Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 08, August-2016

Fuzzy Logic Controller based Impedance Source Converter for PV Grid Connected System

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***Abstract*— The objective of this paper is to identify the problems of photovoltaic grid connected system related issues. The major concern of the survey is to identify the control technique suitable for the PV-Grid connected system and design the fuzzy logic controller for the impedance source network which can give better solution apart from the open loop and crisp set controller. 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

To design a new power electronics converter, one can, on the one hand, develop a new control strategy. On the other hand, one can design a novel power converter topology, so as to obtain specific outputs, more simple control, higher efficiency, less complexity, lower weight, minimal cost, and better robustness. In fact, a control strategy is specified to a certain topology, and the topology determines the control system. Therefore, it is of great significance to coin new power converter topologies to fulfil various requirements in applications, which will thus be the main concern of the presented work. Due to an input source of a converter being either a voltage source or a current source, various traditional converters can fall to two categories: voltage source and current source converters [1].

It is, however, known that voltage source converters suffer from shoot-through problems, applicability only to capacitive loads, and limited output voltage gains; while current source converters have open-circuit problems, applicability only to inductive loads, and limited output current gains. In order to solve these problems, Z-source converters were firstly proposed by Peng in 2002 [1], by coupling an LC impedance network (a two-port network with a combination of two basic linear energy storage elements, i.e. L and C) with the DC source to form a novel source, named Z-source, which is a kind of impedance source (an impedance is denoted by Impedance source can be regarded as a general source, including the current and the voltage sources as two extreme cases, i.e. impedance source can be regarded as the current source when the equivalent impedance is equal to infinity, while as the voltage source when the equivalent impedance is equal to zero. Therefore, the topology of impedance source converters has been widely studied and applied due to its unique features and its design method; for example, a Z network is applied to couple with the traditional converters to improve their functions. Inspired from this design method, more impedance source converters, such as quasi-Z-source converters, trans-Z-source converters, embedded-Z-source converters, have been coined and widely applied in practice, e.g. wind energy systems motor drives, vehicle systems, and solar energy systems. In fact, the design methodology of Z-source and other extended impedance source converters is essentially is based on the impedance network matching mechanism, which instructs how an impedance network can be matched to the sources to fulfill certain requirements. However, the essential impedance matching mechanism has not yet been well understood and revealed, and the design of specific impedance source converters is still an art, lacking of a systematic design methodology. The Z-source inverter is one of quite new ideas designated to renewable energy system, manly fuel cell and photovoltaic [2],[3].

The solar cells used in PV are made with many different technologies, depending on the type of applied concentrator. Usually, with better arrangement of cell and manufacturing the efficiency of cell is about of 40%.

The light concentration, through the increasing of concentration of minority carriers, improves the efficiency of the solar cell logarithmically. The produced current is linearly proportional to the irradiance level. Since the power developed is proportional to product of voltage and current and the voltage increases exponentially with the concentration level, the power increases in the linear way.

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.

II. PHOTOVOLTAIC SYSTEM AND IMPEDANCE SOURCE NETWORK

A. Solar Photovoltaic Panel

Simplified electrical equivalent circuit is enough to explain the importance of R_{sh}, R_s, and I_0. Indeed, the higher the current, the higher the voltage drops across the series resistance. In this way, the diode senses a voltage higher than that one on the external load, so its exponential

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 08, August-2016

behaviour reduces the current in the external circuit when the voltage on the diode is closed to its threshold voltage.

