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# THE OUTPUT VOLTAGE STABILIZATION OF A 3-PHASE MULTILEVEL INVERTER CONSIDERING DC VOLTAGE FLUCTUATIONS USING ANFIS

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## ABSTRACT

*A new approach for the output voltage stabilization of multilevel inverters considering its input voltage fluctuations. The output voltage feedback control and improvement in voltage utilization factor has been presented in this paper. The input DC voltages is feeding to the inverter are considering to be varying with time, In case of solar, wind and fuel cell cogeneration systems, the generated voltage not constant always. In fact, the generated voltages from these sources can varying with time. This paper gives detailed analysis of the improvement on the controllability and absorption of the DC voltage fluctuation by superimposing the moderate odd harmonic wave, implementing Adaptive Neuro Fuzzy Inference System. The results obtained using 5level Diode clamped inverters with 6kw Resistive load with sinusoidal pulse width modulation, Using MATLAB/ simulink.*

***Keywords: Cascaded Multilevel Inverter; Closed Loop Control; Sinusoidal Pulse Width Modulation (SPWM); Superposition Ratio Control; Adaptive Neuro Fuzzy Inference System (ANFIS);***

## I. INTRODUCTION

The last decade's growth in the production of electric energy from renewable energy sources has led to an increased focus on power electronics systems. Renewable energy sources like photovoltaic, wind and wave energy are relying on power converters in order to exchange power with the grid [1]. These inputs are not constant with time always in fluctuating nature and anyone who wants to produce power for the grid has to make sure that their facilities are complying with national grid codes. The grid codes have strict regulations when it comes to the voltage quality, including limits for rapid voltage variations, flicker and harmonic distortion. Rapid voltage variations and flicker are matters of control of the inverter system, but harmonic distortion is created by the pulse width modulated switching of the converter. Different filters topologies can be used in order to reduce the harmonics generated by the switching action in the converter. However [2][3], filters for high power converters can be of substantial size and weight and therefore also of great cost since they are made of several expensive metals. Therefore, a lot of effort is made in order to improve the converter system so that the filter can be reduced while the cried codes and system specifications are still met. There are mainly two ways of reducing the harmonic distortion. One way is to optimize the switching sequence, with harmonics as the most important constraint. Another way is to use several levels to build the fundamental voltage i.e. converters with three levels or more [4][5].

In an effort to improve voltage quality and efficiency, a simple control method for improving the voltage utilization factor of multilevel inverter [9][11]. In this paper a control method which introduced the control of superposition ratio of third harmonic wave into output voltage feedback control and improvement on voltage utilization factor is proposed.

It is applied to the multilevel inverter, and the operation principle and features are explained. Which including Solar, and fuel cells system .The fluctuated inputs are converted to stable output by using Multilevel inverter. By simulation the validity of proposed control analysis has been confirmed.

## II. OUTPUT VOLTAGE TRACKING CONTROL

Two phase output line voltages $V_{RY}$ and $V_{BR}$ are taken into the Simulation the following can be obtained from the fundamental equations for a three-phase three-wire system, and from the relationship between the line voltages and phase voltages [8]:

$$V_{RY}+V_{YB}+V_{BR}=0$$
$$V_{RY}=V_{BN}-V_{YN}$$
$$V_{YB}=V_{YN}-V_{BN}$$
$$V_{BR}=V_{BN}-V_{RN} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Therefore,

$$V_{BN}=1/3(V_{RY}-V_{BR})$$
$$V_{YN}=1/3(V_{YB}-V_{RY})$$
$$V_{BN}=1/3\,(V_{BR}-V_{YB}) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Three phase voltages $V_{RN}$,$V_{YN}$ and $V_{BN}$ are converted into two-phase AC voltages $V\propto$ and $V\beta$ by using the following:

$$\begin{bmatrix} V\propto \\ V\beta \end{bmatrix} = \frac{\sqrt{3}}{2} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{RN} \\ V_{YN} \\ V_{BN} \end{bmatrix}$$

…………………. (3)

Now the magnitude $V_{out}$ of the resultant output vector is calculated as follows:

$$V_{out} = \sqrt{|\dot{V}_\alpha|^2 + |\dot{V}_\beta|^2} \ldots\ldots\ldots\ldots (4)$$

The magnitude Vout corresponds to the effective value of the output line voltage, which is a DC value in the case of a three-phase balanced voltage without fluctuation. Therefore, tracking control of the output voltage can be implemented by maintaining this value at a stable level [8].

