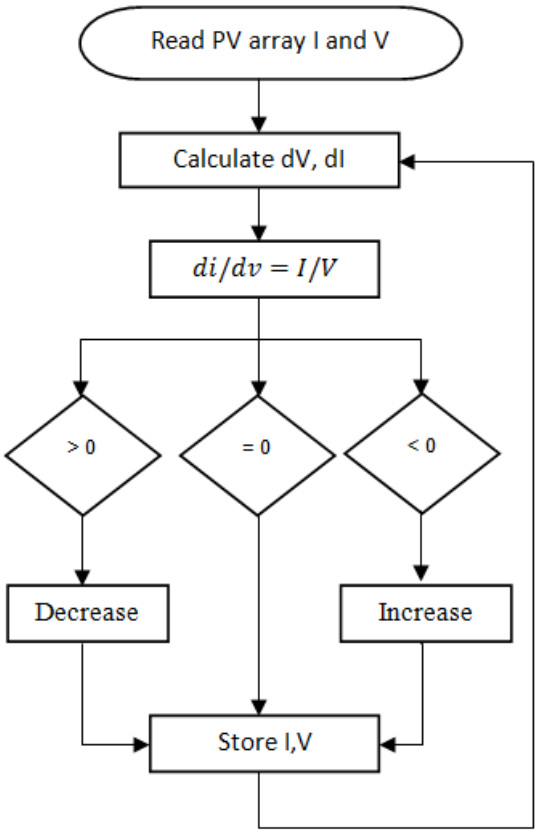


**Figure.3** Incremental conduction algorithm.

## IV. Hysteresis Current Control Method

Hysteresis current control method is a asynchronous control method. It is used for controlling the voltage source inverter. In this method triggering pulses are generated by comparing the two error signals with in the hysteresis band. The output current which is generated from the filter will follow the reference current in a closed loop[12]. as shown in (Figure 4) .

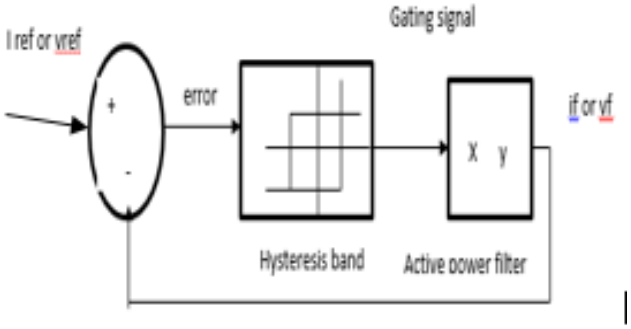


**Figure.4** Hysteresis control technique

This method is easy to implement in real time applications. It consists of comparator and hysteresis band in each phase. The difference of these currents represents the current distortion which is shown below.

$$distorsion = \frac{100}{Irms}\sqrt{\frac{1}{T\int(iact - iref)^2\,dt}}\ \% \qquad (4)$$

The inverter switch operates based on the actual and reference current. From (Figure 5) If actual current more than the upper limit of hysteresis band the inverter upper switch is turned off and lower switch is turned on and the current gets decreased. Then the actual current reaches the lower limit of hysteresis band the inverter lower switch is turned off the upper switch is turned on. The deviation of current between upper and lower in hysteresis band is limited. The switching frequency can be calculated and controlled by adjusting the hysteresis band width. The band width is directly proportional to current ripple and inversely proportional to switching frequency. Switching losses are increases when the band width gets decreases. It is widely used due to simple, fast dynamic response and insensitive to load parameters. It is also known as delta modulation [13].

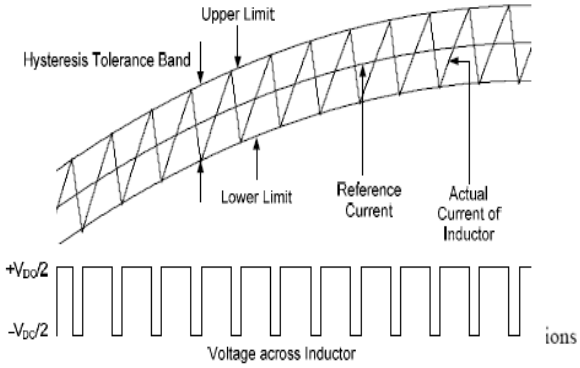


**Figure. 5** Hysteresis band

## V. Proposed System Control Techinique

To design the ZSI based grid connected PV system the relation between grid voltage and PV panel output is given as below. Inverter losses to be neglected then grid power almost equal to the PV panel output power.

