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Design And Control Of Three Level Active NPC Inverter Fed Induction Motor Drive

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ABSTRACT

The existence of multilevel inverters has made easy energy conversion. These energy converting systems are modeled in different ways as per the applications. Demand for less weight with high efficiency, THD, made to increase the levels of the output by increasing the switching frequency in the inverters. As the levels of the inverters increases the THD decreases. This makes the system more efficient. It made researchers to develop different topologies based on different parameters. Due to these advantages the application hub of these inverters are increasing in different fields of industry. Research on these systems has become more now-a-days. These inverters are mainly used for power conversion at generating stations, HVDC etc. In this paper the working and controlling of Active NPC has been explained. Due to its advantages compared with other topologies made ANPC very useful in industrial area. The control strategy, output voltage and current, THD, loss calculations are determined and revealed in this paper.

Index Terms: Multi-level inverter, active neutral point clamped, THD

I. INTRODUCTION

With the continuous increased crisis of energy and need of reducing the production cost of the industry, the first and far most need is to reduce the energy consumption. The main source of energyconsumption in the industries is industrial motors. Now a day's most of the industrial motors are incorporated with efficient drive system to reduce energy consumption of the machine and to feedback regenerated power.

Most of the drive systems are functioned with inverter system. Power quality is the prior factor in case of industrial induction machines with high distorted and harmonic content input in the machine cause extra electrical power losses and unnecessary heating of the machine gives poor operating efficiency of the machine and reducing lifetime and increasing production cost [1].

By considering all these things we started development of fully controlled high power, low THD and low efficient multilevel inverter for mitigating all above the problems related to industrial drives and to give a new technological solution in the industry [3]. These multilevel inverters have gained much attention in industrial area and also in scientific research. The circuits are less complex, needs less filtering and there is no use of transformer. In aspects of cost and efficiency for large power system applications multilevel inverters are beneficial [4].

Among all the topologies Active NPC is mostly used as it has more degrees of freedom and easily controlled by different PWM technologies. It has many ways to clamp the midpoint, in which the current can be conducted through different paths for clamping. In order to apply these all beneficiary aspects in renewable energy conversion, in industrial area, in grid system these inverters are used.

II. PRINCIPLE OF ACTIVE NPC INVERTER TOPOLOGY

Active NPC topology is an extended topology of NPC conventional. In this inverter topology, there are two extra active switches for each phase connected with two anti parallel clamping diodes which helps substantially for distributing the losses [2]. The active NPC provides more degrees of freedom and has many ways to clamp the diode.

