



# **Reduction of THD Level by Selective Harmonics Filter for Microgrid Using Fuzzy Logic Techniques**

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**ABSTRACT:** This paper states that the microgrids supplied by renewable energy sources (RES) are increasingly studied due to their insignificant environmental impact, concerning the classical power plants. The connection of small generation units in low voltage networks tends to be a more reliable solution. A micro grid can be defined as a low-voltage network with its loads and several small modular generation systems connected, both power and sometimes heat (combined heat and power – CHP) to local loads. In this project the DC-DC converter is controlled by means of a closed loop proportional-integral-derivative (PID) and fuzzy logic controllers. Fuzzy controllers are nonlinear, therefore it is more difficult to set the controller gains compared to PID controllers. The idea is to start with a tuning of, conventional PID controller, replace it with an equivalent linear fuzzy controller, make the fuzzy controller nonlinear. The inverter is totally controlled to perform as multi-function device by incorporating active power filter functionality..

**KEYWORDS:** Active filters, Bandpass filters, Proportional-integral-derivative, Fuzzy logic controllers, Microgrids.

## **I. INTRODUCTION**

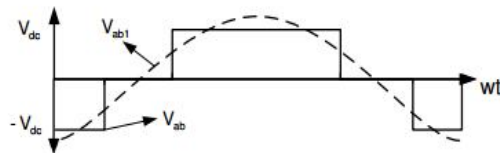
Microgrid is especially required when the sensitive loads are located in the distribution system that is contain several single-phase and/or nonlinear loads. Voltage source inverter (VSI) based distributed energy resources can provide power quality conditioning support. In this paper we are constructing a VSI based flow concentrates on which has the PID and fuzzy controlled power quality improvement system, this solves a overall harmonics reduction. They require filters to accurately detect unbalance and harmonics in the system..

Voltage source inverters are utilized in practical motor drive applications since their invention. In the past, the voltage source inverters were operated in the square wave operation mode. In the square wave operation mode, the inverter phase and therefore line-to-line output voltages have square wave shapes. In Figure 1 the line-to-line output voltage of  $V_{ab}$  and its fundamental component in this operation mode is illustrated for the conventional three-phase two-level inverter. This operation mode has drawbacks such that the inverter output voltage has low order harmonics with large magnitude (such as 5<sup>th</sup>, 7<sup>th</sup>) which are also seen at the motor currents. In spite of these drawbacks, the square wave operation was preferred in the early inverters because of its very low number of switching's, hence low switching losses. The semiconductor switches which were utilized in the early inverters had long turn-on and turn-off times resulting very high switching losses. Therefore by utilizing these switches, switching at high frequencies was practically impossible and instead of the PWM, the square wave operation.

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Inverter output line-to-line voltage waveform and its fundamental component when square wave method is utilized.

Figure 1 Voltage source inverter output

As the semiconductor technology has evolved, faster semiconductor switches have been developed. Today IGBT switches with low turn-on and turn-off times are widely utilized in VSIs. Development of faster semiconductor switches significantly reduced the switching losses of the inverter drives and this reduction enabled operation at higher switching frequencies. Therefore utilization of PWM methods in inverter drives had been possible at various power ratings and the square wave operation had been obsolete except at very high power ratings. Today PWM methods are widely preferred in three-phase motor drives due to their superior characteristics. In the PWM mode operation, an AC motor does not draw low order current harmonics (such as 5th, 7th, 11th, etc.). The lowest order harmonic on the motor current occurs at the switching frequency of the inverter. The frequency is practically high (order of kHz), current harmonics are damped by the motor windings and are not problematic as in the square wave operation case. In the PWM approach, the inverter switches are turned on and off within a carrier period in an appropriate manner and switch pulse patterns are generated. Various PWM methods with unique switch state pulse patterns have been developed with unique characteristics. In this chapter conventional PWM methods are reviewed, new PWM methods are introduced and their performance attributes are theoretically and analytically investigated. And then finally, a thorough performance.. Thus the selective harmonics are filtered and the total harmonic distortion is reduced.

## II. BLOCK DIAGRAM OF HARMONICS REDUCTION USING FUZZY

The main purpose of a DC-DC converter is to supply a regulated DC output voltage to a variable-load resistance from an unstable DC input voltage. DC-DC converters are commonly used in applications requiring regulated DC supply, such as the computers, medical instrumentation and communication devices.

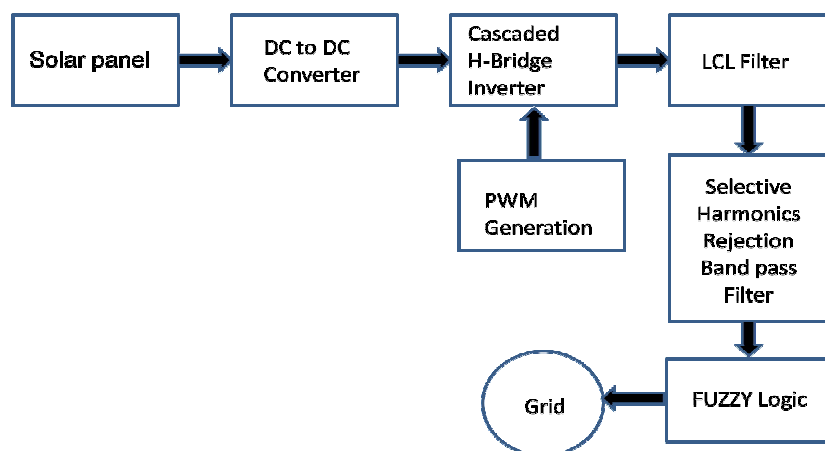


Figure 2 Block diagram using FUZZY.