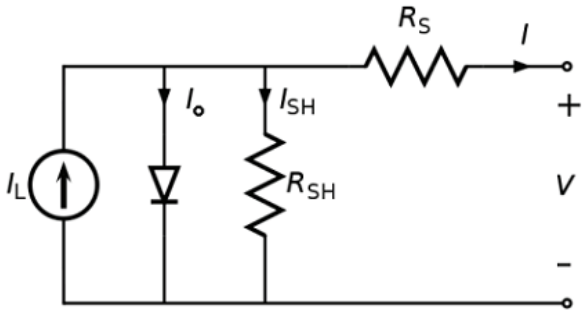

Figure 1 Simplified Electrical Equivalent Network of Solar PV Cell

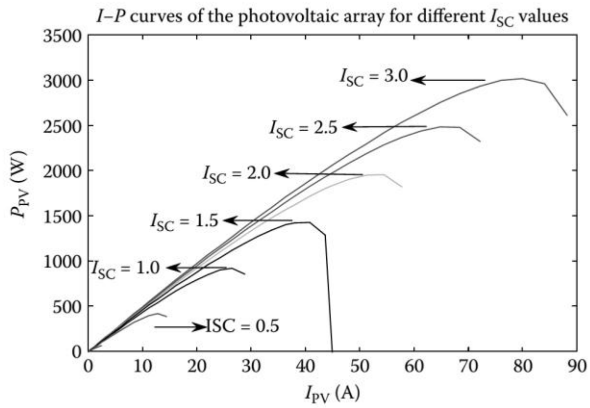

Figure 2 Power-Current Characteristics of PV system For Different I_{SC}

$$r_C = Z_C = \frac{1}{-j\omega C} \approx 0$$

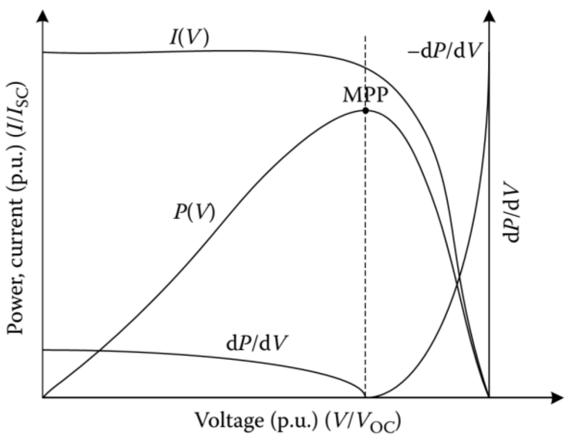

Figure 3 Normalized characteristic of photovoltaic array

B. Impedance Source Converter

There are two types of sources, namely voltage and current sources, any of which could be a generator or a load. A real voltage source can be represented as an ideal voltage source in series with a resistance RVS, with the ideal voltage source having zero resistance, to ensure its output voltage to be constant. The voltage source is normally equivalent to a capacitor C with infinite capacitance, i.e. C = ∞, so that, where Z_C denotes the impedance of the capacitor.

Similarly, a real current source can be represented as an ideal current source in parallel with a resistance rCS, with the ideal current source having infinite resistance, so that its output current is constant, which is normally equivalent to an inductor with infinite inductance, i.e. $L = \infty$ which implies also $r_L = Z_L = j\omega L \approx \infty$, where Z_L represents the resistance of the inductor. Correspondingly, converters can be classified into voltage source converters and current source converters.

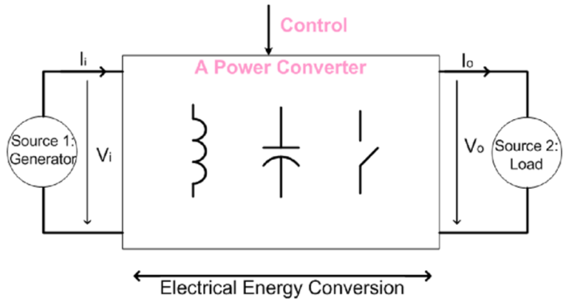

Figure 4 Electrical Energy Conversion using Power Electronic Converter

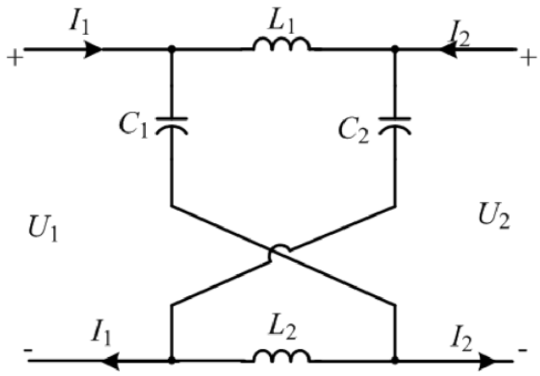

Figure 5 Simple Z-source Lattice Network

$$Z_{Zi}(s) = \frac{(s^2LC+1)Z_{ZL}(s)+2sL}{s^2LC+2sCZ_{ZL}(s)+1}$$

$$Z_{Z0}(s) = \frac{(s^2LC+1)Z_{ZS}(s)+2sL}{s^2LC+2sCZ_{ZS}(s)+1}$$

$$Z_{ZS}(s) = \begin{cases} 0; & if\ \text{D}\ is\ on \\ \infty; & otherwise \end{cases}$$

$$Z_{ZL}(s) = \begin{cases} 0; & at\ \text{a shoot through state} \\ \infty; & at\ \text{open circuit state} \\ Z_Z(s); & at\ \text{normal state} \end{cases}$$

