Indian Journal of Science and Technology, *Vol 9(12), DOI: 10.17485/ijst/2016/v9i12/72173, March 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

A Neuro-Fuzzy Controller for Multilevel Renewable Energy System

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Abstract

This paper proposes concept based new topology based seven level inverter with less number of power electronics switches with utility grid connection. This proposed multilevel inverter operates with only eight power electronics switches at their fundamental frequency. This inverter produces seven level output from the input here we considered as a photovoltaic system. The cost, complexity, switching losses is small because of usage of less number of switches. The DC/DC converter receives input from which the three positive output voltages are generated and the multilevel inverter performs as a polarity reversal that provides both the positive and negative cycle output. For further enhancement in the output waveform, the filter circuit can be integrated in the output terminal of the multilevel inverter. This paper also proposed a concept of a neuro-fuzzy controller for controlling the seven level inverters. The simulation results are observed by means of MATLAB simulink toolbox.

Keywords: Multilevel Inverter, Neuro-Fuzzy Controller, Renewable Energy System

1. Introduction

In numerous rural areas uninterrupted electricity is not accessible from grid. Mostly the grid gets power from hydro power station as well as from thermal power station. As the conservative energy sources are diminishing hasty, in the midst of consequent mount in cost, solar and wind energy offers a superior substitute resource along with free from pollution. The renewable energy resources are profitable and they will not cause any detriment effects on the surroundings. A single phase PV based seven-level inverter is discussed in paper[1]. The PV power generation is a budding modern trend owing to its various advantages resembling inexpensive, ecological responsive power generation.

Multilevel inverter possibly will generate almost sinusoidal output voltage waveform along with output current which will compress the harmonic distortion furthermore improve its power quality[2].

When the level increases, harmonic possibly will decrease however the switches necessary for the conduction of converters may increase. Due to the increase in number of switches, the switching stress may arise that leads towards switching losses.

Conventional different concepts of multilevel inverters such as clamping circuits with diode based multilevel inverter[3], flying capacitor based multilevel inverter and cascaded based multilevel inverter the switches required for the conduction are improved according to the multi levels. In diode-clamped inverter, additional number of diodes is mandatory to generate the number of levels. For flying capacitor inverter, the charges are stored into the capacitor and for that it needs hefty amount of capacitors consequently the cost of switches is amplified. To prevail over these conventional systems, a novel modified multilevel inverter is projected meant for generating seven level of output[4].

The neuro-fuzzy controlled photovoltaic energy generation system consists of DC/DC boost converter, capacitor selection circuit and 7-level inverter. This method plays a crucial task in reducing the amount of

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switches designed for generating seven level of output. It consists of no more than six power electronic switches, moreover only one switch will activate at high frequency at any instant. The solar panel DC outputs are boost up by means of boost converter along with its switches are embarrassed through the Maximum Power Point Technique (MPPT)[5–6]. In favor of supplying power towards the utility, the DC power is rehabilitated to AC by means of single Multi level inverter combined in the company of the capacitor selection circuit. The positive cycle of output are fashioned by the three pathways: 1) Power from boost converter, 2) commencing transformer 3) from single Multi level inverter. The single Multi level inverter breed negative half cycle. Ultimately, the proposed topology is simulated and results are obtained.

The intensity of sunlight and radiations present on the earth surface varies time to time; thereby it causes the changes in input voltage and current. The aim of this concept is to attain maximum regulated output power to utility. Generally, the maximum power is trapped using a DC-DC converter with the help of maximum power point tracking controller. In this paper we considered a basic perturb and observe method. Thereby it improves the efficiency of power generated by the solar panel[7].

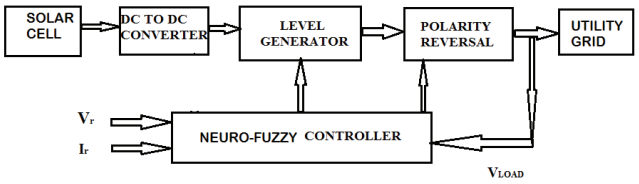

Figure 1. Block diagram of proposed converter with neuro-fuzzy controller.

The neuro-fuzzy control switches present in the converter, capacitor selection circuit and inverter as shown in Figure1. It shows the block diagram of the anticipated level generator controlled by the neuro-fuzzy controller. In favor of PV system there will be change in irradiance as it depends on the environment aspects, for that reason necessitate of boost converter for raising the voltage rating.