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DC-DC converters are also used to provide a stable variable DC voltage for DC motor speed control applications. There are three types of DC-DC converters in use today, linear converters, switched capacitor converters (also known as charge pumps), and switched converters.

Linear converters can only generate lower output voltage from the higher input voltage. Their conversion efficiency is never greater than  $V_{out}/V_{in}$ . In practice, most linear converters operate with typical conversion efficiencies of only 30%. This is the major limitation which makes linear converters not suitable for the task of this paper. The output voltage in switched DC-DC converters is generally controlled using a switching technique, as illustrated by the basic switched DC-DC converter shown in figure 3.

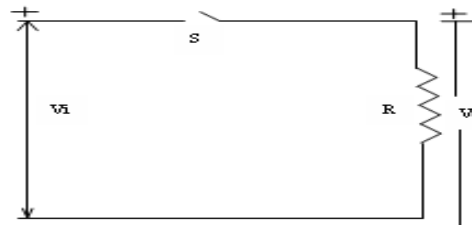


Figure 3 Basic switched DC-DC converter

### III. CASCADED H-BRIDGE INVERTER

A single-phase structure of an  $m$ -level cascaded inverter is illustrated in Figure.4. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Separate inverter level can generate three different voltage outputs,  $+V_{dc}$ ,  $0$ , and  $-V_{dc}$  by connecting the dc source to the ac output by different combinations of the four switches,  $S_1$ ,  $S_2$ ,  $S_3$ , and  $S_4$ . To obtain  $+V_{dc}$ , switches  $S_1$  and  $S_4$  are turned on, whereas  $-V_{dc}$  can be obtained by turning on switches  $S_2$  and  $S_3$ . By turning on  $S_1$ ,  $S_2$ ,  $S_3$ , and  $S_4$ , the output voltage is  $0$ . The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The amount of output phase voltage levels  $m$  in a cascade inverter is defined by  $m = 2s+1$ , where  $s$  is the number of separate dc sources. With an example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges. The phase voltage  $v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}$ . For a stepped waveform such as the one depicted with  $s$  steps, the Fourier Transform of the waveform follows:

$$H(n) = \frac{4}{\pi n} [\cos(n\theta_1) + \cos(n\theta_2) + \dots + \cos(n\theta_s)] \quad (1)$$

Where  $n=1,3,5,7,\dots$

The conducting angles  $1.2.3..s$  can be chosen such that the voltage total harmonic distortion is a minimum. Usually, these angles are chosen so that predominant lower frequency harmonics, 5th, 7th, 11th, and 13th, harmonics are eliminated. Multilevel cascaded inverters have been proposed for such applications as static var generation, an edge with renewable energy sources, and an battery-based uses. Three-phase cascaded inverters can be linked in wye or in delta. Peng has demonstrated a prototype multilevel cascaded static var generator connected in parallel with the electrical system that could supply or draw reactive current from an electrical system.

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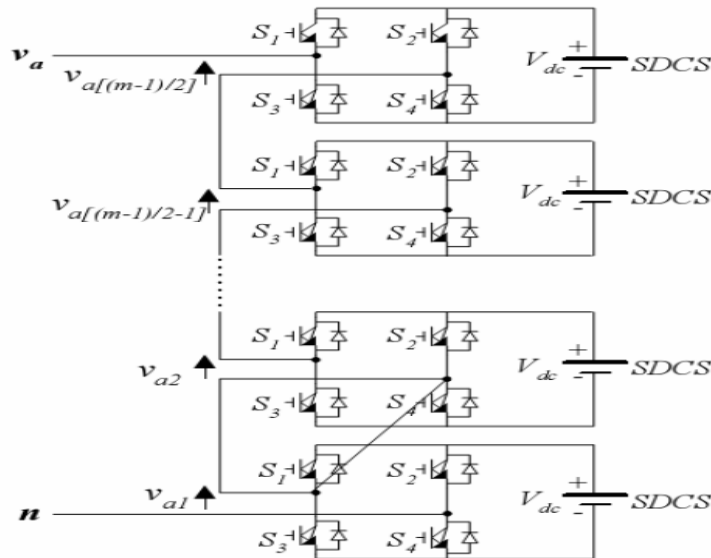


Figure 4 Single-phase structure of a multilevel cascaded H-bridges inverter.

The inverter could be controlled to either regulate the power factor of the current drawn from the source or the bus voltage of the electrical system where the inverter was related. Peng and Joos have also shown that a cascade inverter can be directly connected in series with the electrical system for static var compensation. Cascaded inverters are ideal for allied renewable energy sources with an ac grid, since of the need for separate dc

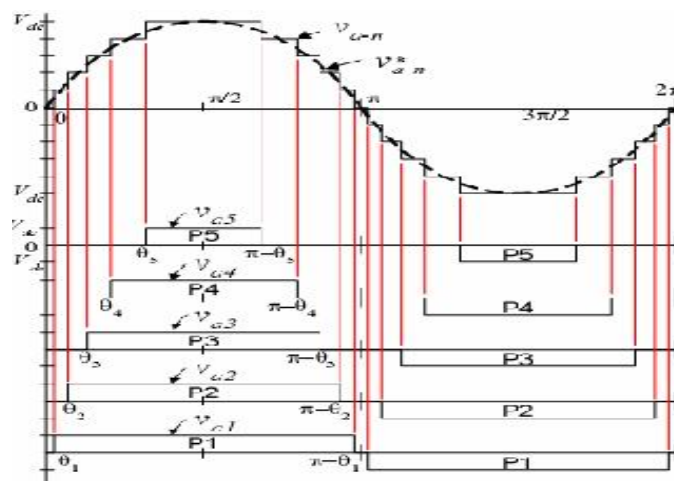


Figure 5 output phase waveform of an 11-level cascade inverter with 5 separate dc.

