POWER QUALITY IMPROVEMENT IN SOLAR FED CASCADED MULTILEVEL INVERTER USING ANFIS CONTROLLER

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Abstract

The presence of harmonics in solar Photo Voltaic (PV) energy conversion system results in deterioration of power quality. To address such issue, our paper aims to investigate the elimination of harmonics in a solar fed cascaded fifteen level inverter with aid of Proportional Integral (PI), Artificial Neural Network (ANN) and Fuzzy Logic (FL) based controllers. Unlike other techniques, the proposed ANFIS based approach helps in obtaining reduced harmonic distortions that intend to an enhancement in power quality. This paper also proposed to provide output voltage regulation in terms of maintaining voltage and frequency at the inverter output end in compatible with the grid connection requirements. The simulations are performed in the MATLAB Simulink environment for solar fed cascaded 15 level inverter incorporating ANFIS based controllers. To exhibit the proposed technique, a photovoltaic plant coupled to multilevel inverter is designed and hardware is demonstrated. All the three techniques are experimentally investigated with the measurement of power quality metrics along with establishing output voltage regulation.

***Keywords: Solar, PV, Multi level Inverter, MATLAB, Power quality,* ANFIS, PWM**

1. INTRODUCTION

Solar energy is harnessed from the sun using PV technologies, solar heating, concentrated solar power, concentrated photovoltaic and are generally characterized based on the way the energy is captured, converted and distributed. They are either classified as active or passive. A PV system converts light into electrical energy taking advantage of the photoelectric effect. The PV system involves an array of silicon semiconductors that collect the photons and changes over to electrons. The generated DC is then converted to AC using converters. Therefore, it is essential to utilize specific MPPT system to maximize the energy captured from the sun. This is generally achieved by using sun-tracking PV’s. The sun-tracking PV's achieve this goal by adjusting itself to the global solar installation shifts and amplifies the captured sunlight radiation to generate maximum power at a steady voltage. Efficiency in the solar array is estimated by the capacity to change over daylight into energy and is an exceptionally unique factor in picking the right panel for the PV system. As a reliable RE source, solar PV's can be successfully integrated into the mainstream power supply.

BOOST CONVERTER

A DC-DC boost converter is used between the PV array and inverter to supply required DC voltage and maintain load voltage constant. The input-output relation of voltage for continuous conduction mode can be defined as

$$Vo/Vin=1/1-D$$

where, D is duty cycle, Vin and Vo are input and output voltages of boost converter. When D increases from 0 to 1, output becomes higher than input voltage. DC-DC boost converter arrangement with PV array with increase in the duty cycle boost converter, average current of PV array increases and a result voltage of PV decreases. Thus, raising duty cycle results in movement of the operational point to the left of the PV array *V-I* characteristics. Likewise decrease in the duty cycle results in decrease in PV array average current and PV array output voltage increases. It results in operating point shifting to the right of PV array V-I characteristic. P&O and FLC are used to automatically vary the duty cycle of DC-DC converter to obtain constant DC voltage.

MULTILEVEL INVERTER

The need for the multilevel converter is to give high output power from the medium voltage source. Sources like batteries, super capacitors, and the solar panel are medium voltage sources

Types of Multilevel Inverter:

1. Diode clamped multilevel inverter
2. Flying capacitors multilevel inverter
3. Cascaded H- bridge multilevel inverter

CASCADED H-BRIDGE MULTILEVEL INVERTER

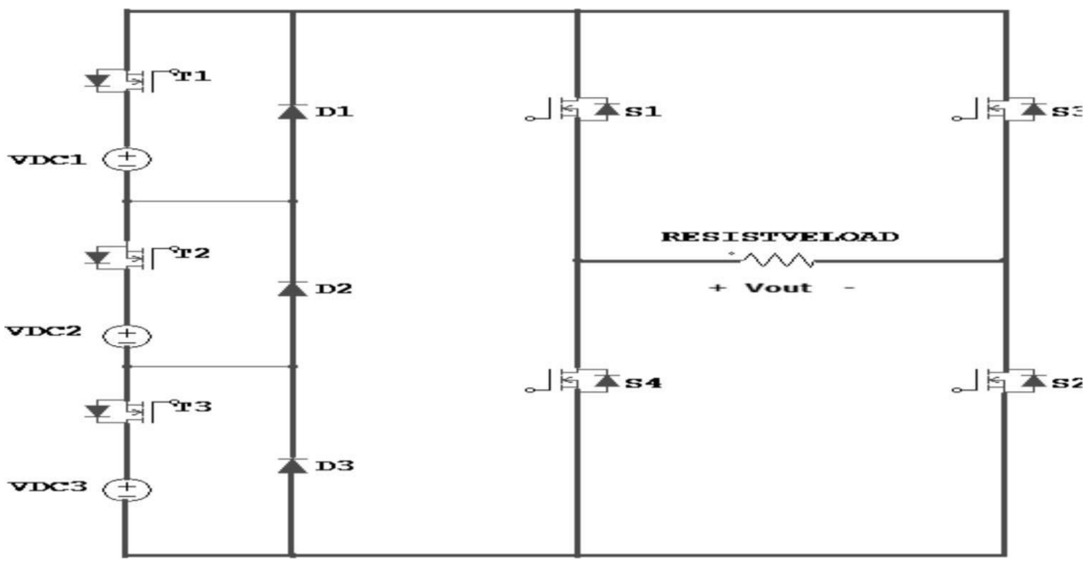


Fig. 1.1 Asymmetrical multilevel inverter

Cascaded H-bridge multilevel converters have been applied where high power and power quality are essential. The cascaded H-bride multilevel inverter is to use diodes and switches and requires less number of components in each level. This topology consists of a series of power conversion cells and power can be easily scaled. The combination of diodes and switches pair is called an H-bridge and gives the separate input DC voltage for each H-bridge. It consists of H-bridge cells and each cell can provide the three different voltages like zero, positive DC, and negative DC voltages. One of the advantages of this type of multi-level inverter is that it needs less number of components compared with other inverters. The price and weight of the inverter are less than those of the two inverters.

To increase the “n” number of output voltage levels the several H-Bridge and DC source are used. To reduce the switches in this topology the Symmetrical and Asymmetrical CHBMLI are utilized. In Asymmetrical Cascaded H Bridge Inverter (ASCHB-MLI) topology the DC source magnitude are unequal. In ASCHBMLI the output voltage is 15 level and they are 15Vdc, 30Vdc, 45Vdc, 60Vdc,75Vdc,90Vdc,105Vdc,0Vdc,-15Vdc,-30Vdc,-45Vdc, -60Vdc,-75Vd.In ASCHMLI the number of switches and number of output voltage levels are represented as follows

$$N\ level=2(n+1)-1$$
$$N\ MOSFET=n+4$$

Where n is the number of MOSFET switches

ADVANTAGES OF MULTILEVEL INVERTER

1. Common Mode Voltage:

The multilevel inverters produce common-mode voltage, reducing the stress of the motor and don’t damage the motor.

2. Input Current:

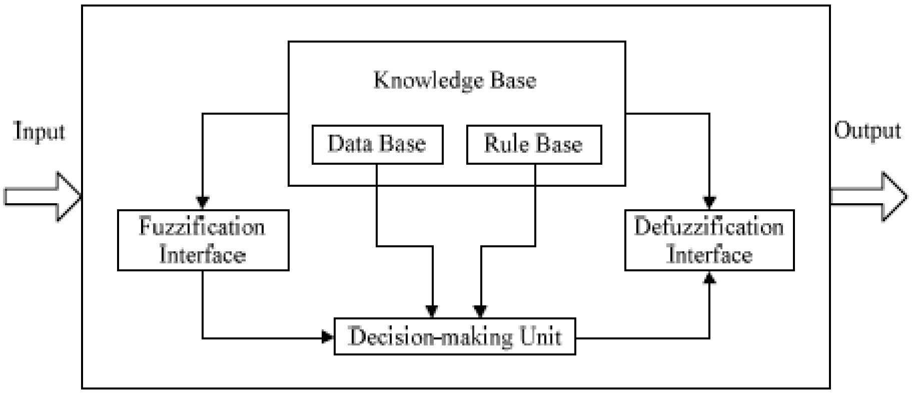
Multilevel inverters can draw input current with low distortion.

3. Switching Frequency:

The multilevel inverter can operate at both fundamental switching frequencies that are higher switching frequency and lower switching frequency. It should be noted that the lower switching frequency means lower switching loss and higher efficiency is achieved.

4. Reduced harmonic distortion:

Selective harmonic elimination technique along with the multi-level topology results



the total harmonic distortion becomes low in the output waveform without using any filter circuit.FUZZY CONTROLLER

Fig 1.2 Block diagram of a fuzzy inference system

The fuzzy logic controller involves three stages: fuzzification, inference mechanism and defuzzification. In fuzzification process the input data is converted into fuzzy membership function. The fuzzy data values are between 0 and 1. Fuzzy rules are framed in Inference mechanism to get the optimal output. In defuzzification, the fuzzy data is converted into real life data. The error between reference voltage and measured voltage and its derivative are input to fuzzy controller.

ANFIS CONTROLLER

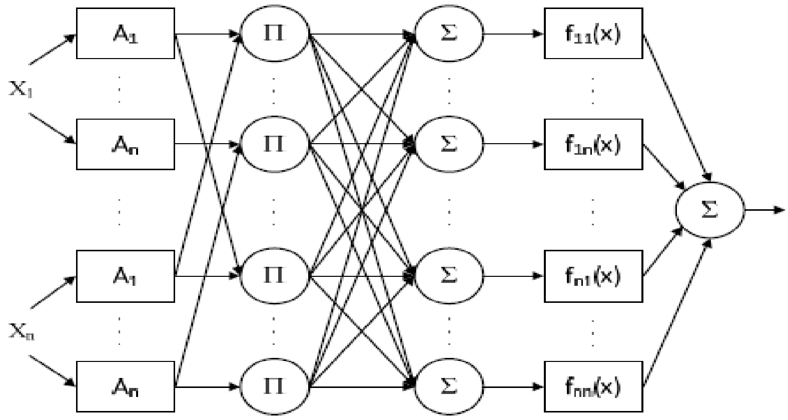


Fig 1.3 Typical Structure of ANFIS

In an adaptive neuro-fuzzy inference technique, that uses a given input/output data set, a fuzzy inference system is constructed, whose membership function parameters are tuned (adjusted) using either a back-propagation algorithm alone, or in combination with a least squares type of method. A network-type structure, similar to that of a neural network, which maps inputs through input membership functions and associated parameters, and then through output membership functions and associated parameters to outputs, can be used to interpret the input/output map. The basic structure of the ANFIS algorithm using a first order Sugeno-type fuzzy system.