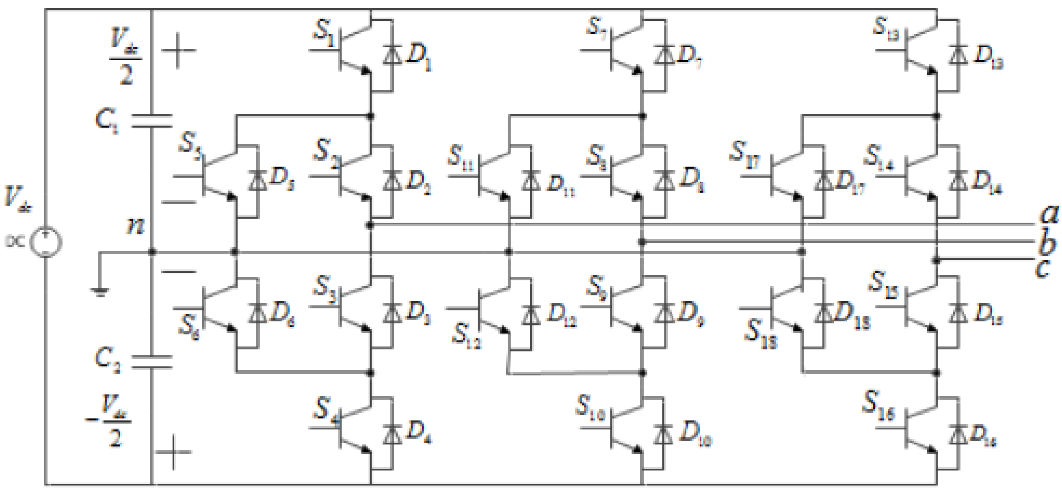

Fig1. Basic circuit of ANPC inverter

TABLE 1SWITCHING STATES OF ANPC

Switching state	Switch Status						Output Voltage
	S_1	S_2	S_3	S_4	S_5	S_6	
+	1	1	0	0	0	1	$+V_{dc}/2$
$0U_2$	0	1	0	0	1	0	0
$0U_1$	0	1	0	1	1	0	0
$0L_1$	1	0	1	0	0	1	0
$0L_2$	0	0	1	0	0	1	0
-	0	0	1	1	1	0	$-V_{dc}/2$

Turning ON the switches s2 and s5, phase current is conducted through the neutral point upper path. In the same way the lower path is also conducted [6]. This gives raise to many zero states in the Active NPC.

The zero states and different commutation techniques in this inverter used to reduce the switching losses and stress on the semiconductors. Main intention is to distribute the losses as they cannot be reduced permanently.

By switching ON switches 1, 2 and 6 positive voltage can be obtained. By turning ON switches 3, 4 and 5 negative voltage can be obtained.

III. SWITCHINGSTRATEGY USED

Different types of PWM strategies can be used for ANPC inverter topology due to extra active switches and the redundant zero state [5]. Among different types of PWM strategies the most popular technique is multi carrier PWM technique. The basic principle of multi carrier PWM is comparison among reference sinusoidal wave form and carrier triangular wave form. The frequency of the carrier is f_c and amplitude A_c is same for multi carrier and the frequency of the sine wave is f_r and carrier wave isA_r.

For generation of m-level, m-1 carrier wave form is needed. For every time interval when carrier triangular is greater than sine the result is 1 otherwise it is zero [1]. The specified techniques is mainly controlled by two parameters amplitude modulation (ma) and frequency modulation (mf)

Frequency modulation (mf)= $\frac{f_r}{f_c}$

Amplitude Modulation =$\frac{2A_r}{(m-1)A_c}$

Phase shifted PWM technique:

PSPWM generation is used in this paper.