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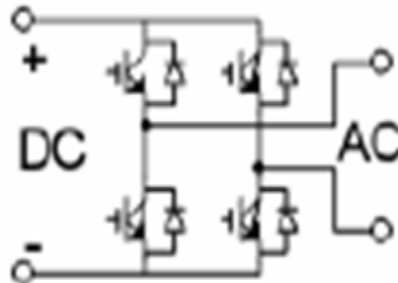


Figure 6 H-Bridge Inverter

sources, which is the case in applications such as photo voltaics or fuel cells. Cascaded inverters has been intended for use as the main traction drive in electric vehicles, where several batteries or ultra capacitors are well suited to serve as SDCSs .The cascaded inverter could also serve as a rectifier/charger for the batteries of an electric vehicle while the vehicle was connected to an ac supply as shown in Fig 6. Additionally, the cascade inverter can act as a rectifier in a vehicle that uses regenerative braking.

#### IV. LC FILTER

An LC circuit, also called a resonant circuit, tank circuit, or tuned circuit, consists of an inductor, represented by the letter L, and a capacitor, represented by the letter C. When connected together, they can act as an electrical resonator, an electrical analogue of a tuning fork, storing energy oscillating at the circuit's resonant frequency.LC circuits are used either for generating signals at a particular frequency, or picking out a signal at a particular frequency from a more complex signal. They are key components in many electronic devices, particularly radio equipment, used in circuits such as oscillators, filters, tuners and frequency mixers. An LC circuit is an idealized model since it assumes there is no dissipation of energy due to resistance. For a model incorporating resistance see RLC circuit. Often, the purpose of an LC circuit is to oscillate with minimal damping, and in this case their resistance is made as low as possible. While no practical circuit is without losses, it is nonetheless instructive to study this ideal form of the circuit to gain an understanding.

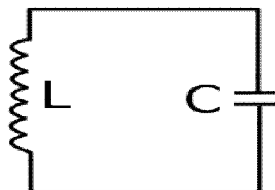


Figure 7 LC Filter

An LC circuit can store electrical energy oscillating at its resonant frequency. A capacitor stores energy in the electric field between its plates, depending on the voltage across it, and an inductor stores energy in its magnetic field, depending on the current through it.If a charged capacitor is connected across an inductor, charge will start to flow through the inductor, building up a magnetic field around it and reducing the voltage on the capacitor.

Eventually all the charge on the capacitor will be gone and the voltage across it will reach zero. However, the current will continue, because inductors resist changes in current. The energy to keep it flowing is extracted from the magnetic field, which will begin to decline. The current will begin to charge the capacitor with a voltage of opposite polarity to its original charge. When the magnetic field is completely dissipated the current will stop and the charge will



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again be stored in the capacitor, with the opposite polarity as before. Then the cycle will continue in a similar way, with the current flowing in the opposite direction through the inductor. The charge flows back and forth between the plates of the capacitor, through the inductor. The energy oscillates back and forth between the capacitor and the inductor until (if not replenished by power from an external circuit) internal resistance makes the oscillations die out. Its action, known mathematically as a harmonic oscillator, is similar to a pendulum swinging back and forth, or water sloshing back and forth in a tank. For this reason the circuit is also called a tank circuit. The oscillation frequency is determined by the capacitance and inductance values. In typical tuned circuits in electronic equipment the oscillations are very fast, thousands to millions of times per second.

### A. Resonance Effect:

The resonance effect occurs when inductive and capacitive reactances are equal in magnitude. The frequency at which this equality holds for the particular circuit is called the resonant frequency. The resonant frequency of the LC circuit is

$$\omega = \sqrt{\frac{1}{LC}} \quad (2)$$

Where L is the inductance in henries, C is the capacitance in farads. The angular frequency  $\omega$  has units of radians per second.

The equivalent frequency in units of hertz is

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi\sqrt{LC}} \quad (3)$$

LC circuits are often used as filters; the L/C ratio is one of the factors that determine their "Q" and so selectivity. For a series resonant circuit with a given resistance, the higher the inductance and the lower the capacitance, the narrower the filter bandwidth. For a parallel resonant circuit the opposite applies. Positive feedback around the tuned circuit ("regeneration") can also increase selectivity (see Q multiplier and Regenerative circuit). Stagger tuning can provide an acceptably wide audio bandwidth, yet good selectivity.

### B. Series LC Circuit Resonance:

Here L and C are connected in series. Inductive reactance magnitude ( $X_L$ ) increases as frequency increases while capacitive reactance magnitude ( $X_C$ ) decreases with the increase in frequency. At a particular frequency these two reactance are equal in magnitude but opposite in sign. The frequency at which this happens is the resonant frequency ( $f_r$ ) for the given circuit.

Hence, at ( $f_r$ ):

$$X_L = -X_C \quad (4)$$

$$\omega L = \frac{1}{\omega C} \quad (5)$$

Converting angular frequency into hertz we get

$$2\pi fL = \frac{1}{2\pi fC} \quad (6)$$

Here  $f$  is the resonant frequency. Then rearranging,

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$$f = \frac{1}{2\pi\sqrt{LC}} \tag{7}$$

In a series configuration,  $X_C$  and  $X_L$  cancel each other out. In real, rather than idealized components the current is opposed, mostly by the resistance of the coil windings. Thus, the current supplied to a series resonant circuit is a maximum at resonance.