The difference between the output voltage references V*out and the resultant vector magnitude Vout is given to the proportional integrator, and the DC voltage compensation on $V_{pi}$ is calculated. A coefficient related to the superposition ratio α is applied to this value, and then a sinusoidal reference is obtained by multiplying by a three-phase sine Wave with amplitude of one[7][8].

The advantage of this system is obtaining the fixed control characteristic, when the AC voltage of any frequency is output, because the signal input to the proportional integrator is the instant DC voltage which does not depend

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on the frequency of the output Voltage. That is, the method can be applied to variable speed drive of electric motors and to other cases when a variable-frequency source is required.

### 2.1 Control Method

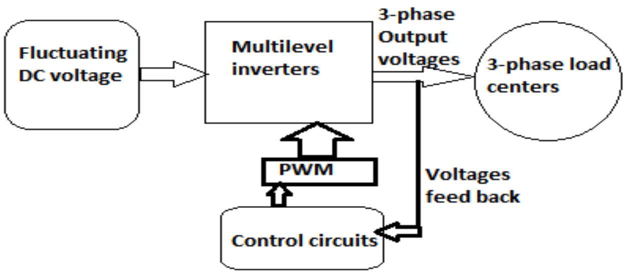


**Fig.1, Block Diagram of Closed Loop Voltage Control Method**

The Input fluctuating DC voltages are generally coming from Co-generation systems Like Wind, Solar and fuel cells etc., these generated voltages are directly connected to multilevel circuit as input. The multilevel inverter circuit outputs are connected to three phase loads. Due to DC voltage fluctuations at input side of inverter, the output voltage of inverter also get distorted but loads which are connected to this circuits requires constant voltage magnitude. To maintain the inverter output voltage magnitude constant irrespective of its DC voltage fluctuations, the output voltages are taken as feed back to control circuit, this output voltage signal is converted in to suitable form, than compare with fundamental rated values next generate the error correcting signal to PWM unit. This PWM circuits generates the switching pulses according to the error signal. In this closed loop control method the output voltages are always constant magnitudes and this control method is to realize improvement on the controllability and absorption of the fluctuation of the DC voltage by superimposing the moderate third harmonic wave. If the instantaneous voltage ripple was absorbed.

ANFIS is perhaps the first integrated hybrid neuro-fuzzy model. A modified version of ANFIS is capable of implementing the Tsukamoto fuzzy inference system. In the Tsukamoto FIS, the overall output is the weighted average of each rule's crisp output induced by the rule's firing strength (the product or minimum of the degrees of match with the premise part) and output membership functions

### 2.2 ANFIS Model

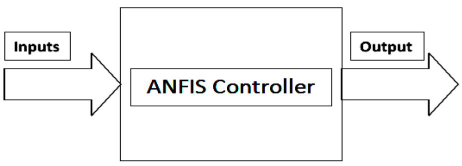


**Fig.2(a),Block Diagram of ANFIS Controller**

The output membership functions used in this scheme must be monotonically non-decreasing. The first hidden layer is for fuzzifications of the input variables and T-norm operators are deployed in the second hidden layer to compute the rule antecedent part. The third hidden layer normalizes the rule strengths followed by the fourth hidden layer where the consequent parameters of the rule are determined. Output layer computes the overall input as the summation of all incoming signals.

In ANFIS, the adaptation (learning) process is only concerned with parameter level adaptation within fixed structures. For large-scale problems, it will be too complicated to determine the optimal premise-consequent structures, rule numbers etc. The structure of ANFIS ensures that each linguistic term is represented by only one fuzzy set. However, the learning procedure of ANFIS does not provide the means to apply constraints that restrict the kind of modifications applied to the membership functions. When using Gaussian membership functions, operationally ANFIS can be compared with a radial basis function network.

