Power Quality Improvement in Grid-Connected Fuzzy Based System Using a Modified Converter of Distributed Generation

R.Lakshman Rao[1], R.sireesha[2], Sobhana.O[3]
[1](M.Tech Scholar, Department of EEE, VNR Vignana Jyothi institute of engineering and technology, Hyderabad.
Email: raviralalakshman@gmail.com)
[2] (Assistant Professor, VNR Vignana Jyothi institute of engineering and technology, Hyderabad.
Email: sireesha_r@vnrvjiet.in)
[3] (Assistant Professor, VNR Vignana Jyothi institute of engineering and technology, Hyderabad.
Email : sobhana_o@vnrvjiet.in)

Abstract
This paper emphasis on the improvement of grid current and we are focusing on the basic issues like 1)To suppress the injection of harmonic contents from non linear loads in to the grid 2) To reduce the power losses of the converter 3) Improve the THD of the grid current. The mentioned issues are overcome by using two parallel inverters through grid synchronization and it is also realized by PI and Fuzzy controllers which have been carried out using MATLAB software.

Keywords: *Photovoltaic system [DC], Grid [AC], Inverters [VSI], PI and Fuzzy logic controllers*

I. INTRODUCTION

In the past years, the utilization of electrical power has been increasing rapidly to meet the growing demand for energy. As a future energy different renewable energy sources like photovoltaic, wind, thermal etc are considered. In this paper photovoltaic (PV) power generation which is generated using sunlight is considered as the input source and connected to the grid, during grid integration the arisen power quality and power loss issues are implemented using different methods. The most conventional approach recently proposed for the loss reduction is reconfiguration of distribution network [1].The most previous works like using of voltage source inverters [VSI] with high switching frequency in order to facilitate reconfiguration of DG into the grid in this method switching loss will be more and high current will flow through the switches [2].Some of the references have suggested different structures of voltage source inverters. Each of this topology have there specific advantage and disadvantage. In [3] two parallel inverters with same configuration have been proposed for load current compensation however the complexity of model concluded in dq0 framework is high. In [4] multi level CHB inverter is used for compensation of reactive contents of load current and harmonics but in switching frequency of each HB inverter is equal to the grid frequency that leads to switching loss to be reduced but it will eliminate only some pre specified harmonics.

Due to above problems we are going for inverters which are connected in parallel with different frequencies. The first inverter is operated with low current and high frequency and second inverter is operated with high current with low frequency and PV is connected with the grid using two parallel inverters.

II. PHOTOVOLTAIC MODULE

A PV system consists of a number of PV cells connected in series which will supply high voltage level. A PV cell is a semiconductor device which consists of a n-type silicon layer at the top and p-type silicon layer at the bottom to form a PN junction that could generate 0.5 to 0.6 V at the junction. The current (I_{cell}) of the PV cell is defined as the area of the cell in combination of temperature (T) and irradiation (G) [5]. A PV module which converts light energy into electrical energy for a specific cell depends on both T and G. In this paper the PV cell is conventionally represented by the (I_{ph}), a diode connected in parallel (D), a shunt resistance (R_{sh}), and series resistance (R_s). The equivalent circuit is shown in the figure 1.

By applying KCL to fig1 we will get

$$I_{ph} = I_d + I_{sh} + I \quad (1)$$

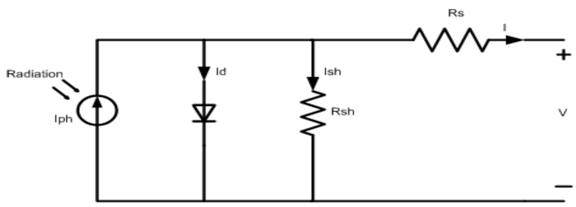

Fig 1: Equivalent circuit of solar cell

If $R_{sh} >> R_s$,Then

$$I_{ph} = I_d + I \quad (2)$$

Equation (2) can be written as

$$I = I_{ph} - I_d \quad (3)$$

Substituing Id in eqution (3), then we get

$$I = I_{ph} - I_o\left[\frac{e^{q}(V_{PV} - I_{PV}R_s)}{nKT} - 1\right] \quad (4)$$

From the above equation we can find the voltage and current of each PV cell.In this paper the output voltage of the PV cell is 550V.