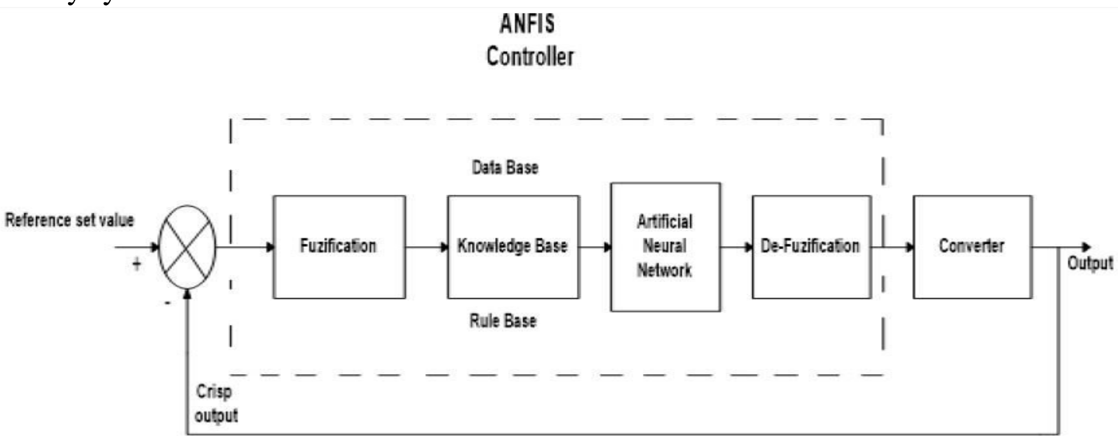


Fig 1.3 Typical Structures of ANFIS

2 PROJECT DESCRIPTION

EXISTING METHODS

The harmonics produced in inverter can cause distortion in current waveform which results in low grid power factor and high total harmonic distortion. With advent of technological development in power electronics and by proper control methods of inverter it is possible to get high energy conversion with high power factor and low harmonic distortion. P, PD, PI controllers are classical controllers which are simple in structure. The advantage of these controllers is their ability to tune according to requirement. But the drawback of these controllers is their inability to maintain stable error.

DEMERITS

- Inability to maintain stable error

PROPOSED METHODS

Proportional resonant (PR) controllers are combination of proportional and resonant controllers. Though these controllers are better than PI controllers, they need accurate tuning and are sensitive to frequency variations. Hysteresis controllers have been used since long time. They do not require any modulator and the hysteresis band can be adjusted to reduce the error. But, these controllers are not appropriate for higher power applications. Sliding mode controllers have the ability to reduce stable errors but a suitable sliding surface is needed and has the limitation of sampling rate. H-infinity controllers, m-synthesis controllers can be used but, they require high computational procedure.