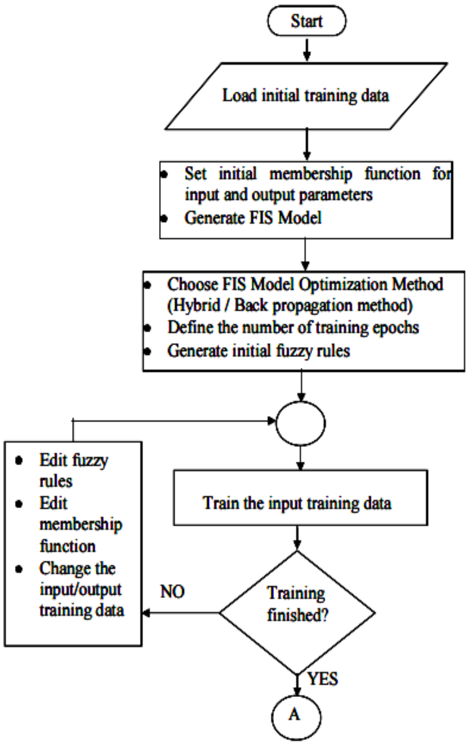


Fig.2(b)

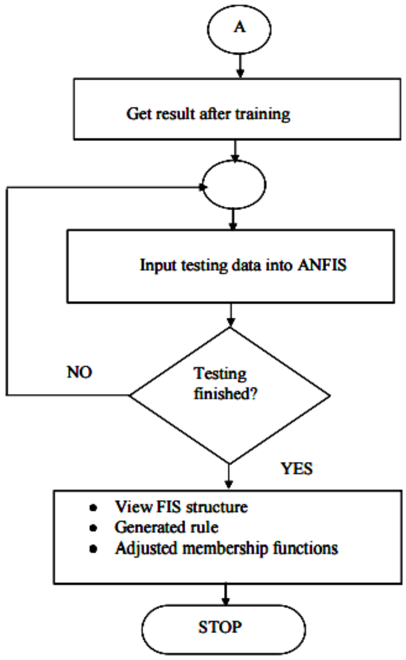


Fig.2(c)

**Fig.2(b)&(c), Flow Chart Diagram of ANFIS Controller**

From block diagram of ANFIS Controller, ANFIS controller is the combination of neural network and Fuzzy Logic. Many inputs are applied to the neural network depending upon the inputs the neural network has some standard output, so depending upon the input and the output the neural network is trained, after training the neural network the output is applied to the fuzzy logic which generates the IF THEN rules and membership functions[12]-[15].

## III. SINE + 3$^{rd}$ HARMONIC PWM TECHNIQUE

The idea of Sine+3$^{rd}$ harmonic modulation technique is based on the fact that the 3-phase inverter-bridge feeding a 3-phase ac load does not provide a path for zero-sequence component of load current. Only three output points are brought out from a three-phase inverter-bridge. These output points are connected to the three supply terminals of the load. Such an arrangement does not cause any confusion for the delta connected load but for a star connected load the neutral point remains floating. However for a balanced, three-phase, star-connected load this should not be a drawback as the fundamental component in the load phase voltage is identical to the fundamental component of inverter's pole voltage[6].

In fact, the floating neutral point has the advantage that no zero sequence current (which includes dc, third and integer multiples of third harmonics) will be able to flow through the load and hence even if the pole voltage is distorted by, say, $3^{rd}$ and integral multiples of third harmonics the load side phase and line voltages will not be affected by these distortions[10]. Accordingly a suitable amount of third harmonic signal is added to the sinusoidal modulating signal of fundamental frequency. Now, the resultant waveform (modified modulating signal) is compared with the high frequency triangular carrier waveform. The comparator output is used for controlling the inverter switches exactly as in SPWM inverter. the low frequency component of the pole voltage will be a replica of the modified modulating signal provided (i) The instantaneous magnitude of the modified modulating signal is always less than or equal to the peak magnitude of the carrier signal and (ii) the carrier frequency is significantly higher than the frequency of modulating signal[6].