III. PROPOSED CONVERTER STRUCTURE

The block diagram of studied network is shown in the fig 2. DG resource like PV arrays with DC output voltage is connected to PCC through the power electronic converters, which are nothing but single phase voltage source inverters. To the PCC we connected a non linear load along with grid. The aim of this project is

1. To improve the power quality of the grid current
2. The power injected in to the grid ,which is generated from the PV arrays
3. The compensation of reactive load current and harmonic presence of the grid current to less than 5% THD with pure sinusoidal current waveform [6].

Thus, the above conditions are can be improved by using grid synchronization with the help of PI and Fuzzy logic controllers

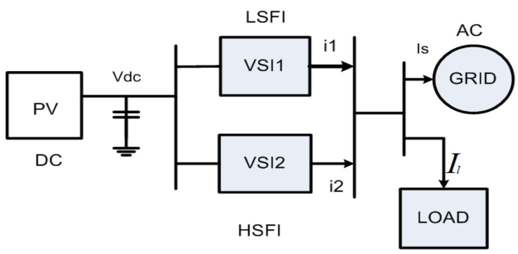

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Fig.2 Block diagram of studied network

A. Converters operation and Power Quality improvement

According to Fig.3 the structure of each inverter is shown is a transistor H-bridge and the inductor is connected at the output side which converts voltage to current transformation

There are two inverters connected in parallel out of them first inverter is low switch frequency inverter has a quasi square voltage with low frequency that is equal to the grid frequency. This inverter is supposed to capture the power which is generated form PV arrays and inject it into the grid. Also, LSFI is used to provide the reactive power compensation corresponding the fundamental component of load current.

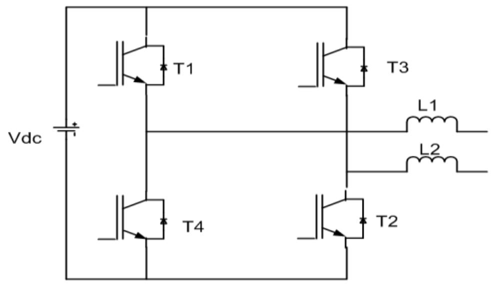

Fig 3: Single phase VSI

The second inverter namely high switching frequency inverter (HSFI) has a high frequency and it is used here to realize the harmonic compensation of the load current. In addition, HSFI has to provide the harmonic distortion of the current generated from LSFI. The cooperation of LSFI and HSFI described here brings a pure sinusoidal current which will be injected into the grid[7].

Although the frequency of the inverter is low and current which flows through the inverter will be high switching loss will not be significant because of switching loss will be low. In this converter, one may use high rated element as well as low frequency switches. On the other hand, HSFI is only used for compensating the harmonic contents. Therefore, the switching loss will be low as the harmonic currents are significantly less than the fundamental one. Consequently, it can be concluded that the efficiencies of proposed interface versus the single inverter with high-switching frequency is enhanced.

B. Control strategy of both inverters:

We are more concerned about the control of output voltage of the inverters, so we are controlling the first inverter namely [HSFI] using the modulation technique called SPWM in this technique the sinusoidal wave (reference signal) is compared with the triangular wave (carrier signal). when the sinusoidal wave is larger than the triangular wave, then the upper switch will be turned on and lower switch is off in vice versa as shown in the figure (4) width of each pulse is changed related to the amplitude of sine wave evaluated at the center of the same pulse .By using this type of technique significantly we are reducing the lower order harmonics. In this project the grid voltage is taken as the reference signal such that grid frequency determines the inverter output frequency[8].