At  $f_x$  current is maximum. Circuit impedance is minimum. In this state a circuit is called an acceptor circuit.

Below  $f_x$   $X_L \ll (-X_C)$ . Hence circuit is capacitive and

Above  $f_x$   $X_L \gg (-X_C)$ . Hence circuit is inductive.

## V. HARMONIC SELECTIVE FILTER DESIGN FOR BANDPASS

Frequency/sequence selective filters were applied to separate the fundamental frequency positive sequence and negative sequence quantities. In this section, frequency/ sequence selective filters, called harmonic selective filters, are employed to separate fundamental frequency from its characteristic harmonics, viz., of order 5 and 7. In order to pass the 5th and 7th harmonics and reject the fundamental frequency, the transfer function of harmonic selective filter is determined as

$$G_{harm}(s) = \frac{1}{1 + \frac{(s-j7\omega_{60})(s+j5\omega_{60})}{k(s-j\omega_{60})}} \tag{8}$$

The harmonic selective filter passes 5th and 7th harmonics at unity gain and zero phase delay, and rejects the fundamental frequency component. When a three-phase signal with fundamental and 5th harmonic is passed through  $G_{harm}(s)$ , the output contains only the 5<sup>th</sup> harmonic.

## VI. FUZZY LOGIC CONTROLLER

### A. Structure Of A Fuzzy Logic Controller:

A fuzzy controller structure is shown in Fig.8 The controller is placed between preprocessing and post-processing blocks.

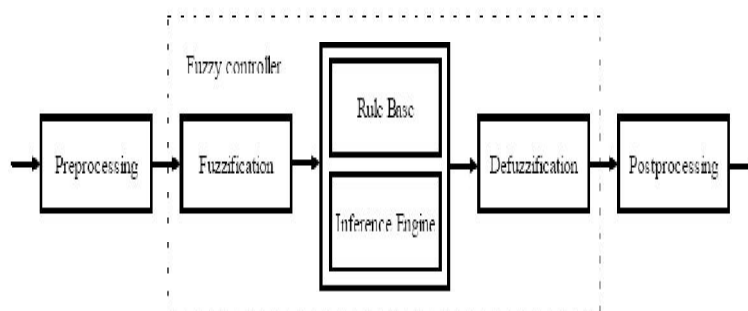


Figure 8 Block diagram of fuzzy controller



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The preprocessing block conditions the inputs, usually crisp measurements, before they enter the controller. The fuzzy logic controller involves four main stages: fuzzification, rule base, inference mechanism and defuzzification. The fuzzification and the defuzzification stages are needed to convert and reconvert real world crisp signals into fuzzy values and vice versa. The inference mechanism determines the matching degree of the current fuzzy input with respect to each rule and decides which rules are to be fired according to the input field. Next, the fired rules are combined to form the control actions. Fuzzy controllers are able to make effective decisions on the basis of linguistic information. Recent developments in fuzzy theory offer several effective methods for the design and tuning of fuzzy controllers. Most of these developments reduce number of fuzzy rules. Because implementation of fuzzy controllers require a large computational time for each step time in order to compute the appropriate control value to be applied to the system. Therefore, a reduction of the large fuzzy rule base is required.

## B. Fuzzy Inference Systems:

The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves membership functions, fuzzy logic operators, and if-then rules. Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply fuzzy systems. There are two types of fuzzy inference systems that can be implemented in the Fuzzy Logic Toolbox: Mamdani-type and Sugeno-type. These two types of inference systems vary somewhat in the way outputs are determined.

## C. Mamdani-Type Fis:

An example of a Mamdani inference system is shown in Fig 9 To compute the output of this FIS given the inputs, one must go through the following is a more detailed description of this process.

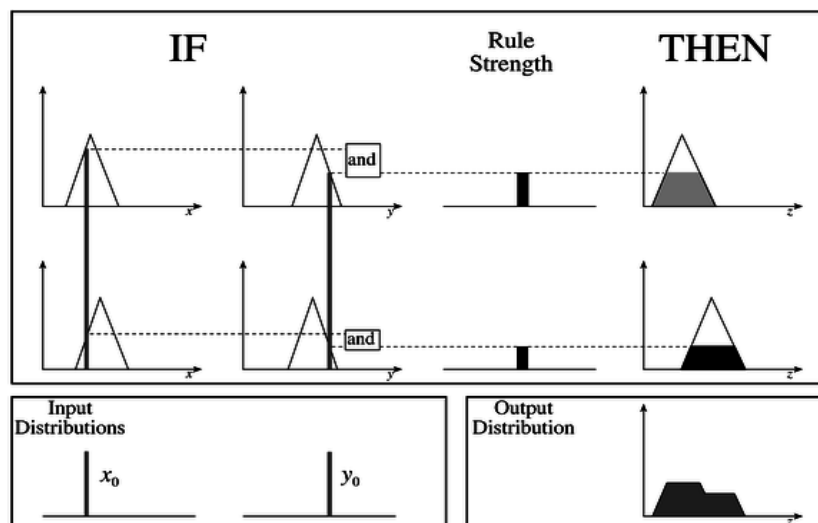


Figure 9 A two input, two rule Mamdani FIS with crisp inputs.





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Here it give the fuzzy rules table.