$$Vp\ Ip = \frac{1}{2} Igp\ Vp\ \ COS\theta \qquad (5)$$

Where $V_P$,$I_P$ are the PV output voltage and output current. While $V_{GP}$ and $I_{GP}$ are the grid peak voltage and current. Where θ phase angle between PV output current and PV output voltage and the grid current is equal to inverter modulation index multiplied by pv output current.

$$Igp = M\ Ip \qquad (6)$$

Substitute equation (5) in (6)

Let us consider unity power factor then the relationship between PV panel output voltage and grid voltage is given below

$$Vp = \frac{1}{2} M\ Vgp \qquad (7)$$

Therefore to design ZSI based grid connected PV system condition is the PV panel output voltage should not be less than half of the grid peak voltage. If the ZSI inverter works as both buck and boost converters and also power losses are very less.

In order to fulfill the requirements INC (incremental conductance), Hysteresis current control method are proposed.

## VI. Simulations

The MATLAB/SIMLINK software is used for simulating proposed converter. It consist of voltage& current control block, switching signal generation, MPPT algorithm block.

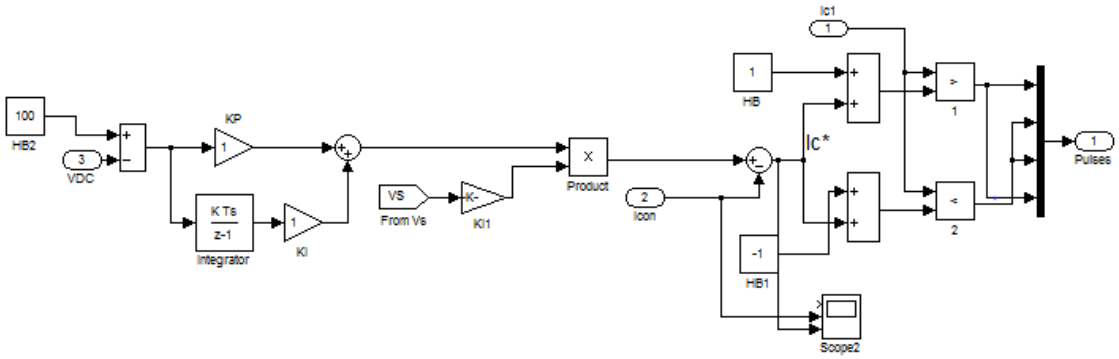


**Figure. 6.** Voltage and current control block.

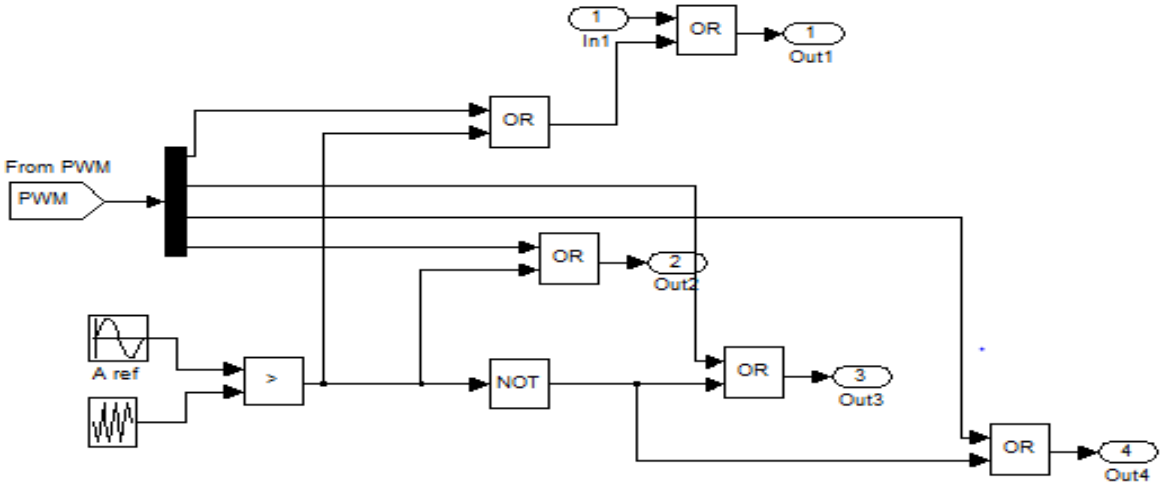


