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Impedance Source Converter for PV Grid Connected System

Ishwar Singh Chandra
Dept of Electronics & Telecommunication Engineering
Raipur Institute of Technology,
Raipur, India

Tikeshwar Gajpal
Dept of Electronics & Telecommunication Engineering
Raipur Institute of Technology,
Raipur India

***Abstract*— Renewable energy sources are becoming very popular for the standalone system as single phase or three phase domestic supply, charging station for electric vehicle, agent based control of wind energy system and battery charging for different localized application. In many applications one need to develop such a system in the control and system transient that the function of the conversion of renewable energy in the usable form must be more efficient for the utility. Since the present scenario of renewable energy comprise of cost effective solar panel as commercial with the various subsidy available. However, problem associated with the system level is conversion of power and the transmission to the consumer end. In this work presents a modelling of impedance source converter for the PV application with single phase and three phase grid connected system, and model is validated using MATLAB/Simulink™**

Keywords—Renewable energy, impedance converter, dc-dc converter; PV system, Grid Connected Converter

I. INTRODUCTION

Renewable energy is future as alternative to the conventional power system with the different voltage and power level. The newly proposed Z-source inverter has proven in the literature to exhibit steady state voltage for desired level. This paper presents the brief introduction on the modelling of the impedance source converter. Impedance source converter is given by the [1] for the fixed network within the system for the generation of pulse during the shoot through state also. In [2] and [3] definite application is given for the converter with the grid connected system and stand alone system. As the energy from the sun is free, the major cost of photovoltaic generation is the installation cost, which is mainly composed of the costs of solar modules and the interface converter system, also called the power conditioning system (PCS). With the development of solar cell technology, the price of solar modules has dropped dramatically. A recent worldwide survey shows that in the last three years, the retail price of solar modules has dropped 16.95%. [3]

Fundamental problem of most renewable energy technologies is that available power is very dependent on various factors such as wind power, intensity of sunlight etc. Therefore, an efficient energy management is not reachable without energy storage, which helps in suit a load power requirement to source characteristics. Assorted types of energy storages are used in field or still under development, but most often applied are electrochemical batteries due to maturity of technology.

The Z-source inverter is one of quite new ideas designated to renewable energy system, manly fuel cell and photovoltaic [2],[3]. To the-same-as VSI switches topology a special Z network is introduced and short-through states may be used in similar manner as in Current Source Inverter. This way single stage buck-boost conversion feature is gained, very useful for interfacing of renewable sources with varying DC voltages.

The basic impedance-source network can be generalized as a two-port network with a combination of two basic linear energy storage elements, i.e., L and C (dissipative components (R) are generally omitted). However, different configurations of the network are possible to improve the performance of the circuit by adding different nonlinear elements into the impedance network, e.g., diodes, switches, and/or a combination of both.

There are several disadvantages of the Current Source Inverter and Voltage Source Inverter, and the impedance source converter is based to overcome such disadvantages. In VSI output voltage cannot go beyond the input voltage as it is buck type converter while the CSI the output voltage cannot be less than the input voltage.

Various literatures have been proposed in past few years in [4]-[17]. Some of the paper proposed method to generate voltage by the standalone system using PV and battery system which is most common approach also known as traditional system.

In this work impedance source converter is discussed with the open loop control and without battery storage system. Impedance source converter

1. has only one stage to realize inversion, boost, and maximum power tracking;
2. has the minimized number of switching devices;
3. needs no dead time;
4. can have shoot through state in the inverter;
5. inherits all the advantages of the six switch inverter system.

II. IMPEDANCE SOURCE CONVERTER

A. *Principle of Operation*

The ZSI has various operating modes as; First it has shoot through mode, whenever any of the leg of inverter get short circuited. For simplification purposes, Z-source network parameters are selected as

$$L_1 = L_2 = L$$
$$C_1 = C_2 = C$$

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which make the Z-source network symmetrical. Accordingly, the capacitor and inductor voltages of the Z-source network becomes,