Figure 2 shows the circuit configuration of proposed seven level inverter which consists of photovoltaic array, direct boost converter along with the multi-level inverter. The capacitor selection circuit is used to send the voltages of seven-levels to the utility grid system[8]. The transformer connected along with the boost converter which will pick up voltage rating with its first level. Other levels are shaped commencing the multi-level and its negative voltage levels are formed from the polarity reversal which will afford positive cycle and negative cycle of output voltages.

1.1 Photovoltaic System based DC-DC Converter

The boost converter effectively helps for improving the solar power. Because the power generated from the solar system is very small and it depends on the sun radiations. A boost converter is basically a DC to DC voltage converter with an output DC voltage more than input voltage.

Figure 3 shows the circuit configurations for the DC to DC boost converter based solar array system. Irrespective to the irradiance variation, regular output voltage and current are maintained in the proposed power generation system[9]. Then the transformer is

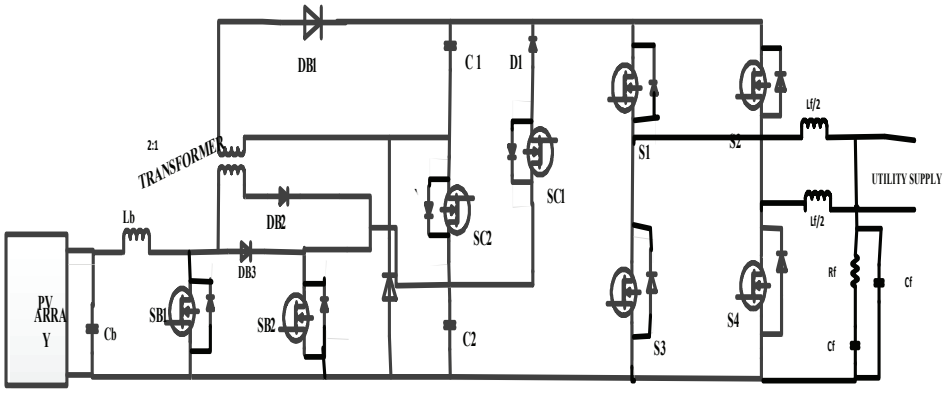

Figure 2. Proposed circuit configurations.

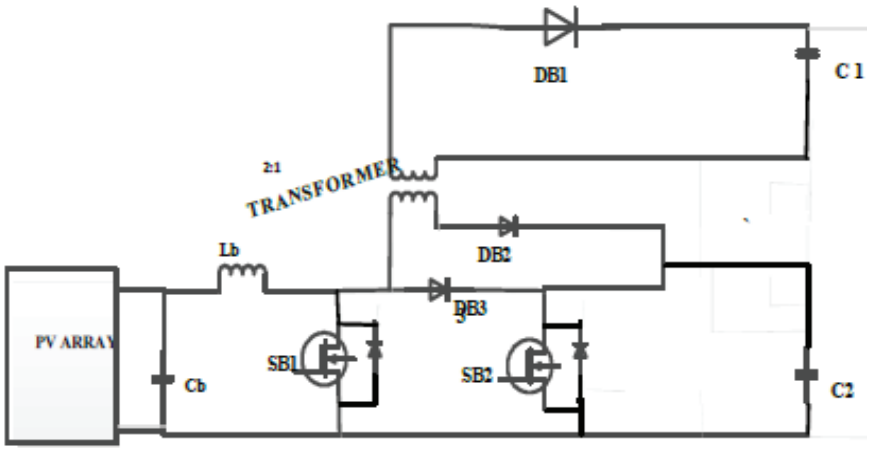

Figure 3. Photovoltaic system along with boost converter.

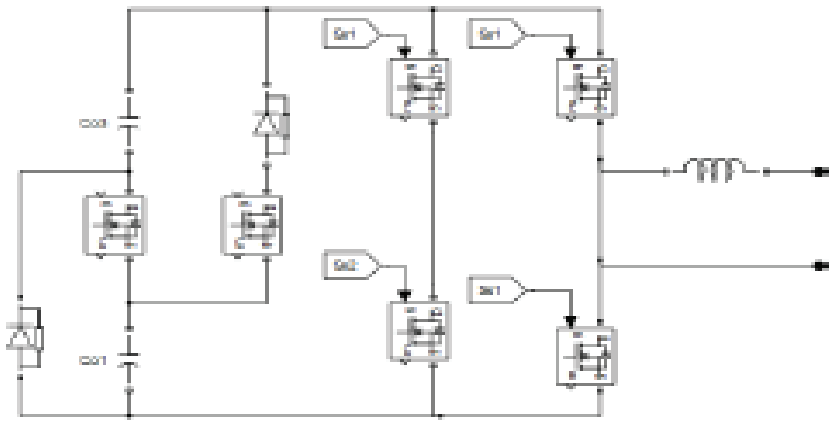

Figure 4. Multilevel inverter circuit configuration.

used in this topic is to boost up the voltage levels which forms the output voltage levels. The charges will be stored in the two capacitors through transformer and boost converter.