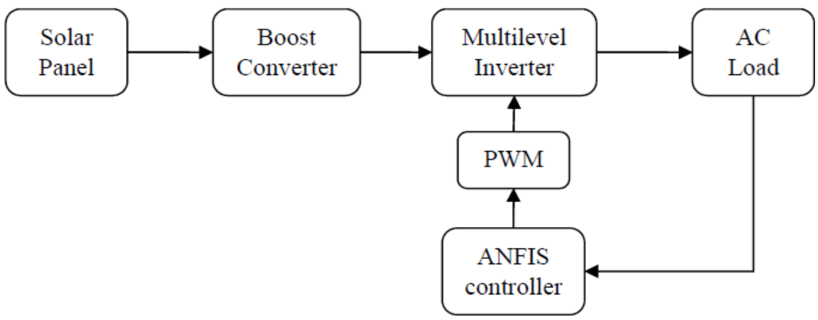


Fig 2.1 Block Diagram of proposed system

CIRCUIT DIAGRAM

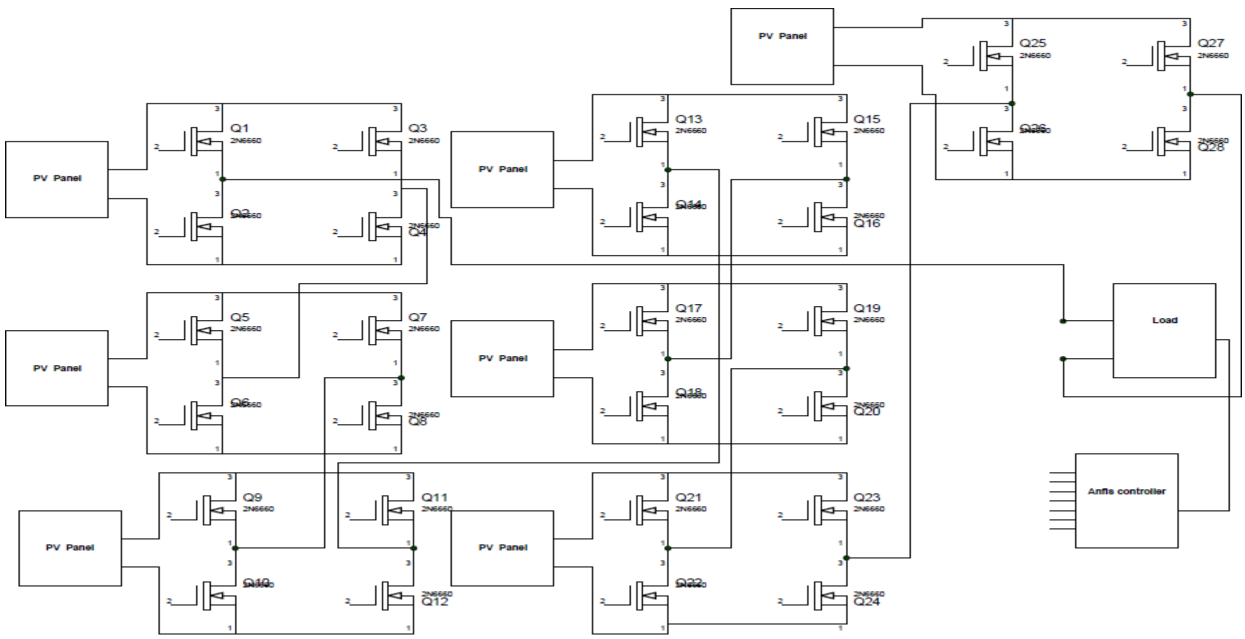


Fig. 2.2 Circuit Diagram of proposed system

3 SIMULATION RESULT

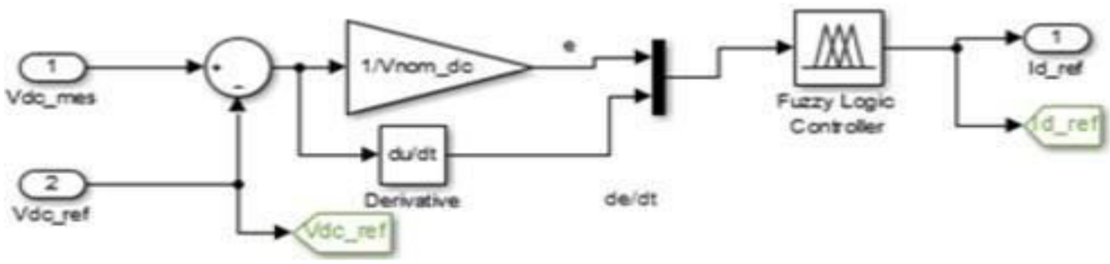


Fig 3.1 Fuzzy controller in inverter side of solar PV system

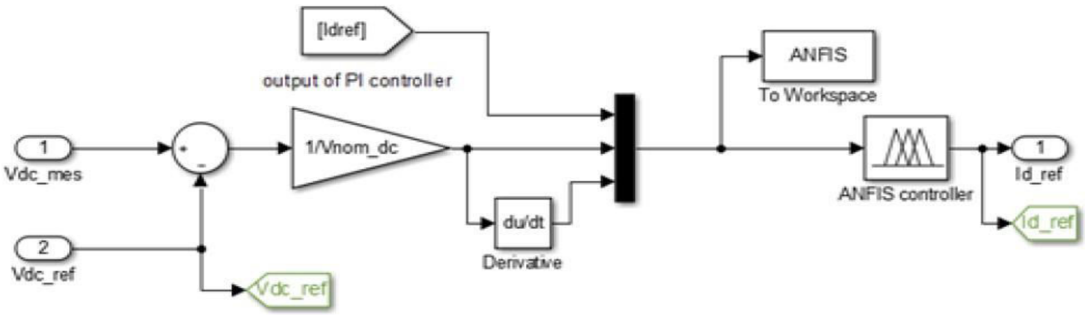


Fig 3.2 ANFIS controller block in inverter side of solar PV system