**Figure. 7** ZSI switching signals generation block.

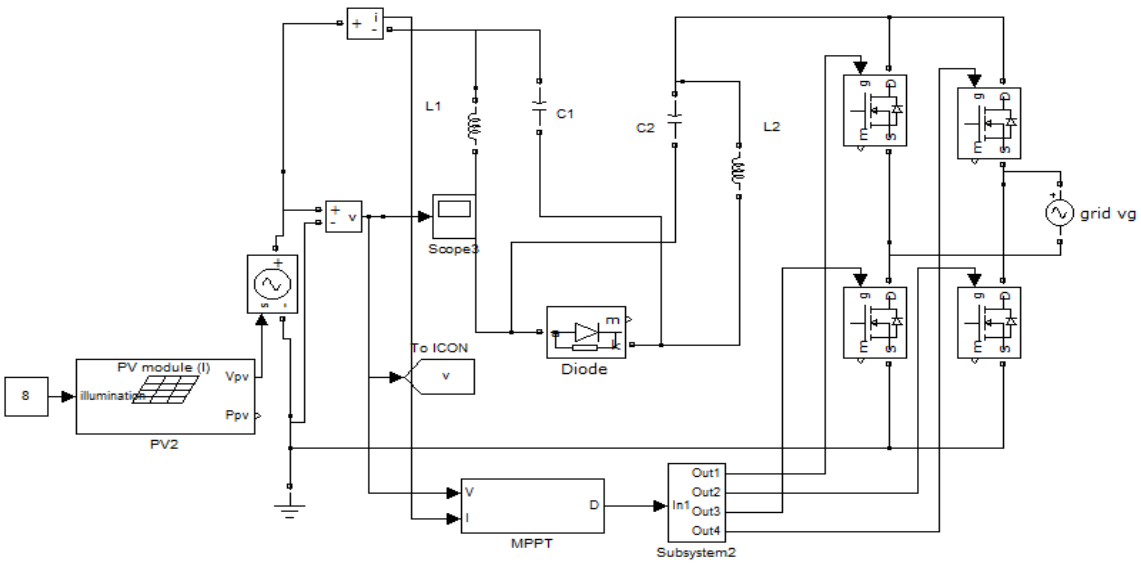


**Figure. 8** ZSI connected with Grid connection.

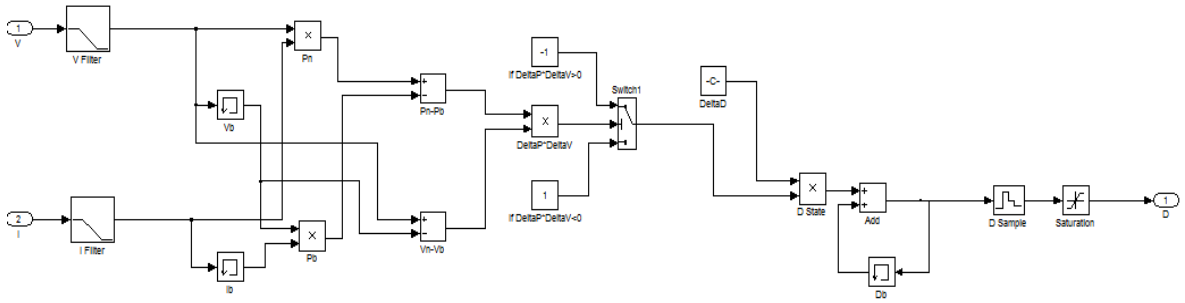


**Figure. 9** MPPT control block.

From the above (Figure 6) we are taking as a grid value and input voltage both compared and to give PI controller. The output value and the Vs block voltage are product and then taking from as a current signal. This signal and input current both compare by using hysteresis current control method. We get pwm pulses these pulses gives to the pwm signal block shown (Figure 7) from the (Figure 9) shows MPPT block we are taking as a V,I signals it will generates pn,pb then the two values differentiate and gives to conditional switch either >0 or <0 after that the Db signal is forms to loop. It will connect again and again to support better value compared to before. The output of the system gives to the signal generator block. These pulses gives to the Mosfet of ZSI circuit block and it is connected to grid shows in (Figure 8)

## VII. Simulation Results

The analysis and performance of the ZSI based grid connected PV system is verified and simulation results are shown below.