Table 1. Rules table

$A/B$	NB	NS	ZZ	PB	PS
NB	S	S	M	M	B
NS	S	M	M	B	VB
ZZ	M	M	B	VB	VB
PB	M	B	VB	VB	VVB
PS	B	VB	VB	VVB	VVB

A & B are two inputs, NB-Negative Big, NS-Negative Small, ZZ-Zero, PB- Positive Big, PS-Positive Small, M-Medium, S-Small, B-Big, VB-Very Big, VVB-Very Very Big.

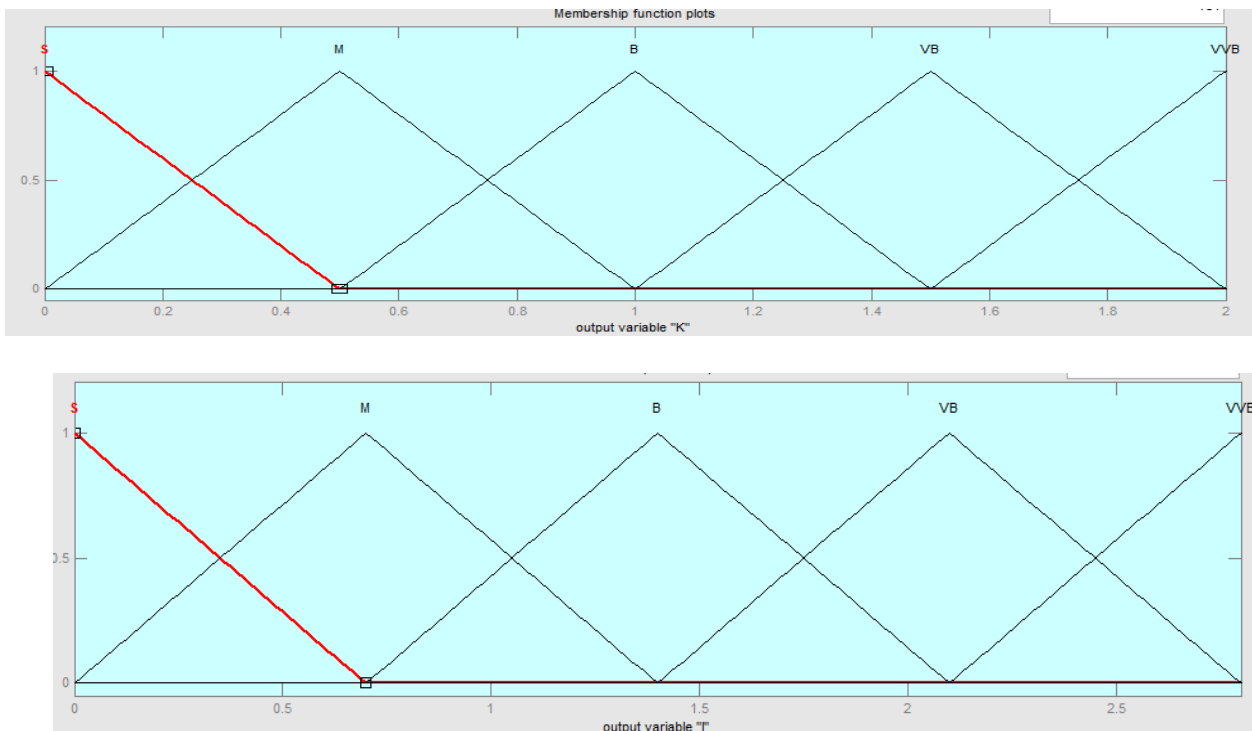


Figure 10 Membership functions for fuzzy controller

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## VII. SIMULATION RESULTS

The simulation diagram illustrates that the performance of PID with tuning the fuzzy controller which tracks the minimum THD value of the voltage ,since the whole system in stable. In this simulation diagram PV array is get the DC source and its converted to AC .so ,the harmonics will produced in that system and then it will be reduced with this type of method.