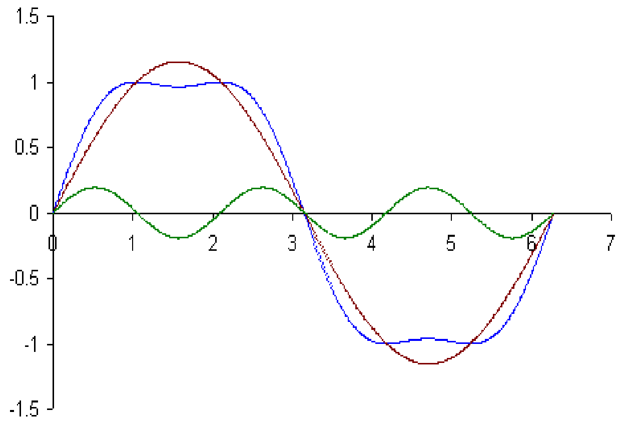


**Fig.3, The Modulating Signal for Sine+3rd Harmonic Modulation**

The addition of small percentage of $3^{rd}$ harmonic to the fundamental wave causes the peak magnitude of the combined signal to become lower than triangle wave's peak magnitude [6]. In other words, a fundamental frequency signal having peak magnitude slightly higher than the peak magnitude of the carrier signal, if mixed with suitable amount of $3^{rd}$ harmonic may result in a modified signal of peak magnitude not exceeding that of the carrier signal.

Thus the peak of the modulating signal remains lower than the peak of triangular carrier signal and still the fundamental component of output voltage has a magnitude higher than what a SPWM can output with m = 1.0. Thus the fundamental voltage output by the inverter employing Sine+$3^{rd}$ harmonic modulation technique can be higher [6].

## IV. SIMULATION RESULTS

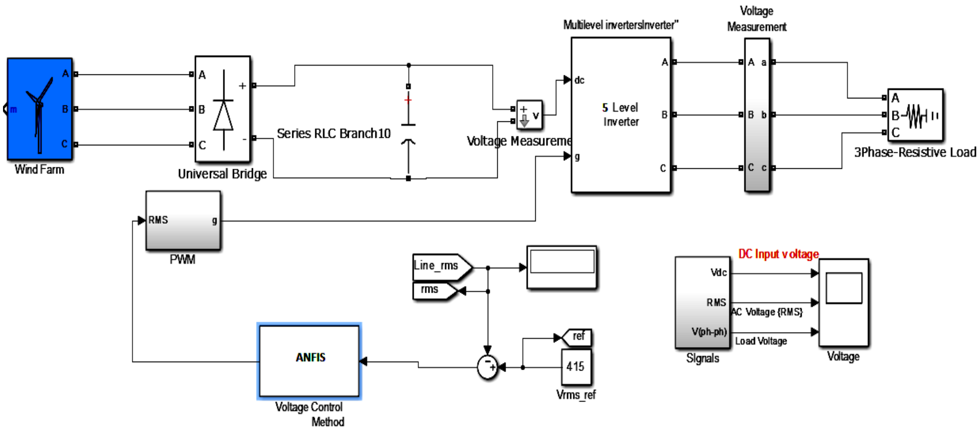


**Fig.4, Simulation Block Diagram of the Output Voltage Stabilization in Multilevel Inverter Considering Wind Power System**