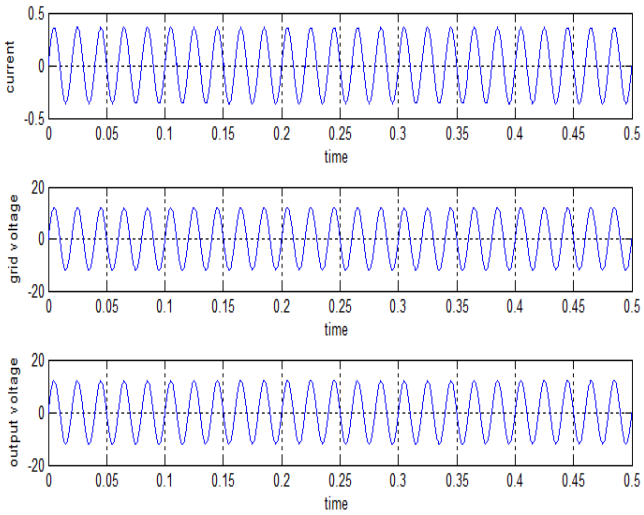


**Figure.10.** Current and voltage waveforms for proposed ZSI system.

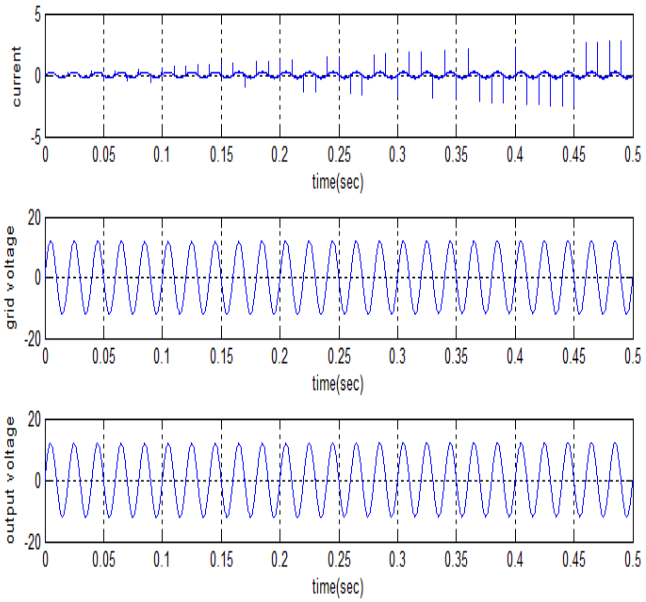


**Figure.11.** Current and voltage waveforms for CSI system.

From the above (Figure 10) and (Figure 11) are shown the comparison of ZSI and CSI. The ZSI current has no spikes in current distortions.