$$v_{L1} = v_{L2} = v_L$$
$$v_{C1} = v_{C2} = v_C \qquad (1)$$

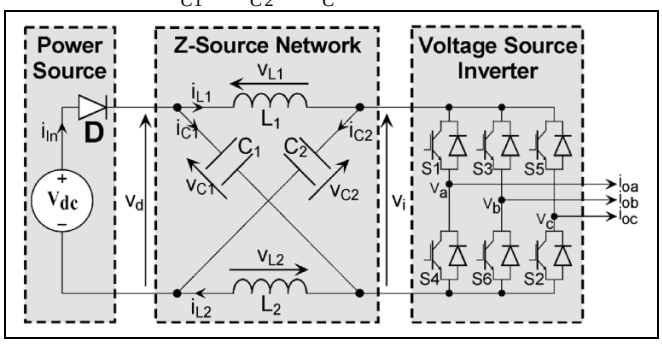

Figure 1 Grid Connected Converter

B. *Mathematical Farmulation of Impedance Source Converter*

In this paper mathematics involved in the operation of impedance source converter is also discussed with the different voltage and current level at different output element. For the analysis of any dc-dc converter best way to employ is volt-second balance through the inductor coil and current-second balance through the capacitor of unit. Voltage-second balance is given as equation (2);

$$V_L = \frac{T_1 V_C + T_0 (V_0 - V_C)}{T}$$
$$\frac{V_C}{V_0} = \frac{T_1}{T_1 - T_0} \qquad (2).$$

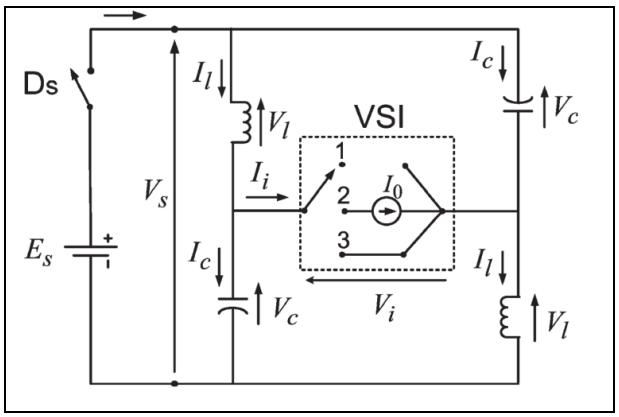

Figure 2 Working States of Impedance Converter

Whereas, T_1 and T_0 are the states of operation as non shoot-through interval and shoot-through intervals of operation. In this conversion the input to the output is taken as in equation (3);

$$\frac{V_i}{V_0} = \frac{T}{T_1 - T_0} = B \qquad (3)$$

In this the voltage level of the output depends on the input voltage and boost factor B which is equal to,

$$B = \frac{T}{T_1 - T_0} = \frac{1}{1 - 2\frac{T_0}{T}} \qquad (4)$$

The output voltage is given as equation (5)

$$\hat{v}_{ac} = m.\frac{\hat{v}_i}{2} \qquad (5)$$

Hence from equation (3) and equation (5) it is clear that the performance of the system depends on the modulation index and the boost factor which can be given as;

$$\hat{v}_{ac} = mB\frac{V_i}{2} \qquad (6)$$

From equations aforementioned we can write that the capacitor voltage is given as;

$$\frac{V_C}{V_{in}} = \frac{1 - \frac{T_0}{T}}{1 - 2\frac{T_0}{T}} \qquad (7)$$

Equation (6) is the output voltage equation applied at the load to get the single or three phase supply. Equation (7) enables the output voltage and control output voltage end.

III. Comparative Analysis With Conventional Converter

Before proceeding for the application of the impedance converter and the unit response of the network with simulation and inverter unit, it becomes necessary to compare the system with the existing model and behavior of conventional converter. As the conventional converter has buck, boost and buck-boost mode of operation one need to develop the comparative analysis.

In this work a brief analysis has been presented with respect to impedance source converter. Figure 3 shows the basic waveform of comparison for the all three converter. It is clear the boost mode of operation can be done easily with the impedance source converter.