1.2 Seven-Level Inverter

An inverter is installed in the system to convert the DC power generated into AC power for use in appliances. The proposed multilevel inverter shown in Figure 4 consists of single Multi level inverter at which seven levels of voltages and current are generated. For the negative power flow, this inverter will provide polarity reversal by which the positive and negative cycles are formed. The filter inductor at the load side reduces the harmonic content and maintains the sinusoidal waveform. The PWM signals are given for all the switches present in the boost converter and single Multi level inverter.

1.3 Modes of Operation for Seven-Level Inverter

- In mode 1 the switches S1 and S4 are in on state while the switches Sc1, Sc2, S2 and S3 are in off state condition. During this mode the capacitor C1 is discharged through diode. And the output voltage during this mode is Vdc/3.
- During this mode 2 operation, the switch Sc1 is conducts along with the switch S1 and S4. Then the capacitor discharges through the diode and the output voltage during this mode is 2Vdc/3.

- In case of mode 3 the switches Sc1, Sc2, S1 and S2 four switches are in conduction, then the capacitors c1 and c2 discharges through the diodes then the output voltage appears in this mode is Vdc.
- In this case the switches S3 and S4 are conducts by turn off the all other switches. Therefore the output voltage appears is zero.
- The remaining switches S2 and S3 conducts for generating the negative seven level voltages.

1.4 Control Block Diagram

This proposed control diagram is designed for controlling the boost converter and the seven level inverters. This seven level inverter converts the DC power at low levels to high level AC system and provides the power to utility grid system. In these selection capacitors C1 and C2 are used for improving the voltage levels. The DC to DC converter is supplied by the solar power generation system along with the maximum power point tracking system for improving the voltage of the solar power plant[10]. These control diagrams for multi-level and DC-DC converter are shown in Figure 6 and Figure 7.

Table 1. Switching pattern for seven level inverter

Sc1	Sc2	S1	S2	S3	S4	Vo
0	0	1	0	0	1	Vdc/3
1	0	1	0	0	1	2Vdc/3
1	1	1	0	0	1	Vdc
0	0	0	0	1	1	0

2. Adaptive Neuro-Fuzzy Inference System

The ANFIS is one of the important controllers in adaptive techniques. This section provides the information regarding the designing of neuro-fuzzy controller. These neural network controller consists of two inputs that are Δe and Δde and it has one output that is f ∈ {Δe, Δde}[11]. Each input consists of 5 membership functions. Figure 8 shows the configuration of ANFIS for a mamdani type and it has two input and one output.

According to Figure 9, it is a mamdani based fuzzy controller with two inputs and one output and the rules are formed according to if-then statements. μAi and μBi are the membership functions of memberships with the fuzzy sets and these inputs are related with the operator logical AND. The hybrid learning algorithms are implemented for obtaining the values of system parameters. These learning algorithm is a function of linear and nonlinear parameters[12]. These explanations are implemented in Matlab/Simulink software.

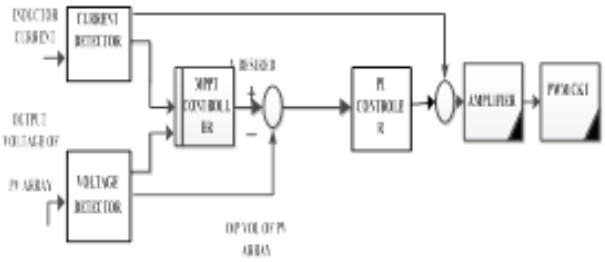

Figure 7. Control block diagram for DC-DC converter.