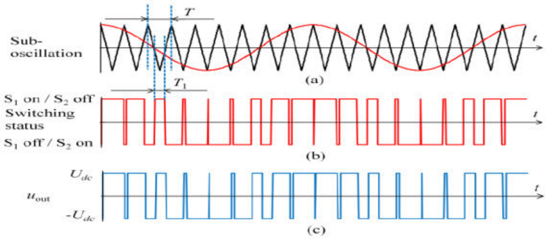

Fig 4: SPWM Technique

The second inverter namely [LSFI] has a low switching frequency and the output voltage of this inverter is controlled by using pulse generator technique the switching frequency will be low and harmonics will generate due to this harmonics will inject in to the grid for the compensation of this harmonics we are going for the high switching frequency inverter

IV.PI CONTROLLER

At present, the PI controller is most widely adopted in industrial application due to its simple structure, easy to design and low cost. A controller is one which compares controlled values with the desired values and has a function to correct the deviation produced. The PI controller is nothing but the combination of proportional plus integral controller. The PI controller can decrease the steady state error without disturbing stability of the system.

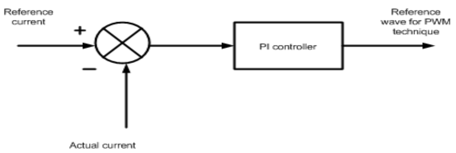

Fig.5 Grid synchronization with pi controller

$$\frac{U(s)}{E(s)} = K_p + \frac{K_i}{s} \qquad (5)$$

From the fig.5 actual current is taken as the grid current and reference current is taken as grid voltage and it is given to the PI controller and we will get the desired output which we will take as reference sine wave for the PWM technique for high switching frequency inverter. By using PI controller we will get THD of grid current less than the 5% from the fig 10 the THD level will be 3.24%

V. FUZZY LOGIC CONTROLLER

The identified power quality and synchronization problems can be effective reduced by controlling inverter. Fuzzy logic is widely employed in controlling technique. The word "fuzzy" maintain fact that the logic concerned will wear down ideas that can't be expressed as "true" or "false" however rather as "partially true". Though various approaches like genetic algorithms and ANN will perform even as well as formal logic in several cases, formal logic has the advantage that the answer to the matter is forged in terms that human operators will perceive. From the fig 11 the THD value will be 0.35 which is less than the pi controller. From the fig.6 the reference and actual current is given to the fuzzy logic controller

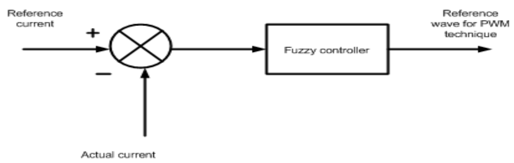

Fig.6 Grid synchronization with fuzzy controller

So their expertise is employed for the current control. The membership functions for inputs $V_{dc\text{-}ref}$ and V_{dc} are seven each and also output I_{max} has seven membership functions as shown in Fig.5.