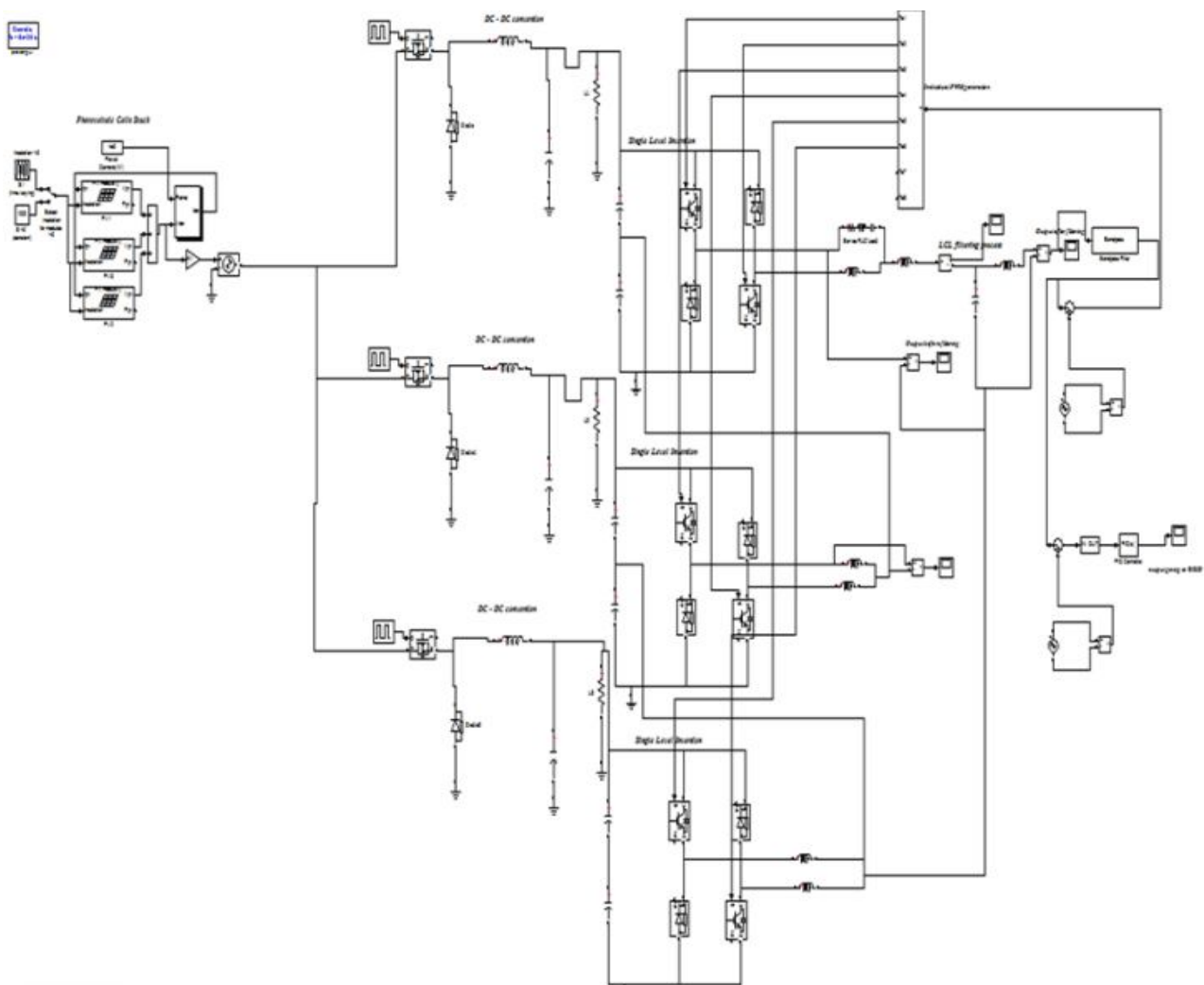


Figure 11 simulation diagram

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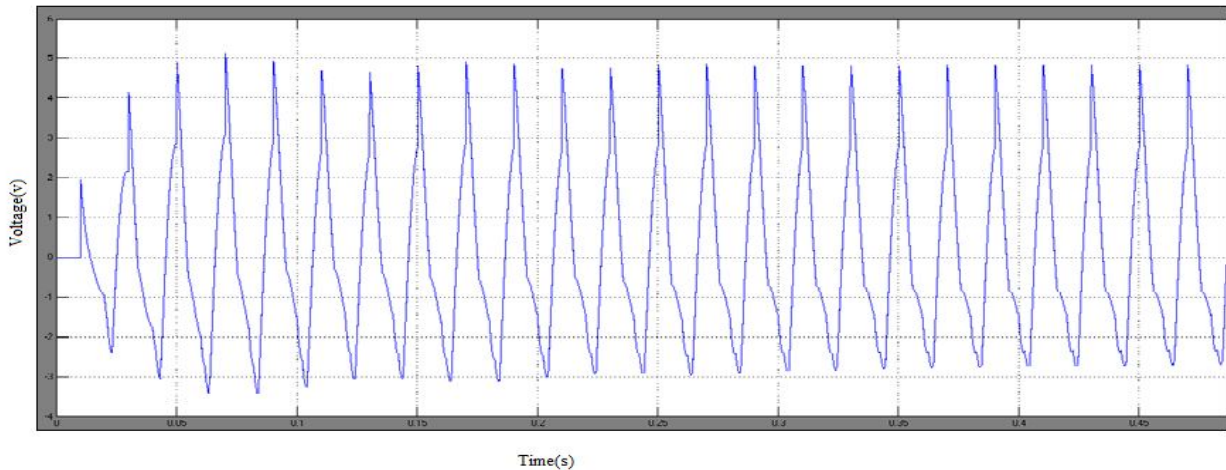