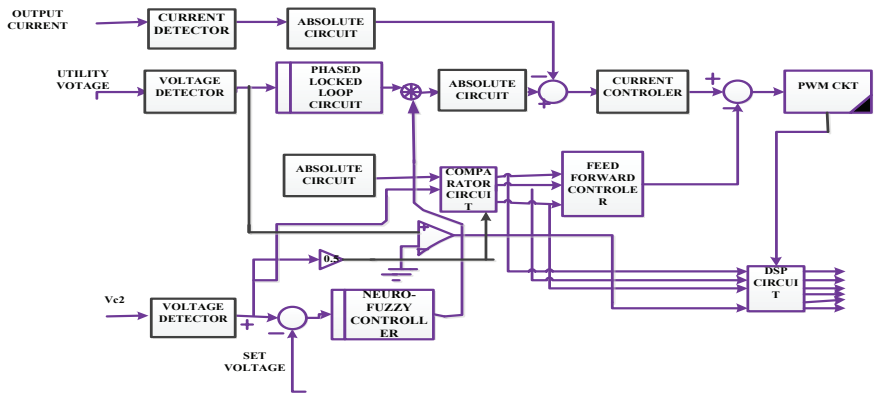

Figure 6. Closed loop control diagram for multi-level inverter.

2.1 Algorithm for Neuro Controller

- Assume the inputs and outputs in the normalized form with respect to their maximum values and these are in the range of 0-1.
- Assure the No. of input stages given network.
- Indicate the No. of hidden layers for the network.
- Design the new feed forward network based on the system parameters 'transig' and 'poslin'.
- Assume the learning rate be 0.02 for the given network.
- Identify the number of iterations for the system.
- Enter the goal.
- Train the network based on the given input and outputs.
- For the given network Generate simulation with a command 'genism'

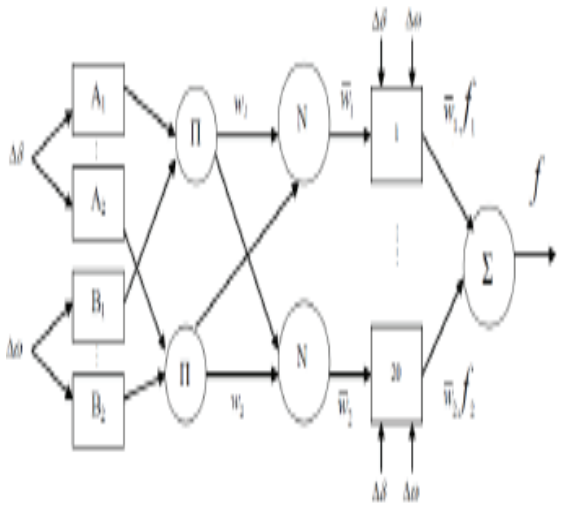

Figure 8. ANFIS architecture.

2.2 Fuzzy Controller

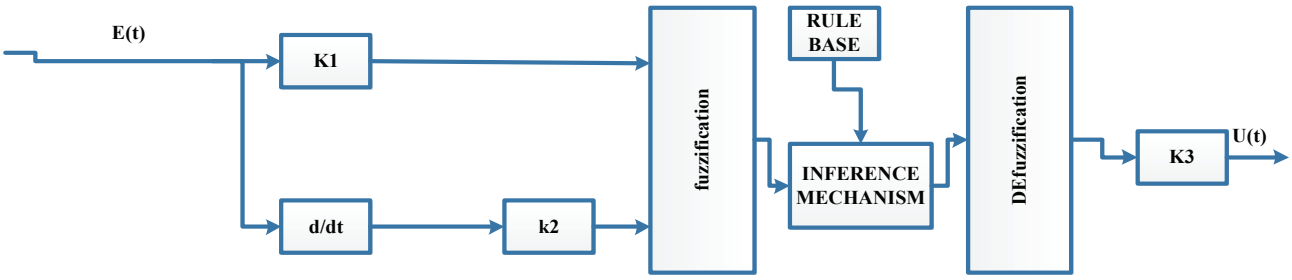

Figure 9. Configuration of fuzzy inference system.