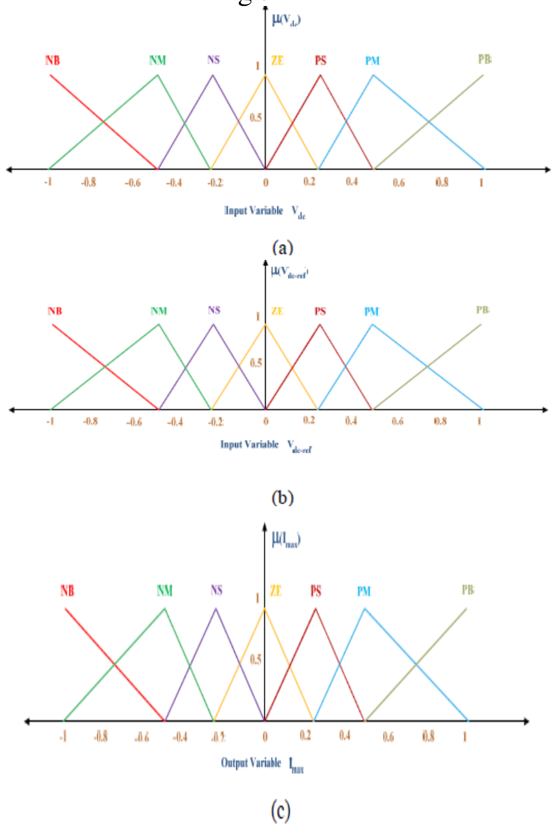

Fig 5: (a) Input V_{dc} normalized membership function; (b) Input $V_{dc\text{-}ref}$ normalized membership Function; (c) Output I_{max} normalized membership Function.

Table I. The rules for FLC

E / CE	NB	NM	NS	Z	PS	PM	PB
PB	Z	PS	PM	PB	PB	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PS	NM	NS	Z	PS	PM	PB	PB
Z	NB	NM	NS	Z	PS	PM	PB
NS	NB	NB	NM	NS	Z	PS	PM
NM	NB	NB	NM	NM	NS	Z	PS
NB	NB	NB	NB	NB	NM	NS	Z

From the table I, each error and its change in error is divided into 7 X 7 membership functions as: Negative Big (*NB*), Negative Medium (*NM*), Negative Small (*NS*), Zero (*Z*), Positive Small (*PS*), Positive Medium (*PM*) and Positive Big (*PB*). Negative Big (*NB*), Negative Medium (*NM*), Negative Small (*NS*), Zero (*Z*), Positive Small (*PS*), Positive Medium (*PM*) and Positive Big (*PB*).

V. MATLAB/SIMULINK RESULTS

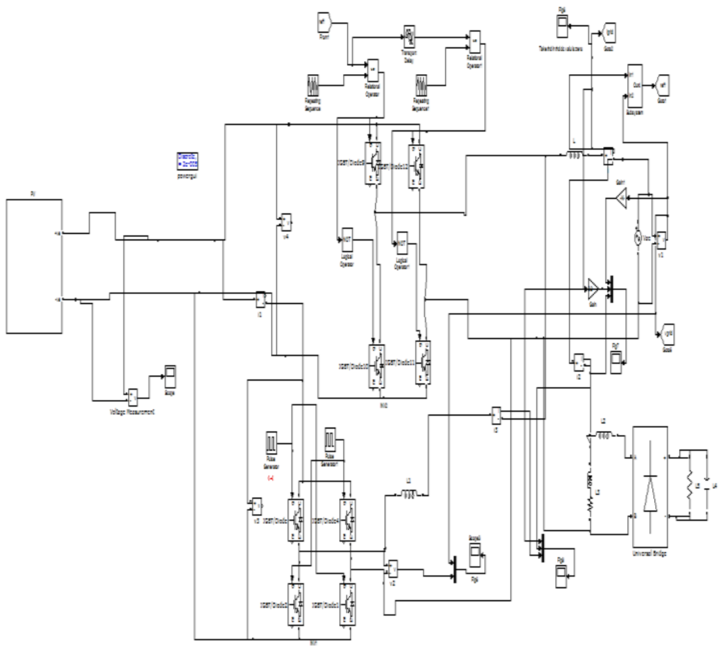

Fig 6: MATLAB/Simulink model of proposed system with PI controller

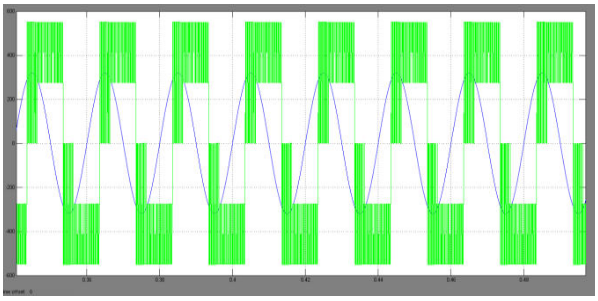

Fig.7 shows the Comparison of LSFI output quasi square voltage and the grid voltage