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$$Z_{Zi}=\begin{cases}\dfrac{2sL}{1+s^2LC}; & \text{at a shoot through State}\\[2ex] \dfrac{s^2LC+1}{2sC}; & \text{at a Open Circuit State}\\[2ex] \dfrac{\left(s^2LC+1\right)Z_Z\left(s\right)+2sL}{2sCZ_Z\left(s\right)+s^2LC+1} & \text{at a normal State}\end{cases}$$

$$Z_{Z0}=\begin{cases}\dfrac{2sL}{1+s^2LC}; & if\ \text{D} \ is\ on\\[2ex] \dfrac{s^2LC+1}{2sC}; & otherwise\end{cases}$$

III. FUZZY LOGIC RULES AND SIMULATION

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. To understand why use of fuzzy logic has grown, understand what is meant by fuzzy logic. Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic.

However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of fuzzy logic.

Building a fuzzy inference system

Fuzzy inference is a method that interprets the values in the input vector and, based on user defined rules, assigns values to the output vector. Using the GUI editors and viewers in the Fuzzy Logic Toolbox, can build the rules set, define the membership functions, and analysed the behaviour of a fuzzy inference system (FIS).

The fuzzy controller is characterized as follows:

1. Five fuzzy sets for each input and outputs: NB (negative big), NS (negative small), Z (zero), PS (positive small), PB (positive big).
2. Triangular membership functions for simplicity.
3. Fuzzification using continuous universe of discourse (COD).
4. Implication using Mamdani's 'min' operator
5. Defuzzification using the 'height' method.

Table-1 shows the fuzzy logic rule based system for the development of fuzzy inference system, whereas fuzzy logic surface for operation is given in figure-6. Here, the results are taken in two different conditions as in open loop operation and in close loop operation.

Table 1 Fuzzy Logic Rules

Change in error (Δe)	Error (e)				
	NB	NS	Z	PS	PB
NB	NB	NB	NB	NS	Z
NS	NB	NB	NS	Z	PS
Z	NB	NS	Z	PS	PB
PS	NS	Z	PS	PB	PB
PB	Z	PS	PB	PB	PB

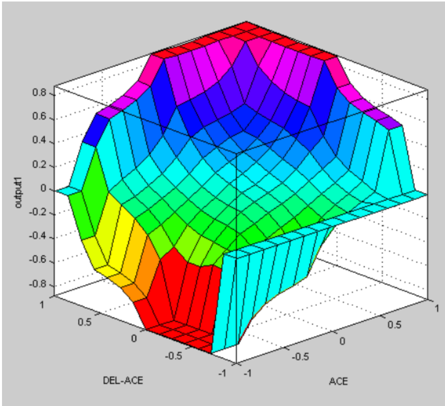

Figure 6 Fuzzy Logic Rule Surface

Figure 7 shows the output voltage in open loop of operation. It is clear that the settling time of system is very high and there is occurrence of disturbances during the initial settling. This disturbance may cause the failure of system as protection unit may act.

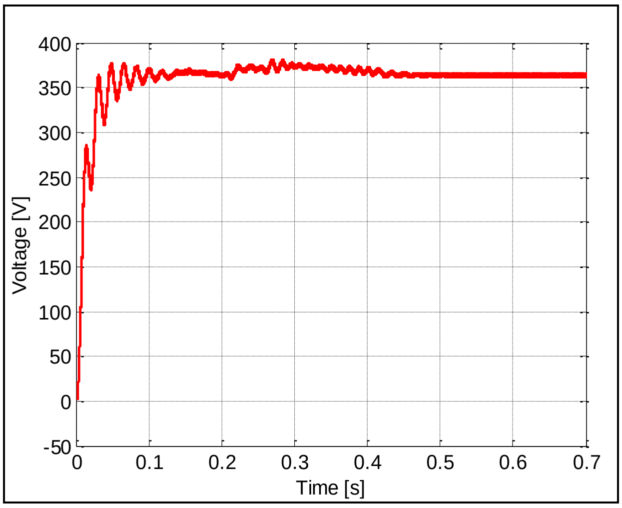

Figure 7 Output voltage without controller

THD is about 1.58% which is quite in the limit prescribed by the IEEE. In the close loop operation fuzzy based system has been introduced in the network it follows the rule given in the FIS(Fuzzy information system) file. Reference of operation is given as 230√2 for the peak DC-Link voltage.