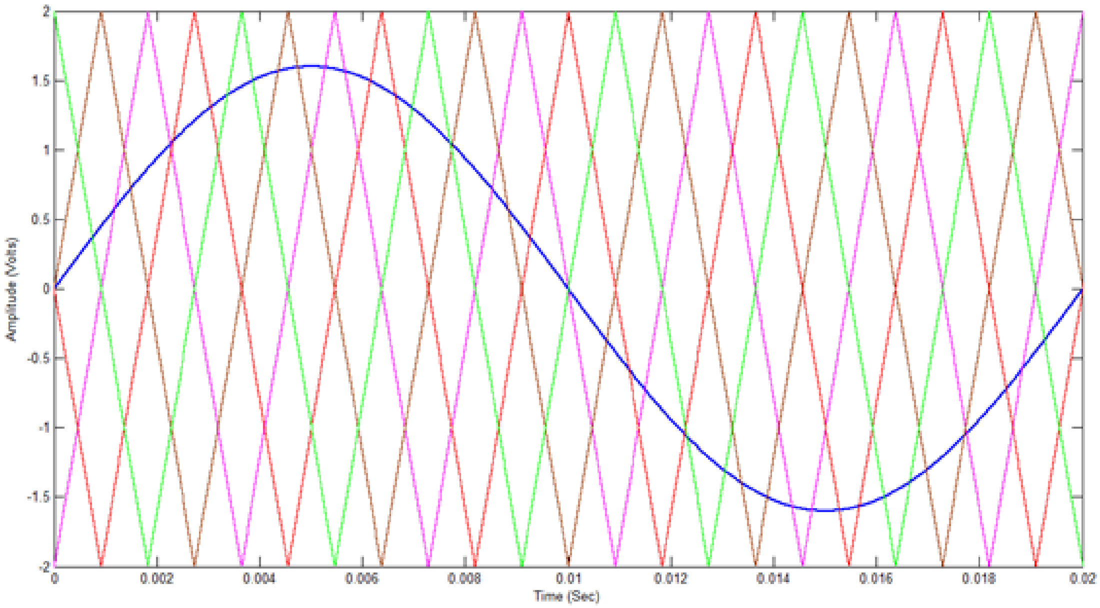

Fig.2 PSPWM carrier arrangement (ma=0.8 ; mf=20)

The rules for PSPWM strategy are,

1. As in Fig two carrier wave are taken
2. When magnitude of sine wave is greater than triangular wave form switches S1, S2&S3 is ON. The output of the inverter is $+V_{dc}/_2$
3. When the magnitude of the sine wave is greater than the triangular wave formswitches S3, S4 & S5 is ON the output voltage level of the inverter isFor all other switching states the output voltage is zero.

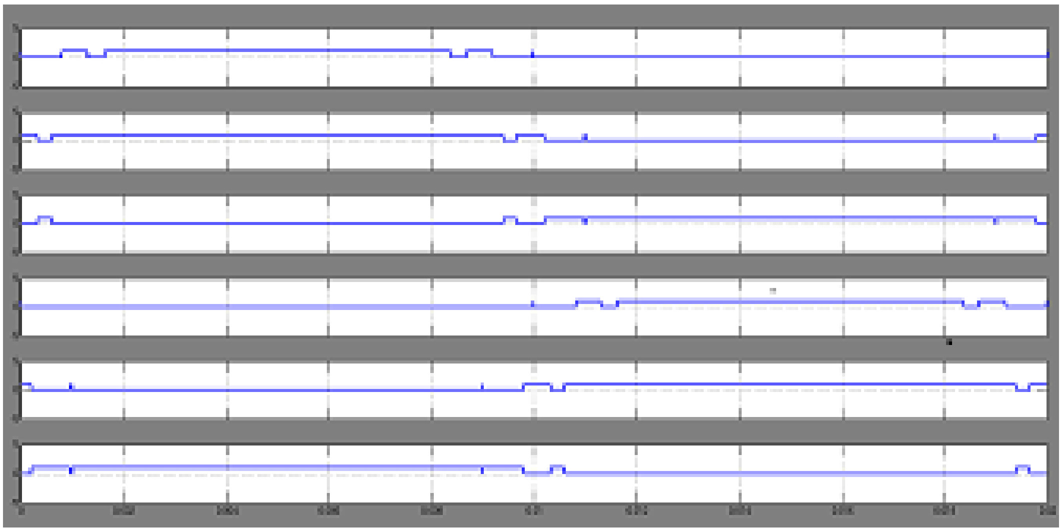

Fig.3 Simulated switching pulses

IV. CLOSED LOOP CONTROL STRATEGY USED

Strategy to balance the neutral point voltage:

For balancing the neutral point voltage of Active NPC inverter SV (space vector) modulation technique is used. In this strategy small P type and N type switching states will be replaced by other switching states that will not affect the neutral point voltage [4].

Zero and medium voltage states are also there to balance the neutral point voltage.