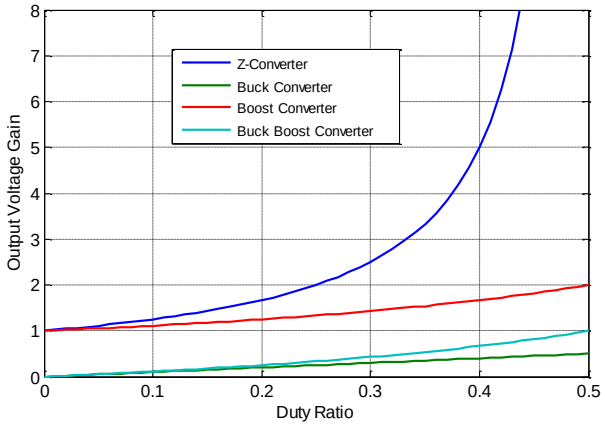

Figure 3 Comparative analysis of Impedance source converter for the other conventional converter

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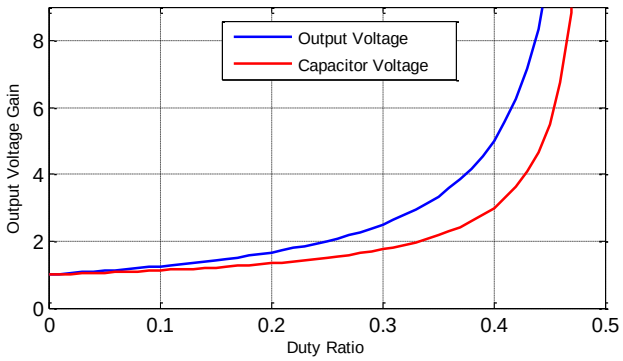

Figure 4 Gain of Voltage at output and the capacitor

An excellent style manual for science writers is [7].

IV. SIMULATION & RESULTS

To validate the system with the desired output level output voltage has to be modified with the system level. The simulation diagram is given in figure 5 with the various element of the system. Photovoltaic, impedance source converter and then the inverter is connected in the system for the detailed model of a grid connected system in this the modelling of the system is done with the simulation level.

Table -1 gives the parameter of simulation for which the system is modeled and detailed analysis has been performed. The model has various part but the aim of this paper is to give the analysis of grid connected photovoltaic system with the inverter either three phase or single phase domestic system. In most common application three phase induction machine is the desired load profile with the 0.8 lagging power factor. The system has been modeled for the same without induction machine and same power factor three phase load. The analysis can also be extended for the unbalanced and balanced system along-with different power factor and the power demand. But for the validation of the system with available load and available supply the system has been simulated using MATLAB.

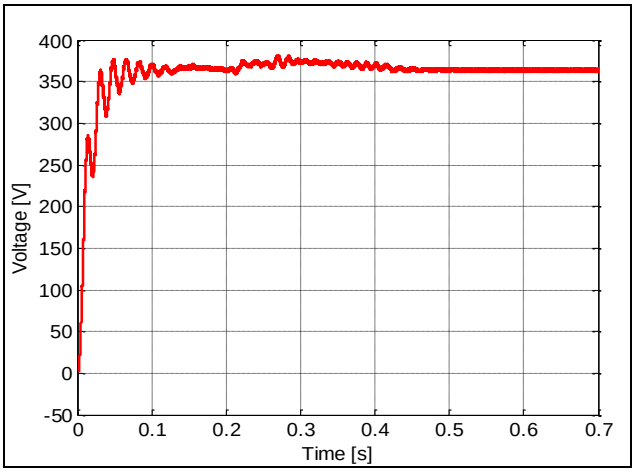

Figure 6 Output Voltage of DC-DC Converter for PV Application as given for the Impedance Source Converter

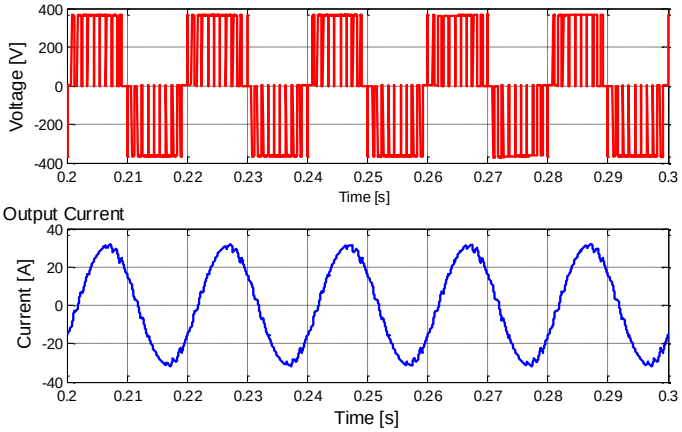

Figure 7 AC Output Voltage from Inverter

Figure 6 shows the output voltage of the system with as included with transient and steady state response of the system. it is very much clear that the system has several input disturbances which can be observed in the outlput of the