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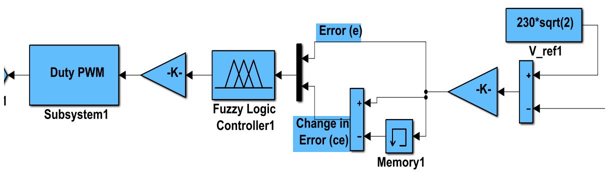
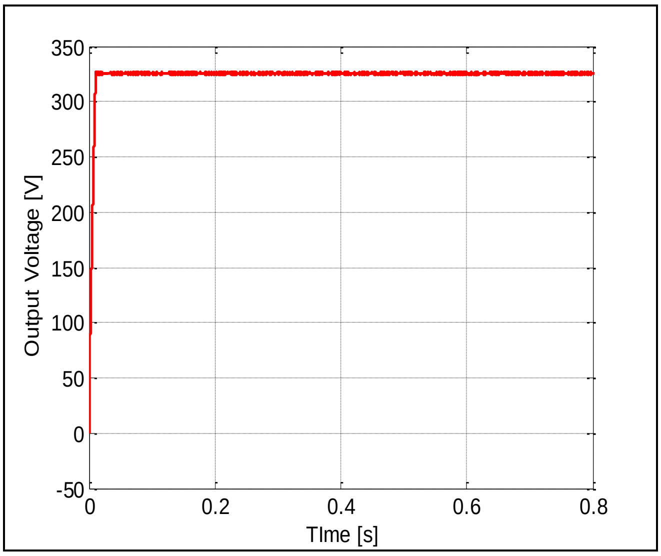


Figure 8 Fuzzy based closed loop control to generate duty pu



lse.

Figure 9 Output voltage during close loop operation

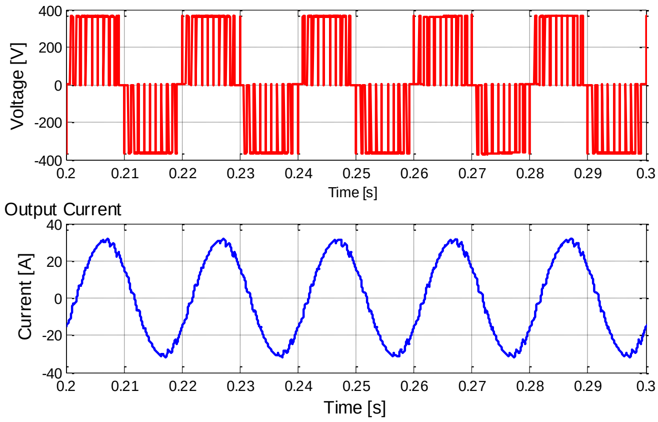


Figure 10 Two Level single phase output voltage

Figure 9 depicts the output voltage at close loop operation. It is very much clear that the close loop dc voltage at the dc link is very stable and does not have any over limited oscillation that may cause the disturbance to the network.

A three phase voltage and current is presented at the end with figure 12 and 13 for the three phase consumers. Parameter of operation for simulation is given in table -2. Single and three phase supplies are part of 50Hz system only.

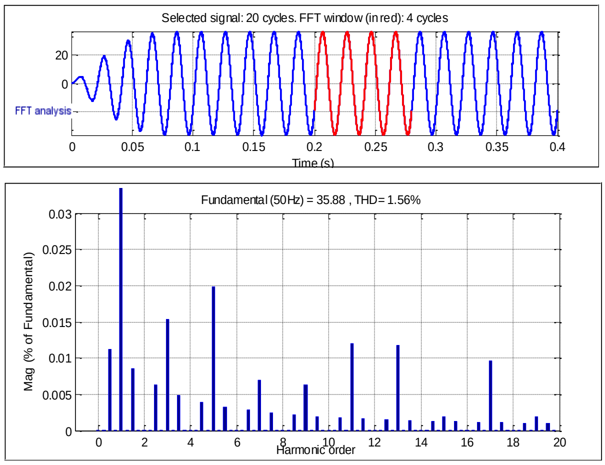


Figure 11 THD distribution among different level of harmonics and overall content