Strategy to balance the Capacitor Voltage:

DC level injection is used to balance the capacitor voltage. In this method a variable off set voltage is continuously added in the controller to balance the potential of dc bus [4]. This process is done by calculating peak to peak amplitude, third harmonic content and total harmonic distortion.

$$Vd = 2/3[Va\sin\omega t + Vb\sin(\omega t - 120) + Vc\sin(\omega t - 240)]$$

$$Vq = 2/3[Va\cos\omega t + Vb\cos(\omega t - 120) + Vc\cos(\omega t - 240)]$$

$$V0 = (Va + Vb + Vc)/3$$

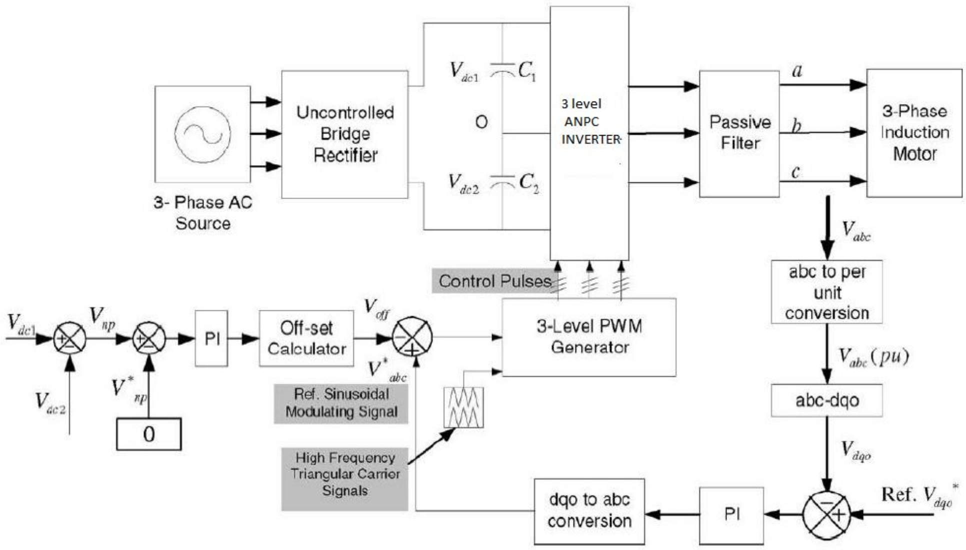

Fig.4 Closed loop control employed

V. LOSS CALCULATION:

The losses in the inverter are highly influenced by the temperature generated across the switches. Temperature generation across the switches depends on the voltage stress across the switch. Hence more the switches, lesser will be the losses across the switches. Thus they have less temperature generation across the switches [4].

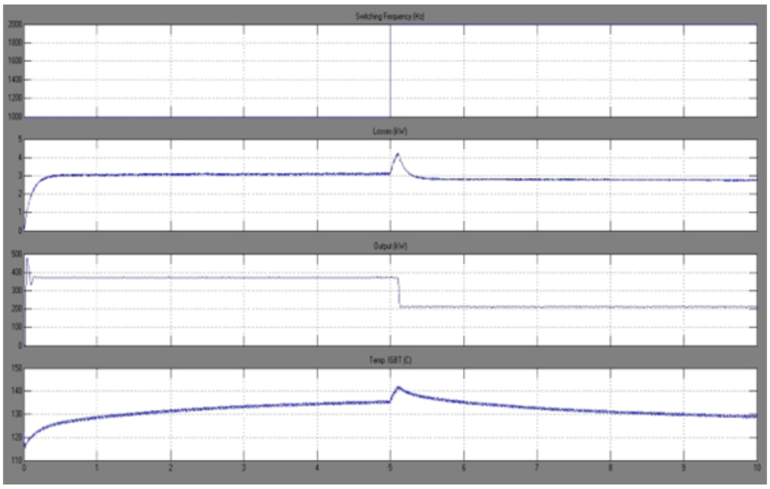

Fig.5Waveforms of Total Losses, Output Power and Temperature of 3-level Active NPC at 2000 frequency for a stop time of 10sec