PI CONTROLLER ANALYSIS

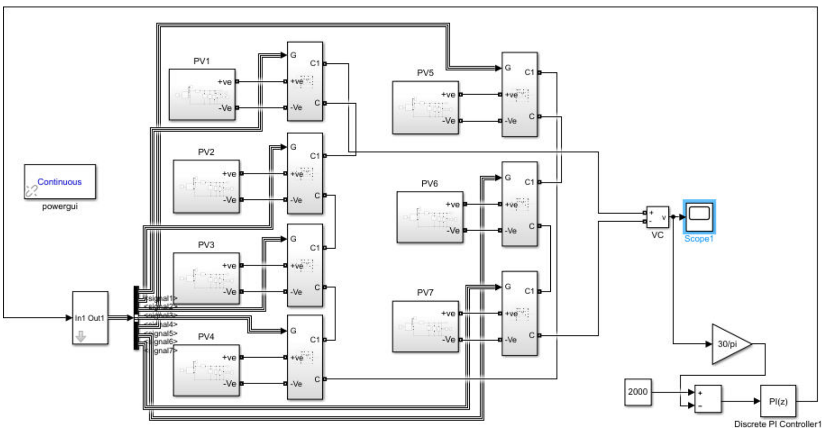


Fig 3.3 SIMULATIONS FOR PI CONTROLLER

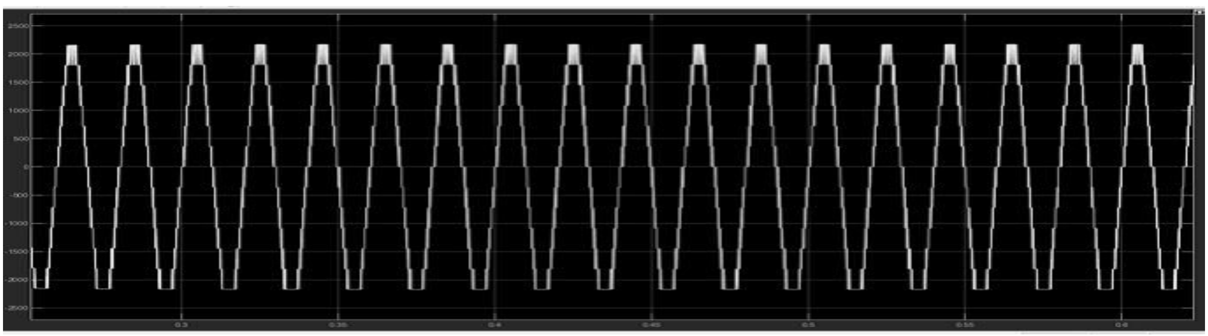


Fig 3.4 OUTPUT WAVEFORM FOR PI CONTROLLER

FUZZY CONTROLLER ANALYSIS

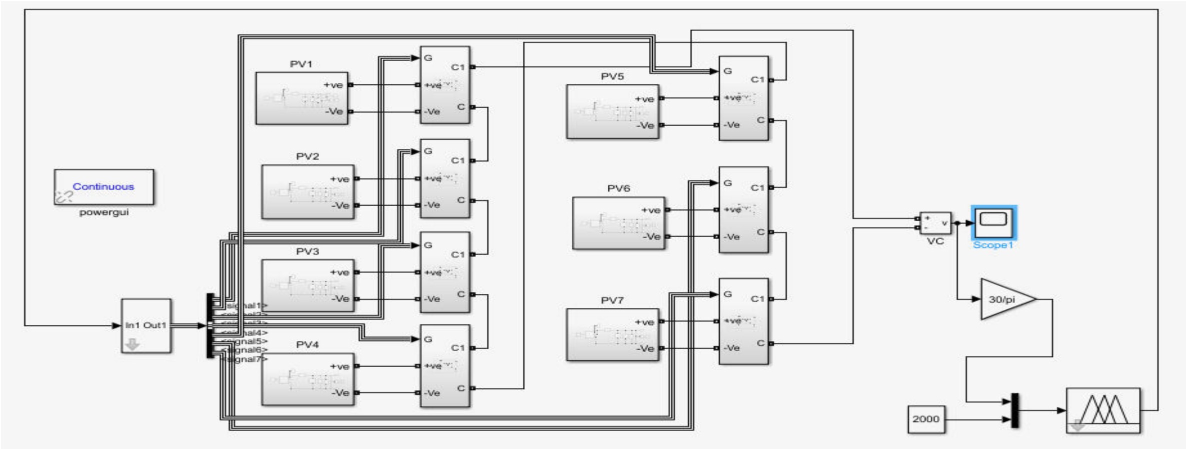


Fig 3.5 SIMULATION FOR FUZZY CONTROLLER

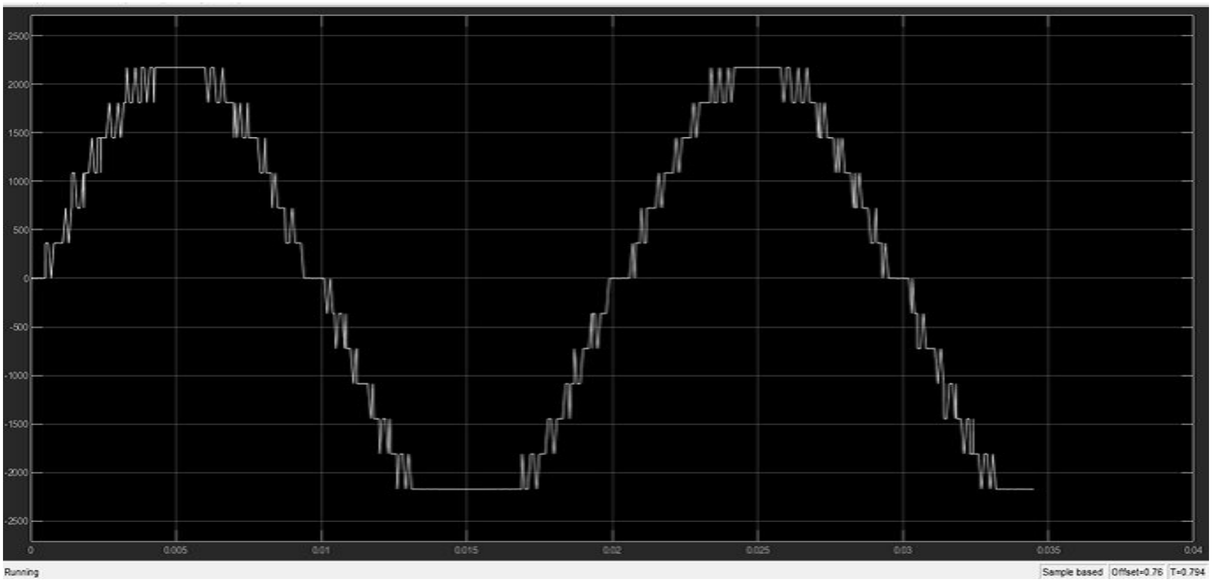


Fig 3.6 OUTPUT WAVEFORM FOR FUZZY CONTROLLER

ANN CONTROLLER ANALYSIS