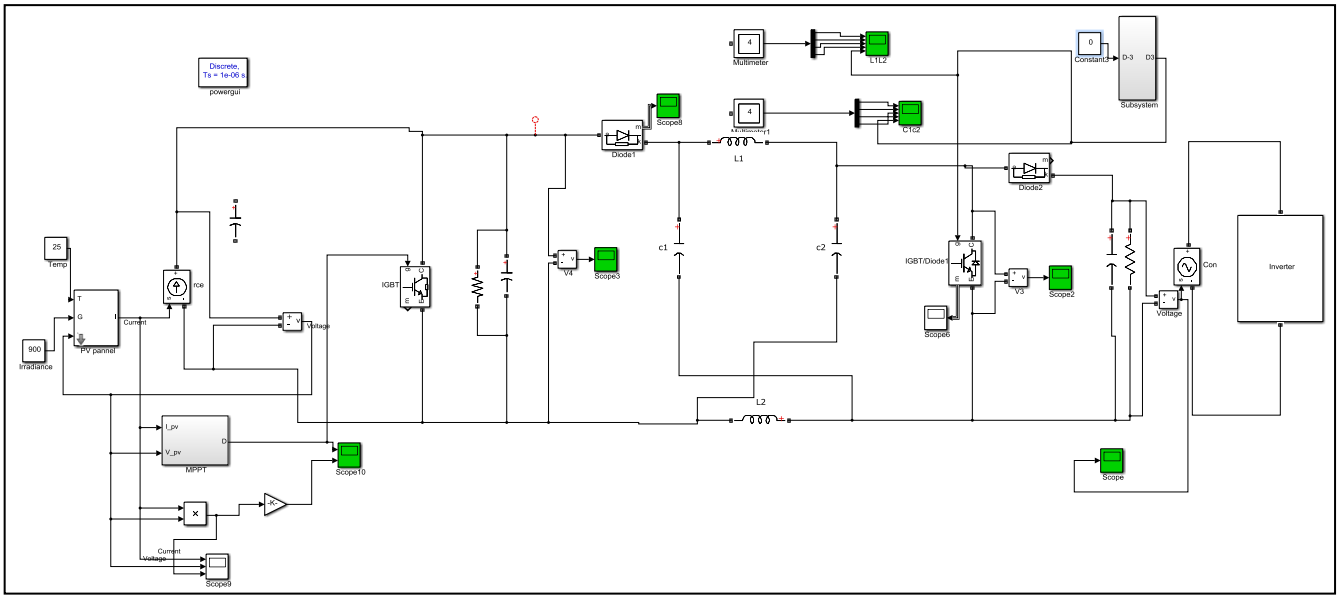

Figure 5 Simulation Diagram With Complete Model

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system. In addition, figure 7 is the waveform of output voltage of the inverter of single phase supply with the R-L load of 0.8 lagging power factor. In this the voltage ratio are taken for the systematic approach of the domestic level single phase supply with least current harmonics. Figure 8 and figure 9 are the voltage and current of the three phase power conversion as three phase load. The three phase inverter has the same frequency for the operation. However, this three phase inverter can be modelled for the system with frequency other than the 50 [Hz] as per the requirement of the converter applcation.