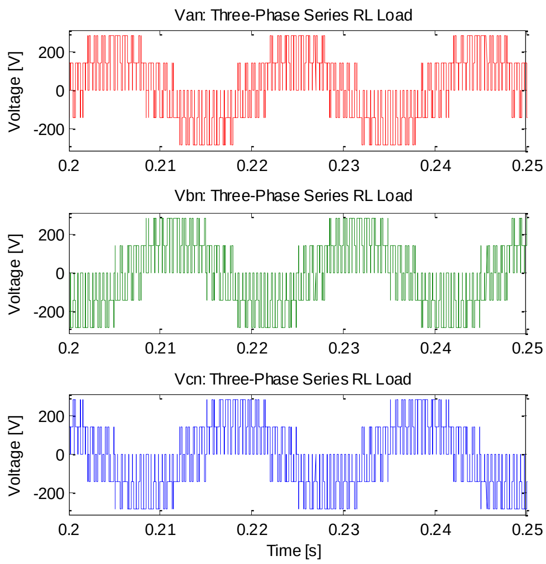


Figure 12 Three phase output voltage

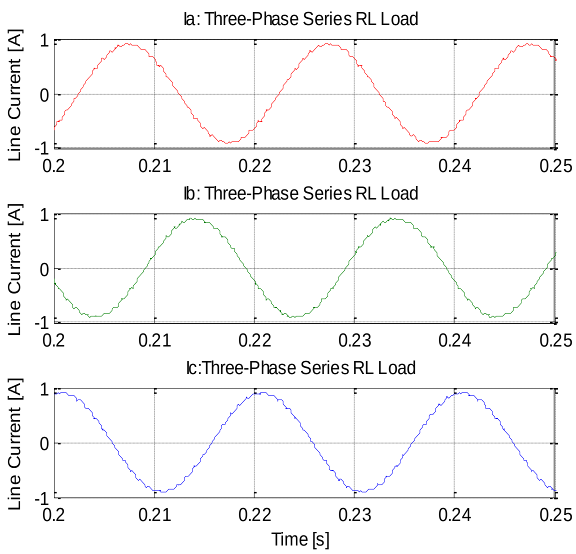


Figure 13Three phase output current

Table 2 Parameter of Simulation

Parameters	Values
Three Phase Load (50Hz)	
Rated Voltage	230 [V]
Rated Power/Frequency	1000 [W]
Resistance	10 [ohm]
Inductance	20 [mH]
Power Factor	0.8 lag
Photovoltaic Source	
Nominal Power Peak	11960 [W]
OC Voltage of Panel Peak	460 [V]
SC Current of Panel Peak	26 [A]
Impedance Source Converter	
Nominal Voltage	230√2 [V]
Inductance L1, L2	2.7 [mH]
Capacitance C1, C2	25 [µF]
DC-Link Capacitor	470 [µF]
Single-Phase Load (50Hz)	
Rated Voltage	230 [V]
Rated Power/Frequency	1000 [W]
Resistance	10 [ohm]
Inductance	20 [mH]
Power Factor	0.84 lag

IV. CONCLUSION

In this work grid connected system has been introduced for the domestic level single phase and three phase as popular at the consumer end. Also, different mppt method of PV system has been discussed. The MPPT methods are popular for the tracking of maximum power that can be extracted from the system. In addition, literature related to grid connected system with their advantage and application have also been discussed. According to the literatures various problems associated is identified and proposed methodology using impedance source converter have been discussed. There are different types of PV-battery system for grid connected operation appear in the system with the time. These systems have been discussed in detail with the different configuration. Among these configurations one may use the any configuration with proposed fuzzy system and impedance source converter. An impedance source converter with the advantage over voltage source and current source have been discussed in the Laplace domain analysis is also included. A overall modelling using MATLAB-2013a has been followed by simulation in close loop and open loop operation. At the end THD for the single phase system is found in limited with the IEEE standards.

ACKNOWLEDGMENT

This paper is part work of master of engineering under the guidance of Mr. Tikeshwar Gajpal, at RITEE Raipur.

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