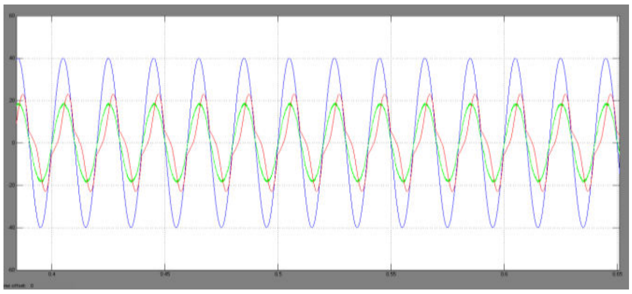

Fig 8: The Grid voltage (V_s), grid current (i_S), Load current (i_L)

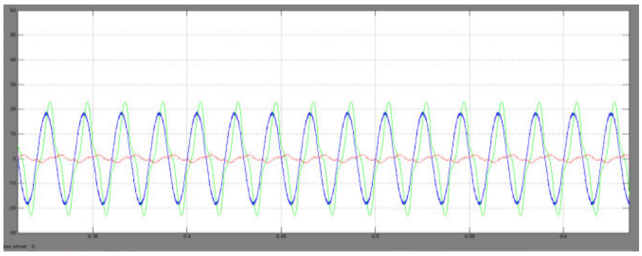

Fig 9: LSFI current (i_L), HSF[current (i_2) and the total current supplied by both inverters

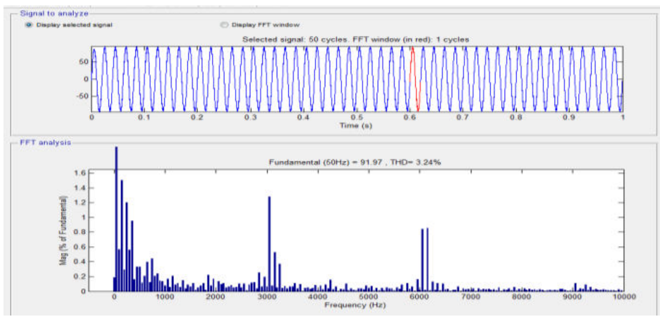

Fig 10: THD response of grid current with PI controller

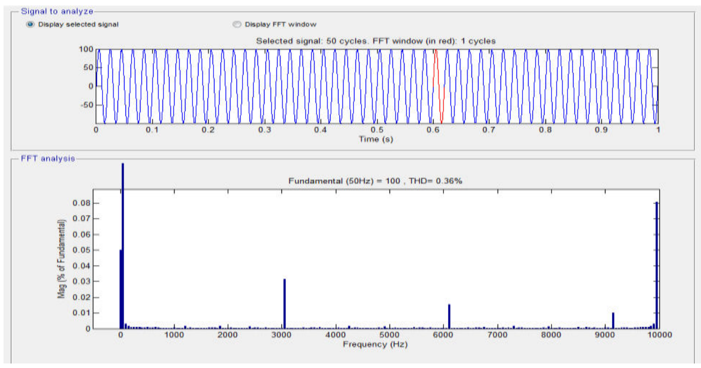

Fig 10: THD response of grid current with fuzzy logic controller

TABLE II

Cases	Source current THD (%)
Using PI controller	3.24
Using FUZZY controller	0.36

VI. CONCLUSION

In this project a distributed generation source is connected to grid using a converter that contains two parallel inverters with different operation for each of them. The converter is controlled in such a way that it injects the active power of the DG sources to grid and compensates the reactive power and harmonic components of the load current. PI and Fuzzy logic controllers are used in this concept and performance of the controllers are analyzed. Using these methods the power quality of the grid is improved and the power loss of it is reduced. The analysis of the work have been carried by using MATLAB/Simulink.

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