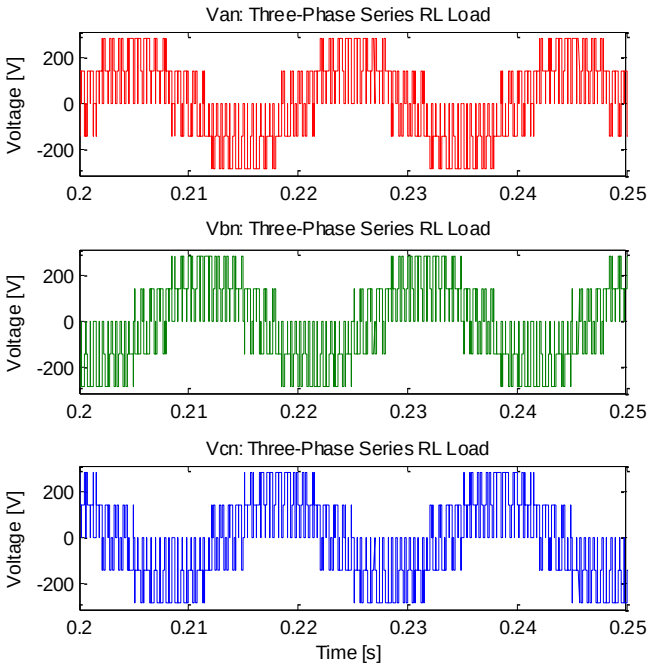

Figure 8 Three phase Output Voltage

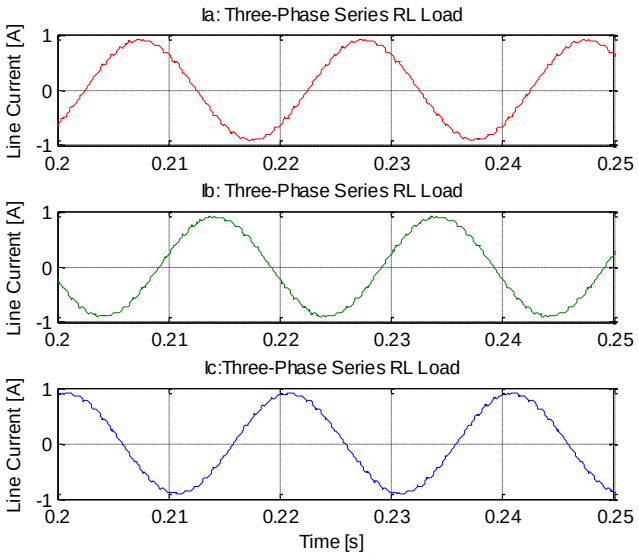

Figure 9 Output current of Inverter Unit.

In figure 10 the FFT analysis of the system is performed with the three phase power conversion in this it is clear that the current harmonic in the system is coming less than the 5% as per the IEEE-519, 1992 standard.

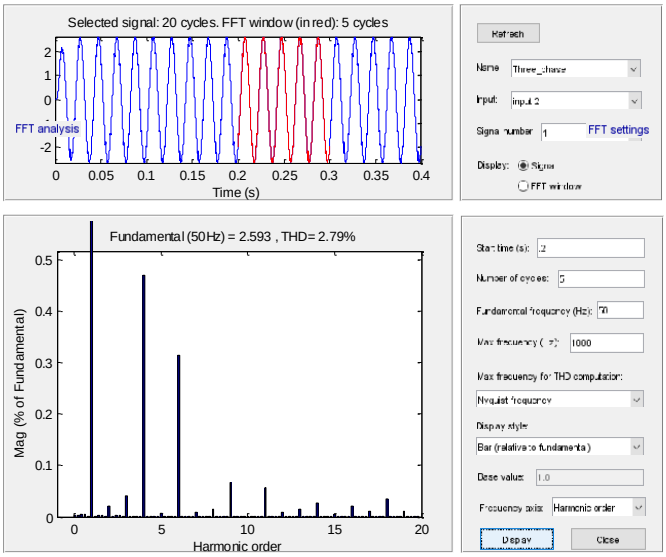

Figure 10 FFT analysis of Output Current

TABLE I. PARAMETER FOR SIMULATION

Parameter	Value	Unit
Input Voltage	120	V
Output Voltage	380	V
Vac Peak to Peak	380	V
Output Current	30	A
Frequency	50	Hz
Power Factor	0.8	-

In Figure 10 the number of cycle for the analysis of THD (Total Harmonic Distortion) is taken, which provides the better and accurate analysis of functional system. It should be noted again that the Z-source concept can be applied to the entire spectrum of power conversion. Based on the concept, it is apparent that many Z-source conversion circuits can be derived

V. CONCLUSION

Conclusively, one can observe that the condition of power developed in the sustained renewable can be improved by increasing the stage efficiency of power converter by means of the switching device and state. In this work study of PV and Impedance Source converter is presented and validated successfully in MATLAB/SIMULINK® environment. Also, the inverter circuit with the two levels out in reduced THD is presented in the work. Current THD is almost 2.79% which can be accepted by the virtue of application in different circuitry.

This paper focused on a Z-source inverter for Photo-Voltaic applications. Through the example, the paper described the operating principle, analyzed the circuit characteristics, and demonstrated its concept and superiority. Analytical and simulation results have been presented. The Z-source inverter can boost–buck voltage, minimize component count, increase efficiency, and reduce cost.

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