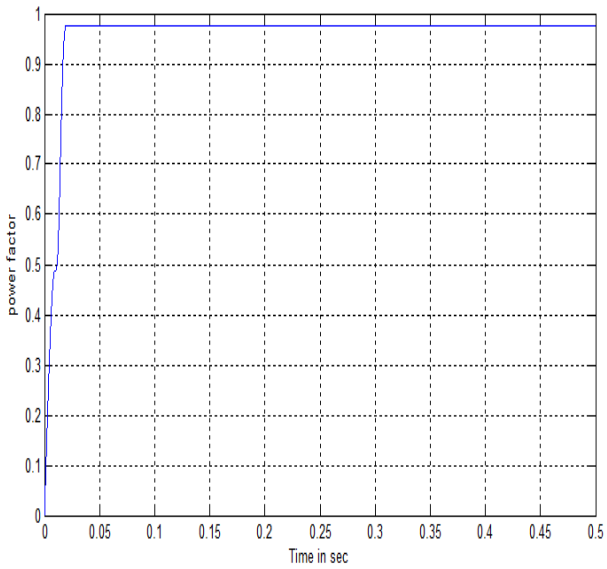


**Figure. 12.** Power factor for proposed zsi system.

If the power factor of the proposed ZSI system is 0.975

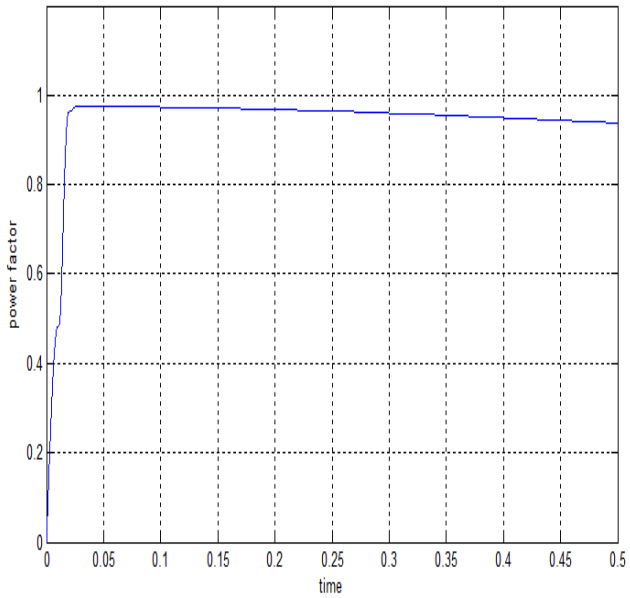


**Figure.13** Power factor for current source inverter.

If the power factor of the current source inverter is 0.938.

Finally from the (Figure 12) and (Figure 13) are shown about the power factors of ZSI and CSI. The ZSI power factor of the system is improved.

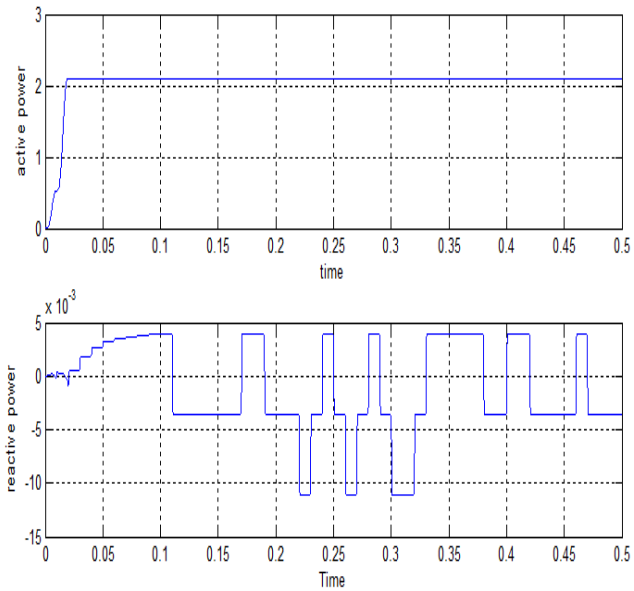


**Figure. 14.**Active and reactive power wave forms of zsi inverter.

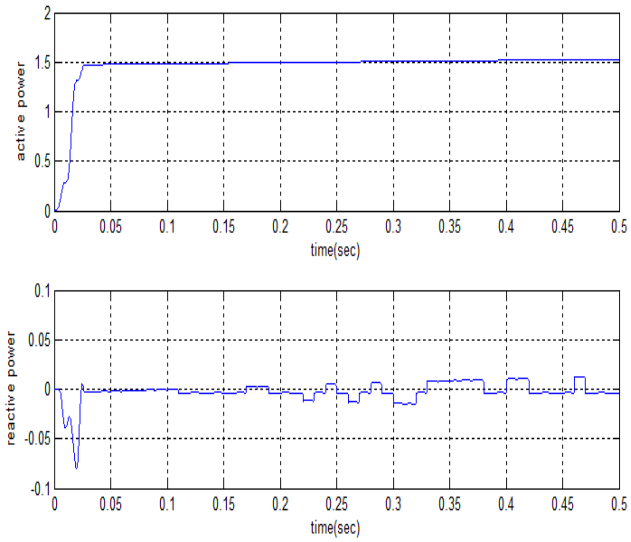


**Figure. 15.** Active and reactive power waveforms of csi inverter.

Above (Figure 14) and (Figure 15) presents the active power and reactive power of the ZSI and CSI respectively. From this we can conclude that active power reactive powers in ZSI is improved than CSI.