2.3 Simulation Explanations

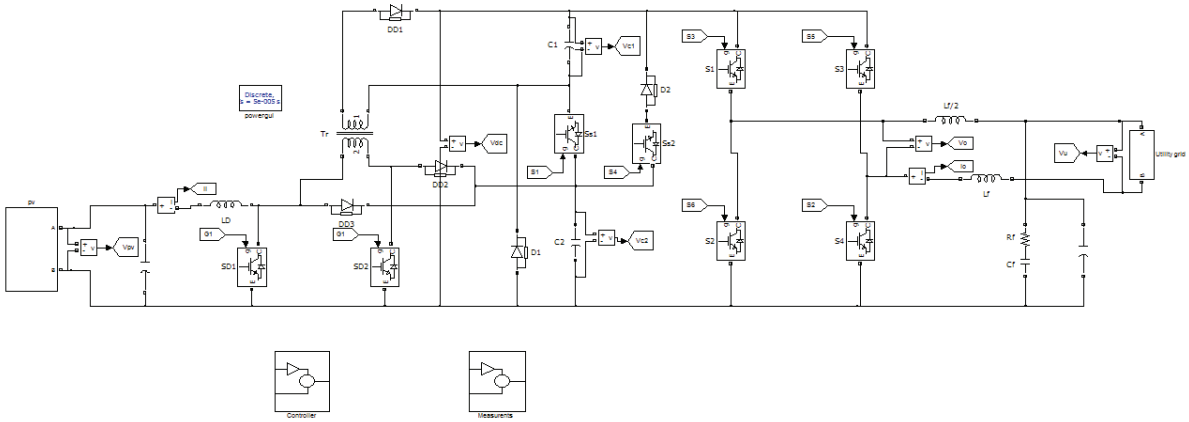

Figure 10. Simulation diagram for proposed system.

For verifying the performance of the proposed photovoltaic system, a configuration was developed with a closed loop controller based on the fuzzy controller. The simulation diagram for this proposed system is as shown in Figure 10.

In the above shown solar power generation system, the solar system generates the output voltage is nearly 75.6V and this voltage is boosted to approximately 95V with the help DC to DC power converter and again this DC voltage is increased to nearly 180V with the help of dual switch controlled DC-DC boost converter. This boosted voltage is applied to seven level converter system with the use of charged capacitors C1 and C2.

The simulation result of neuro-fuzzy based hybrid multilevel inverter output voltage is and shown in Figure 11. And Figure 12 and Figure 13 show the simulation result of output load current and utility grid voltage respectively.

Figure 14 shows the simulation result of utility grid voltage and current waveforms shows unity power factor conditions. And Figure 15 shows the total harmonic distortion value of output voltage for neuro-fuzzy based multilevel renewable energy system.

3. Advantages:

- No capacitor unbalance problems.
- Improved the THD and power factor.
- Compactness.
- Low switching losses.

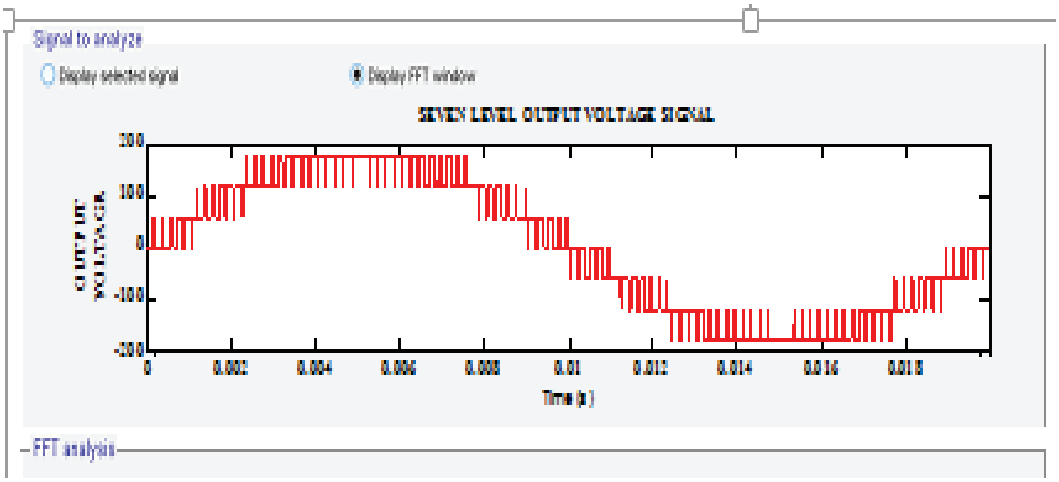

Figure 11. Simulation result for seven level output voltage.