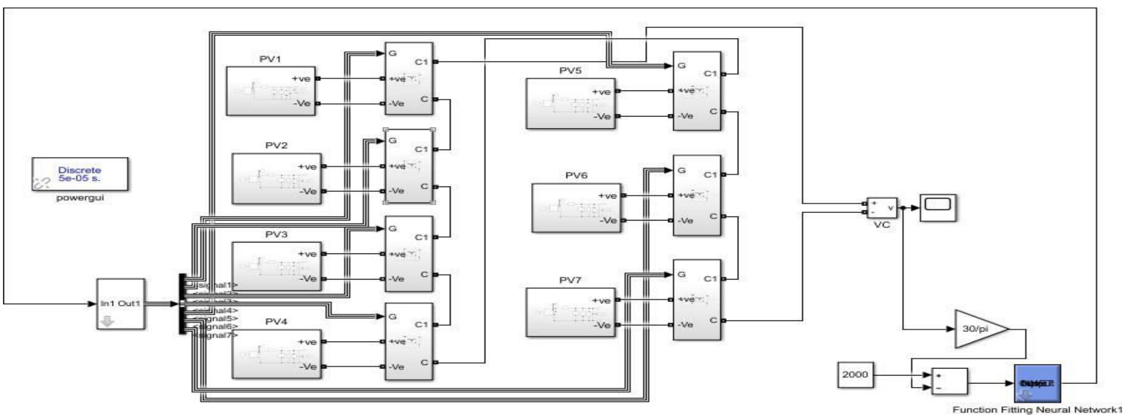


Fig 3.7 SIMULATION FOR ANN CONTROLLER

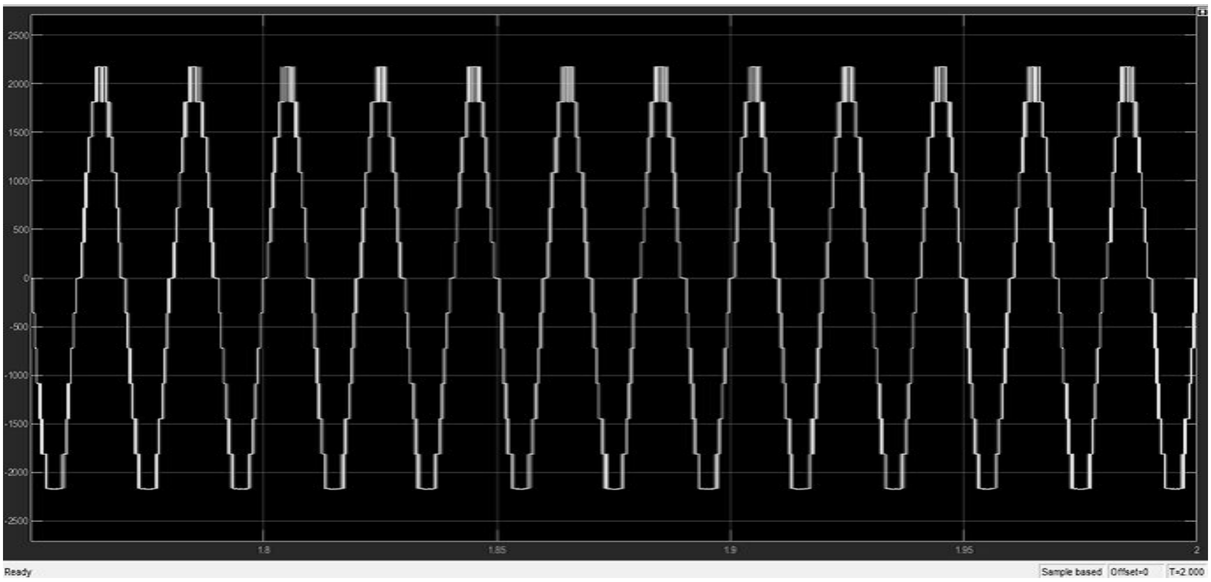


Fig 3.7 OUTPUT FOR ANN CONTROLLER

ANFIS CONTROLLER ANALYSIS

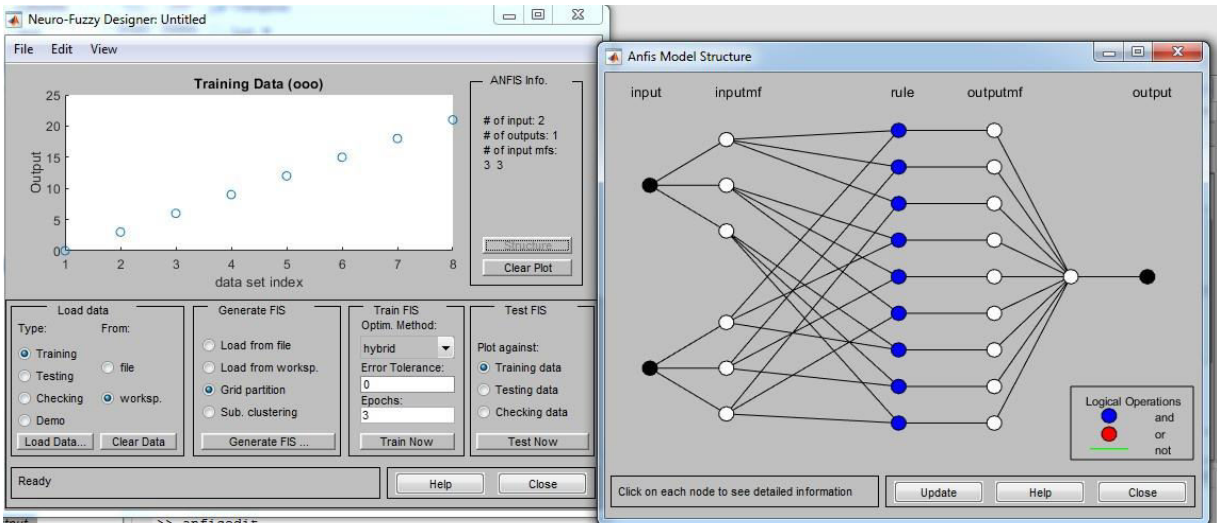


Fig 3.8 ANFIS ARCHITECTURE IN MATLAB

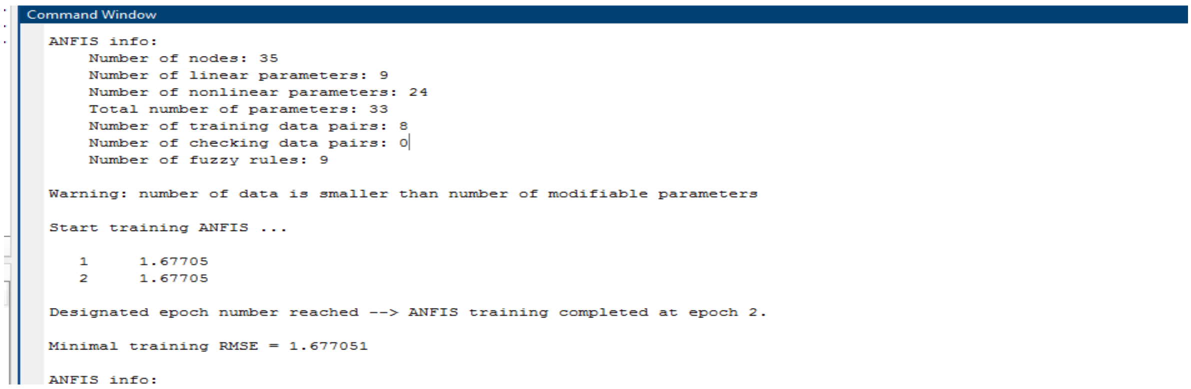


Fig 3.9 ANFIS PARAMTERS

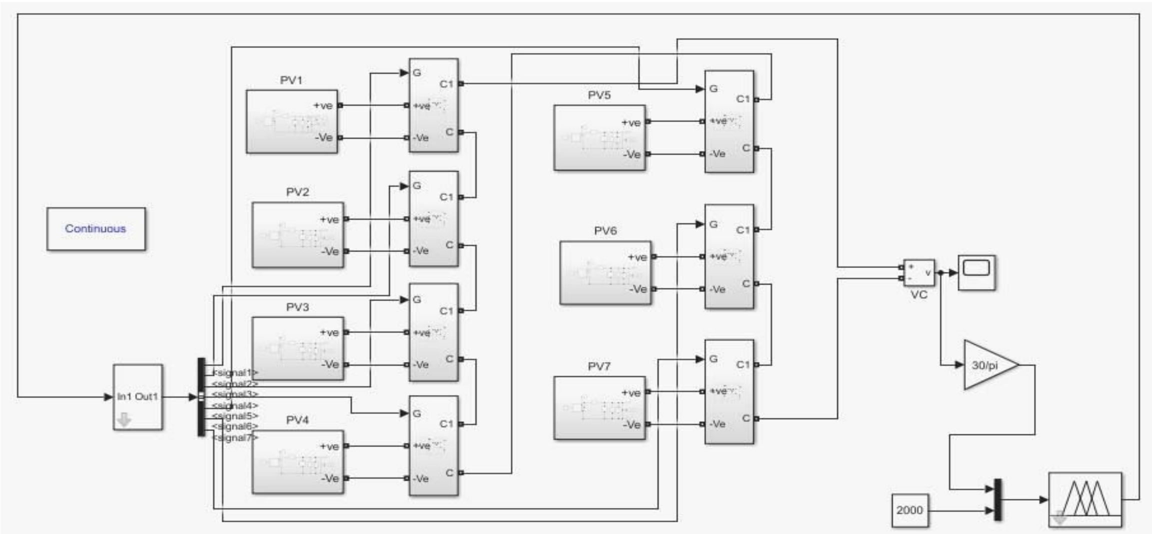


Fig 3.9 SIMULATION FOR ANFIS CONTROLLER