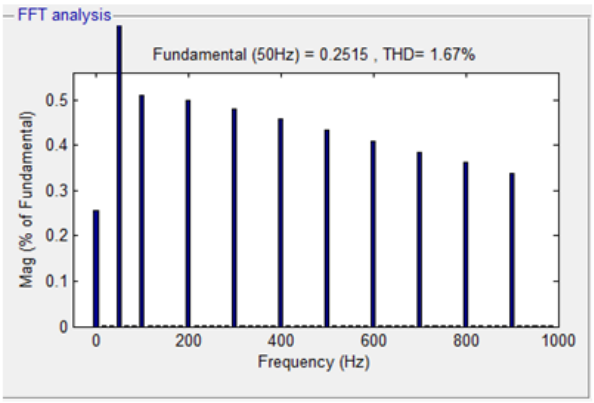


**Figure. 16.** Total harmonic distortion for proposed ZSI system.

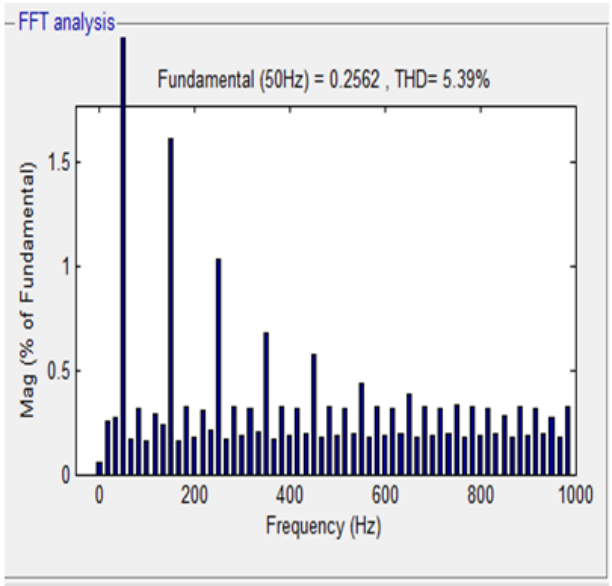


**Figure. 17.**Total harmonic distortion for csi system.

The above (Figure 16) and (Figure 17) presents the total harmonic distortion of ZSI and CSI respectively. From this we can conclude that THD of ZSI value 1.67 is improved than the CSI value 5.39.

**Specification of simulated parameters**

**Table 1**

| Parameter | Value |
|---|---|
| Input voltage | 12v |
| Frequency | 50Hz |
| Inductance L1 | 1e-3 |
| Inductance L2 | 1e-3 |
| Capacitance c1 | 1000e-6 |
| Capacitance c2 | 1000e-6 |
| Load resistance | 100ohm |
| Load inductance | 100e-6 |

From the above (Table 1) represents the design parameters of the simulation parameters. If the input voltage of the system is 12v. And frequency 50Hz and the ZSI of inductances $L_1$ , $L_2$ is 1e-3 and capacitances are $C_1$,$C_2$ is 1000e-6. And then load resistance 100ohm and load inductance 100e-6.

**Comparison result analysis**

**Table 2**

| Parameter | CSI | ZSI | Without injecting |
|---|---|---|---|
| THD | 5.39% | 1.67% | 31.05% |
| Power Factor | 0.938 | 0.975 | 0.91 |
| Active Power | 1.5 VA | 2.2 VA | 1.2 VA |

The above (Table 2) represents the comparison analysis of the ZSI and CSI respectively. From this we can conclude the ZSI of the THD and power factor and also the active powers of the system is improved and executed.

## VIII. Conclusion

The ZSI based single stage grid connected PV system has been proposed without conceive a high DC voltage and heavy transformer we can meet requirement of grid. In proposed system the control scheme consists of ICT algorithm to increase system performance during both normal irradiance atmospheric conditions. The advantages of single stage grid connected PV system is the PV output power is delivered with improved power factor, less cost and low THD. The total harmonic distortion value of the current injecting into grid value was 1.67% in simulation result. The feasibleness and strength of proposed system has been victoriously measured with several simulation work are executed.

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