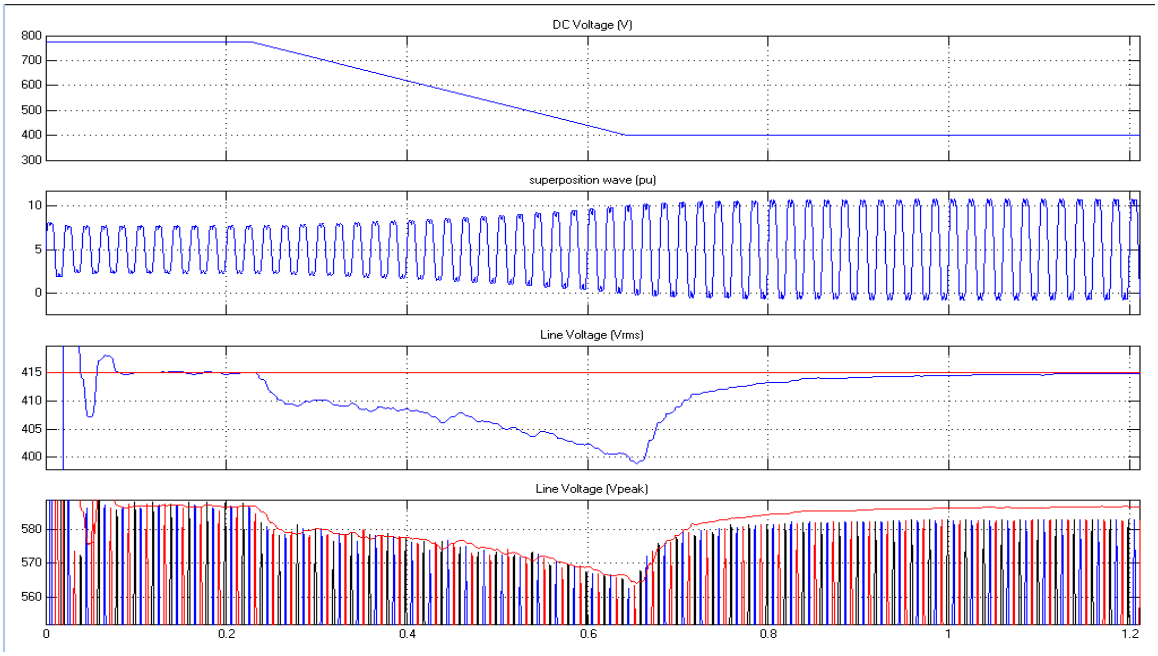


**Fig.5, Simulation Results of 5-Level Inverter Connected to Resistive- Load Using ANFIS-Controller (a). Input DC Voltage a Step Change in $V_{dc}$ of 32% (399.09-774.69)(b) Superposition Signal Wave (pu) (c) Line Voltage (Vrms) (d) Line Voltage(Vpeak)**

From fig.5 (a) The input DC voltage is constant from 0sec to 0.22 sec at this time the DC voltage magnitude as 775v after that the voltage is decreased from 775v to 399v with the time 0.22sec to 0.62sec,after that the voltage magnitude is constant up to 1.2sec as 399v.

From fig.5 (b) can observe that the input DC voltage is constant from 0sec to 0.22sec at this time the superposition wave is also constant, when the DC voltage is decreased from 0.22sec to 0.62sec the superposition wave has been improving correspondingly, from the scale from 0.62sec to 1.2sec scale the superposition wave

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is constant.From fig.5 (c) can observe that input DC voltage is constant from 0sec to 0.22 sec at this time the output line voltage (Vrms) is also constant magnitude i.e 415V. After that the DC voltage step change in $V_{dc}$ at 32% lesser than rated value and maintain constant voltage. From fig.5(d), can observe that the input DC voltage magnitude is constant (0sec to 0.2sec) accordingly output line voltage (Vpeak) is also constant voltage magnitude, when the DC voltage magnitude is step change in Vdc 32% less than rated value, even though the inverter output voltages are maintain stabilized voltages.

From fig.6, can observe that inverter output voltages are maintain the constant voltage magnitudes even though input DC voltage fluctuations, such that the superposition wave has been improving to control the inverter output voltages as shown in fig.6(b)and(d).

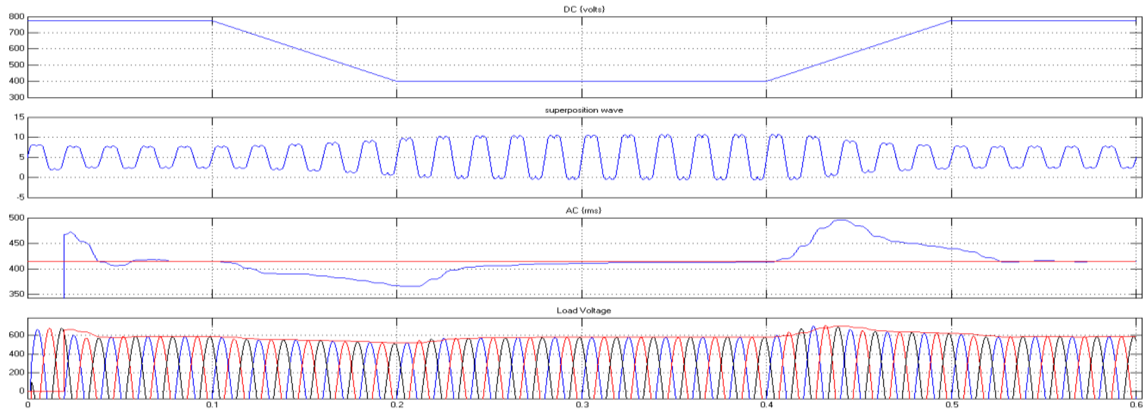


**Fig.6, Simulation Results of 5-Level Inverter Connected to Resistive- Load Using ANFIS-Controller (a) a Step Change in $V_{dc}$ of 32% (399.09-774.69)v(b) Superposition Signal Wave (c) Line Voltage (Vrms) (d).Line Voltage(Vpeak)**