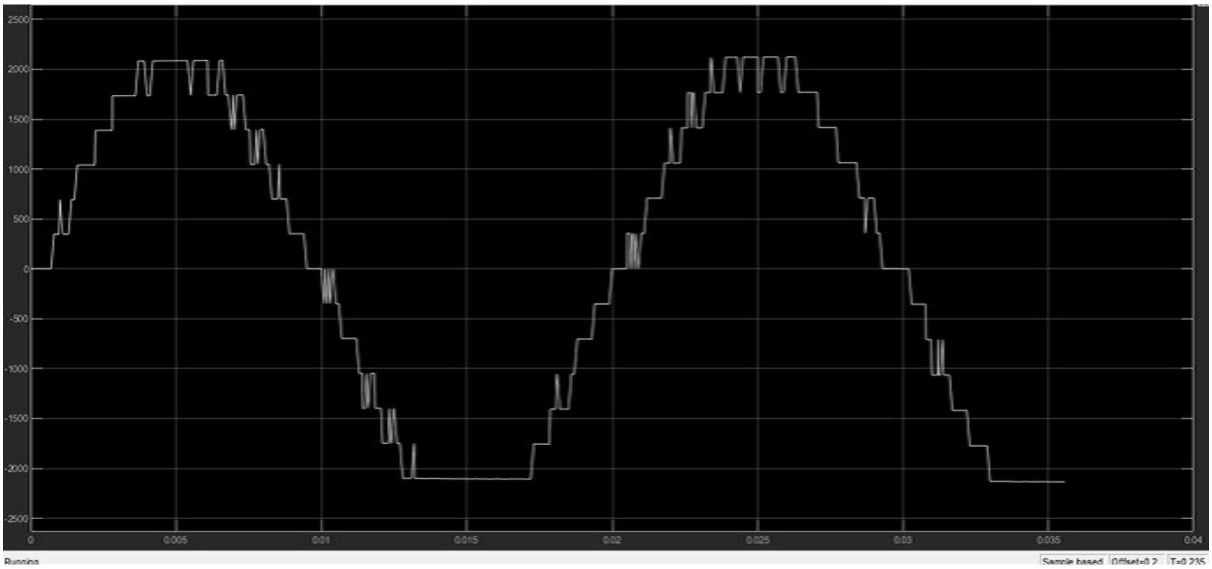


Fig 3.10 OUTPUT WAVEFORM FOR ANFIS CONTROLLER

THD analysis of ANFIS controller

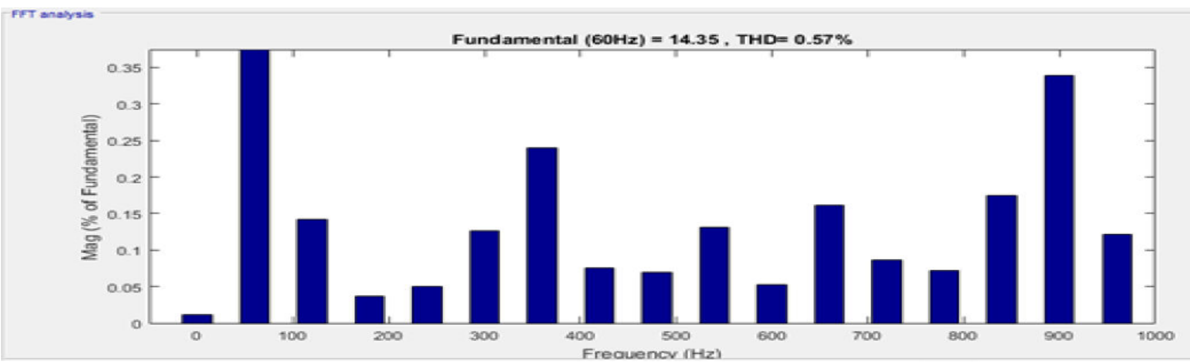


Fig 3.11 THD analysis of ANFIS controller

COMPARISON OF RESULTS

S.NO	METHOD	LEVEL	THD	VR DEVIATION
1	PI	15	8%	9.3
2	ANN	15	7.94%	9.7
3	FLC	15	5.49%	4.6
4	ANFIS	15	4.02%	3.8

3 CONCLUSION

In this work, Inverter control using ANFIS controller is implemented for power quality improvement in grid connected PV system. The obtained results are compared to fuzzy controller. Adaptive Neuro Fuzzy Inference system provides better control over fuzzy control. The proposed controller in inverter improves the power quality. It has been found that ANFIS controller gives less THD and improved power factor as compared to fuzzy controller.

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