Figure 12 After LCL Filter

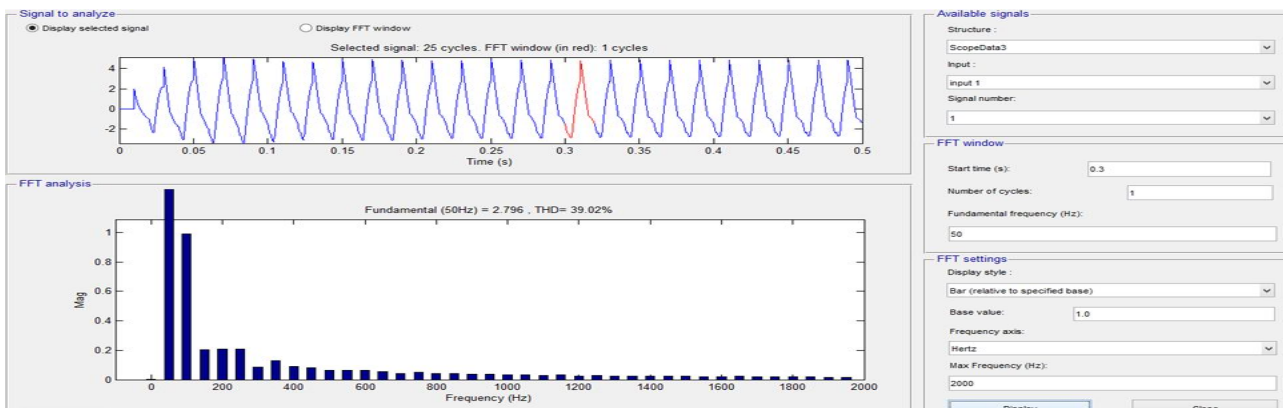


Figure 13 After LCL Filter THD value

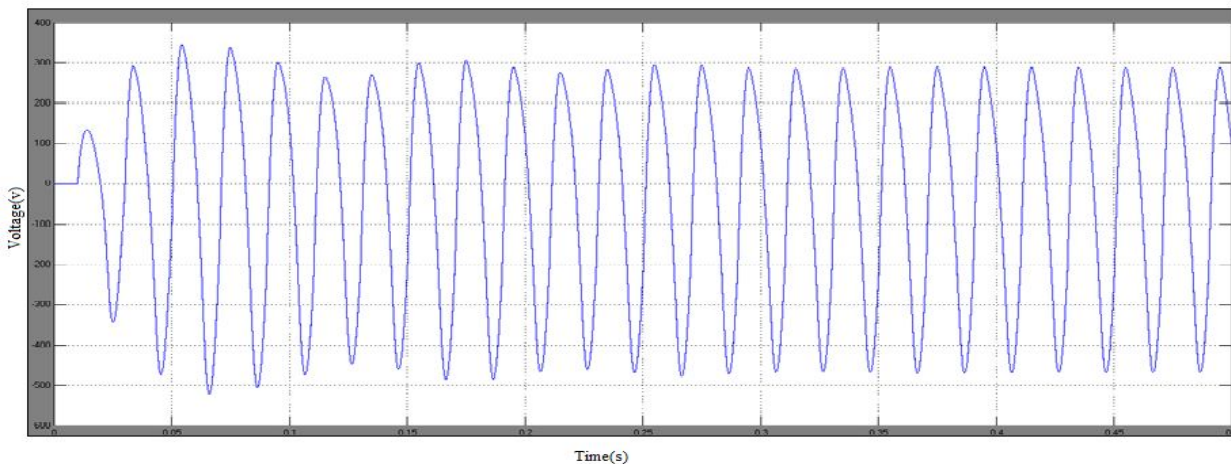


Figure 14 After Band pass filter

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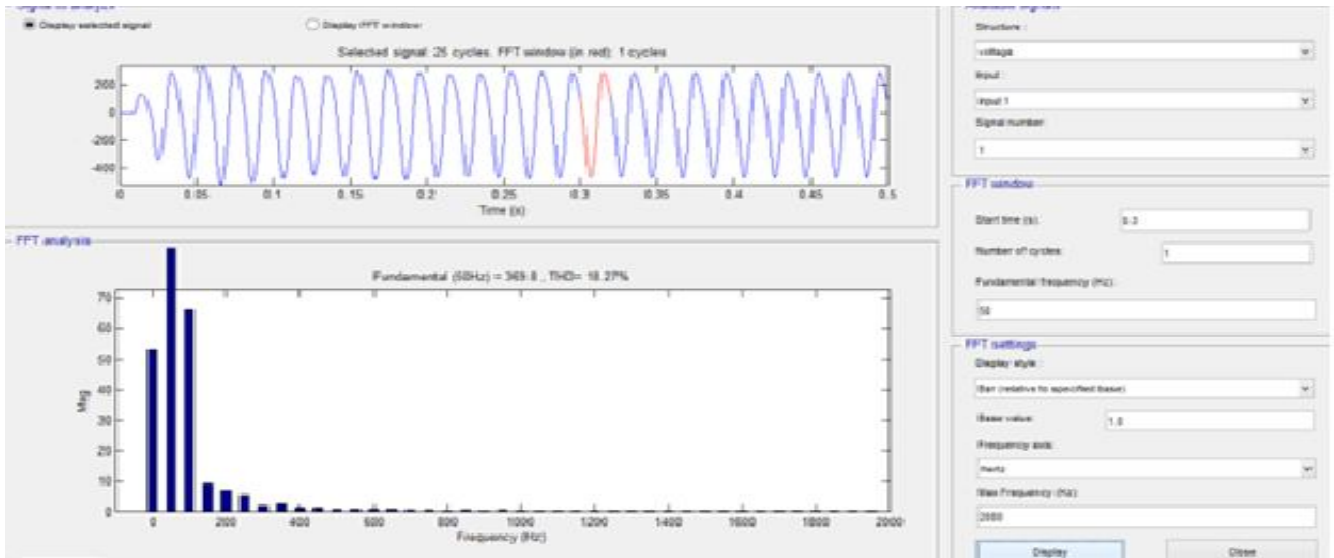