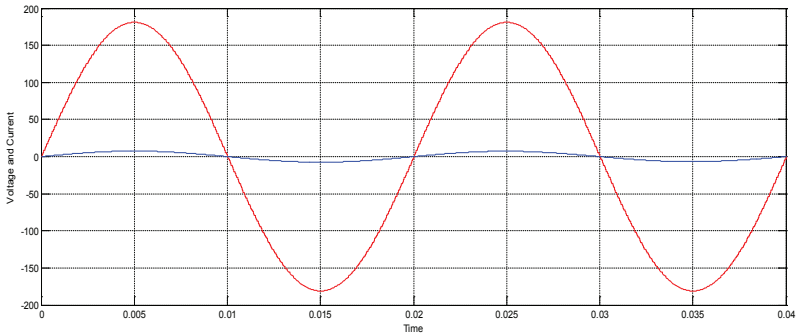

Figure 12. Simulation result for output current.

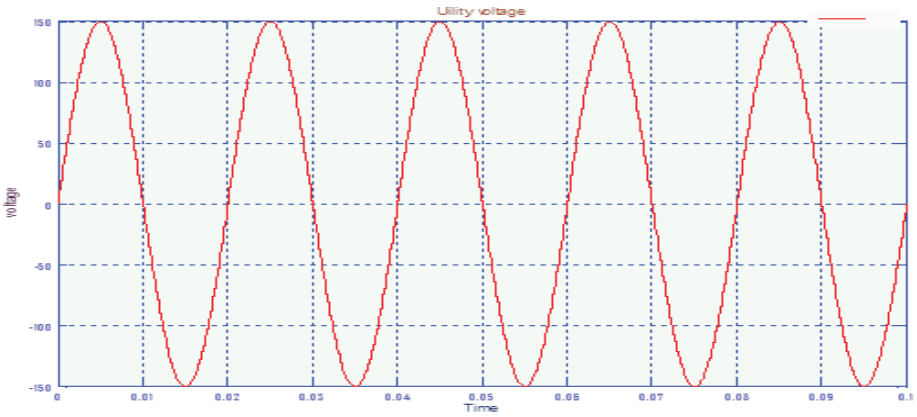

Figure 13. Simulation result for utility grid voltage.

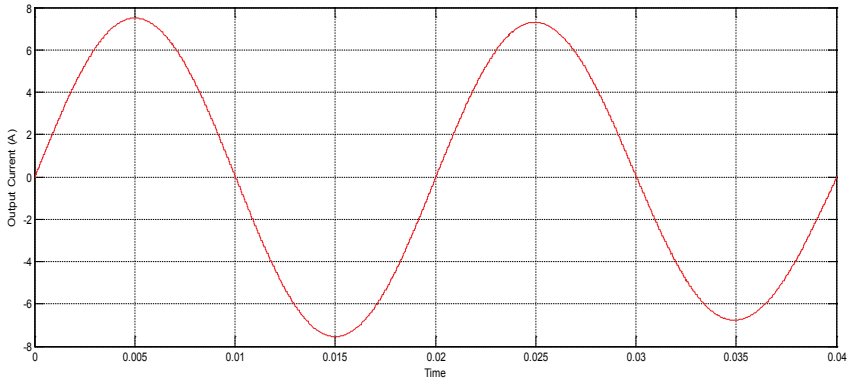

Figure 14. Simulation result for utility grid voltage and current for unity power factor.

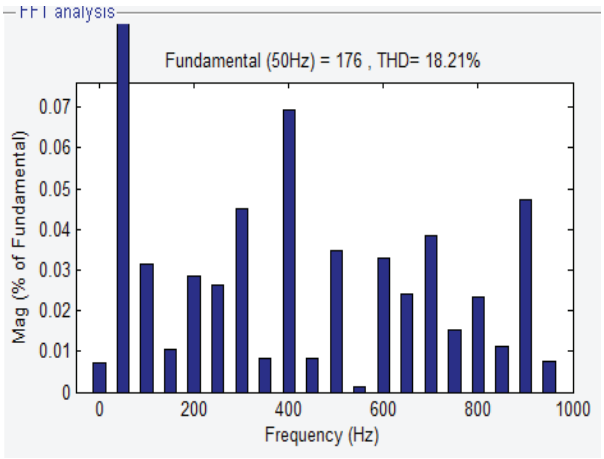

Figure 15. THD for output voltage.

4. Conclusion

The main features for this proposed converter has less cost, reduced size and have high efficiency. By the help of reduced number of switches, seven-level of output voltages are generated thereby it reduces the switching and conduction losses. The THD of seven-level inverter is less compared to the five-level and three-level inverter. The ANFIS controller could control the switches present in the boost converter and multilevel inverter. For generating the seven levels of the output voltages we use only six power electronic switches at high frequency at any time. As the inverter level increases, the filter requirements and harmonic content decreases.

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