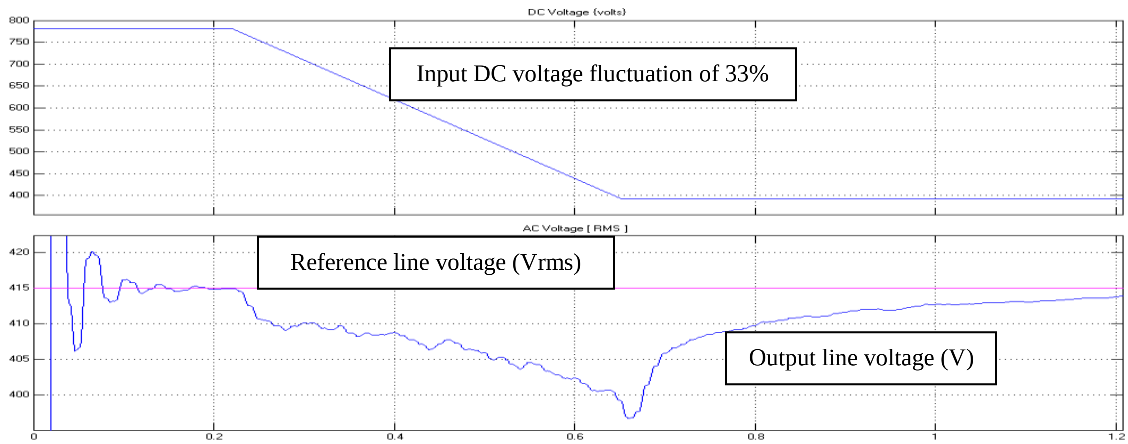


**Fig.7, Simulation Results of 5-Level Inverter Connected to Resistive- Load. Using ANFIS-Controller (a) a Step Change in $V_{dc}$ of 33%(780.56-393.21)V (b) Line Voltage (Vrms)**

From fig.7, can observe that input DC voltage magnitude fluctuation of 33% is applied to multilevel inverter circuit connected to 6kw resistive load. But correspondingly the inverter output line voltage is not reach to the rated value. Fig.7(b), shows that the output voltage stabilization of multilevel inverters with ANFIS-controller can effectively up to input voltage fluctuations of 32% only. If above this limits the output line voltage response has been not in acceptable limits.

**Table1: Multi Level Inverter-Output Voltage Performance with ANFIS -Controller.**

| S.No | ANFIS controller with Resistive load | Input DC voltage fluctuation range | 5level Inverter Output Line voltage (THD) | Stabilization of inverter output voltage |
|---|---|---|---|---|
| 1 | Resistive Load(6Kw) | 32%(774.69-399.09)V | 0.14% | 0.4sec |

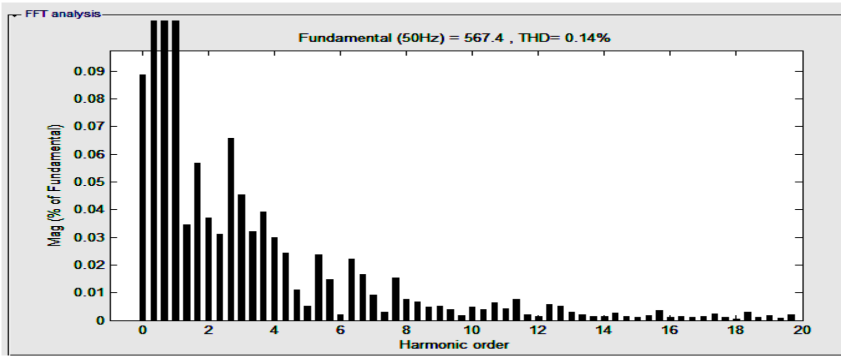


**Fig.8, THD of Output Line Voltage of Multilevel Inverter Connected to Resistive Load(6kw)**

## V.CONCLUSIONS

Using Adaptive Neuro Fuzzy Inference System (ANFIS) controller With SPWM has been maximum controllability and absorption of the fluctuations of input DC voltage is up to 32%. And also it contain of less THD and fast response of controllability and absorption of DC voltage fluctuations. Further, can implement high speed digital control by means of a single chip microcomputer, which lower costs and smaller size as well as decreased computational complexity.

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