Figure 15 After Band pass Filter THD value

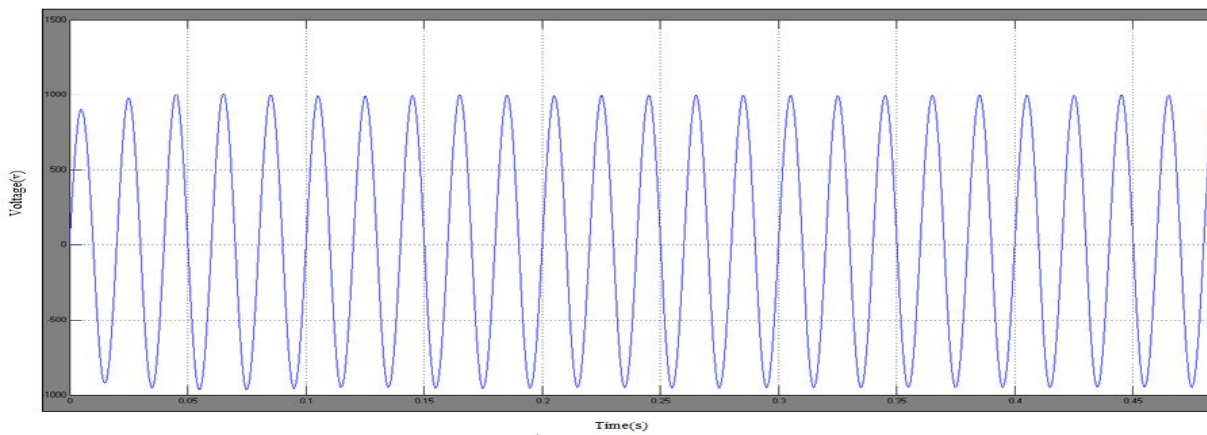


Figure 16 After PID and Fuzzy controller

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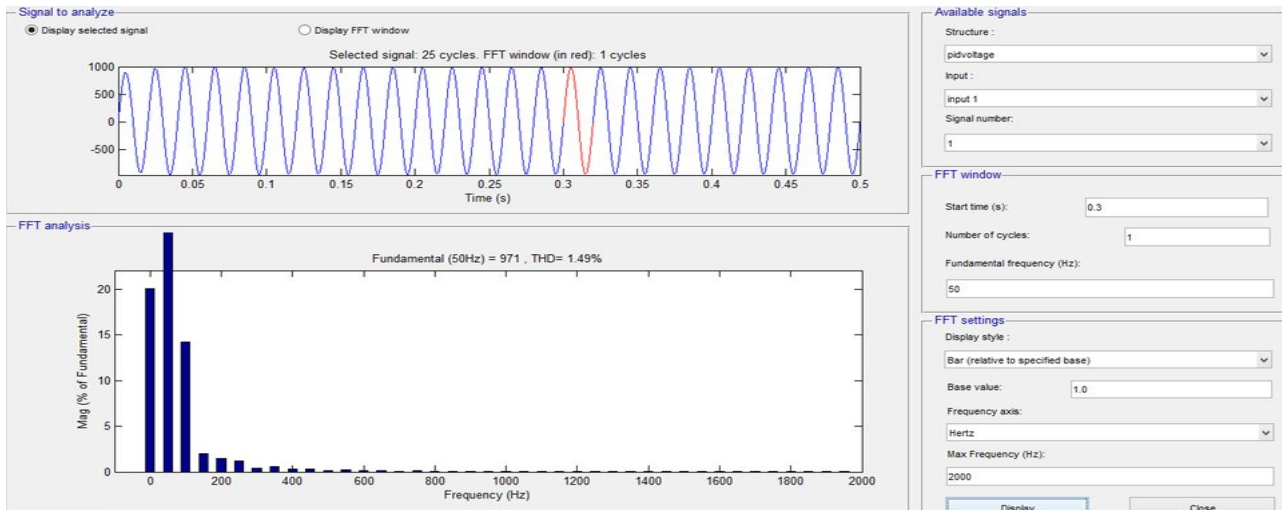


Figure 17 After PID and Fuzzy controller THD value.

## VIII. CONCLUSION

In this work, fuzzy control of THD is implemented in order to extract maximum system stable. The main goal of implemented fuzzy controller is to tune the PID controller. The total harmonic distortion is achieved by using FFT analysis to all the different cases and its reduced greatly. With PID and fuzzy ,after LCL filter the THD value is 39.02%,after Band pass filter the THD value is 18.27% and after fuzzy the THD value is 1.49%.So, the system should have more efficient and stable.

## REFERENCES

- [1] J. Arrillaga, M. H. J. Bollen, and N. R. Watson, "Power quality following deregulation," Proc. IEEE, vol. 88, no. 2, pp. 246–261, Feb.2000.
- [2] S. Bhattacharya, D. M. Divan, and B. Banerjee, "Synchronous reference frame harmonic isolator using series active filter," in Proc. EPE,Florence, 1991, pp. 3.30–3.35
- [3] J. Hafner, M. Aredes, and K. Heumann, "A shunt active power filter applied to high voltage distribution lines," IEEE Trans. Power Del.,vol. 12, no. 1, pp. 266–272, Jan. 1997.
- [4] G. Saccomando and J. Svensson, "Transient operation of grid-connected voltage source converter under unbalanced voltage conditions,"in Proc. IEEE IAS Annu. Meeting 2001, Oct. 2001, vol. 4, pp.2419–2424.
- [5] M. Illindala and G.Venkataramanan, "Control of distributed generation systems to mitigate load and line imbalances," in Proc. PESC 2002, Jun
- [6] F. Briz, A. Diez, and M. W. Degner, "Dynamic operation of carrier- signal-injection-based sensorless direct field-oriented AC drives,"IEEE Trans. Ind. Appl., vol. 36, no. 5, pp. 1360–1368, Sep./Oct. 2000. 2002, vol. 4, pp. 23–27
- [7] S. Gataric and N. R. Garrigan, "Modeling and design of three-phase systems using complex transfer functions," in Proc. PESC, 1999, vol.2, pp. 691–697.
- [8] M. Illindala, "Vector Control of PWM-VSI Based Distributed Resources in a Microgrid," Ph.D. dissertation, Dept. Electr. Eng., Univ.Wisconsin-Madison, Madison, WI, 2005.
- [9] Mahesh Illinda And Giri Venkataraman" Frequency/Sequence Selective Filters For Power Quality Improvement In A Microgrid" In IEEE Transactions On Smart Grid, Vol. 3, No. 4, December 2012

## BIOGRAPHY



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