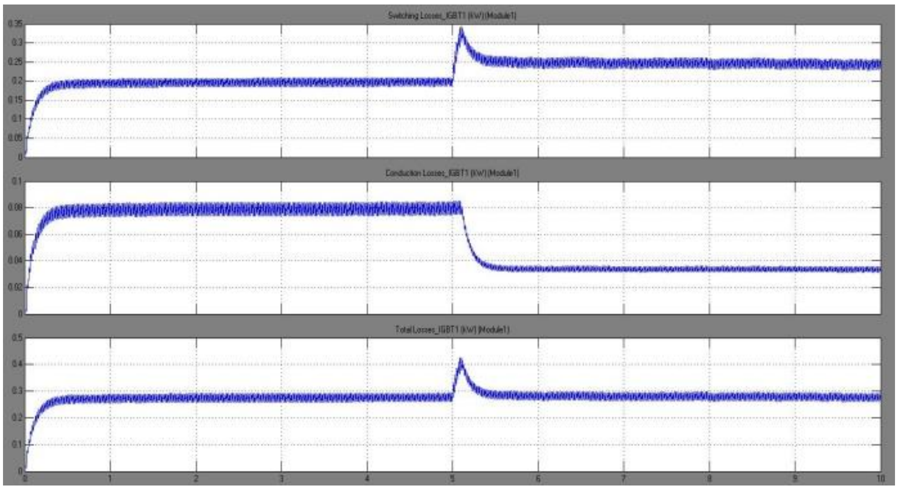

Fig6.Effect of Change in switching frequency on Switching and Conduction losses for Active NPC: For Switching frequency 1000 Hz for 5 sec and 2000Hz for next 5 sec

TABLE 2EVALUATION OF LOSSES

FREQUENCY (HZ)	SWITCHING LOSSES(KW)	CONDUCTION LOSSES(KW)	TOTAL LOSSES (KW)
1000	0.1145	0.03278	0.1472
2000	0.2384	0.0323	0.2707

VI. SIMULATION OF ACTIVE NPC AND RESULTS

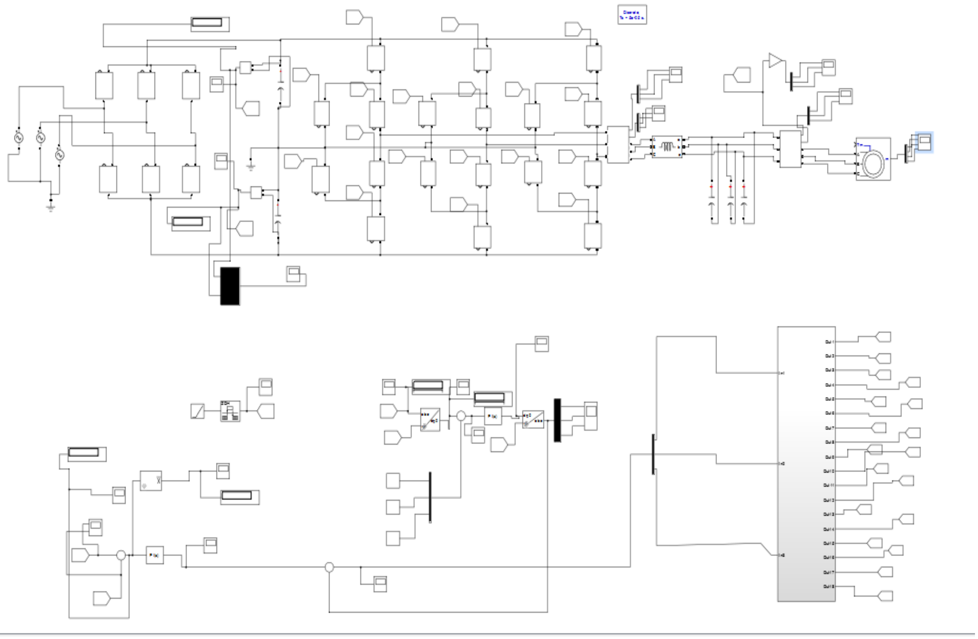

Fig.7 Simulated circuit diagram of ANPC inverter fed induction motor

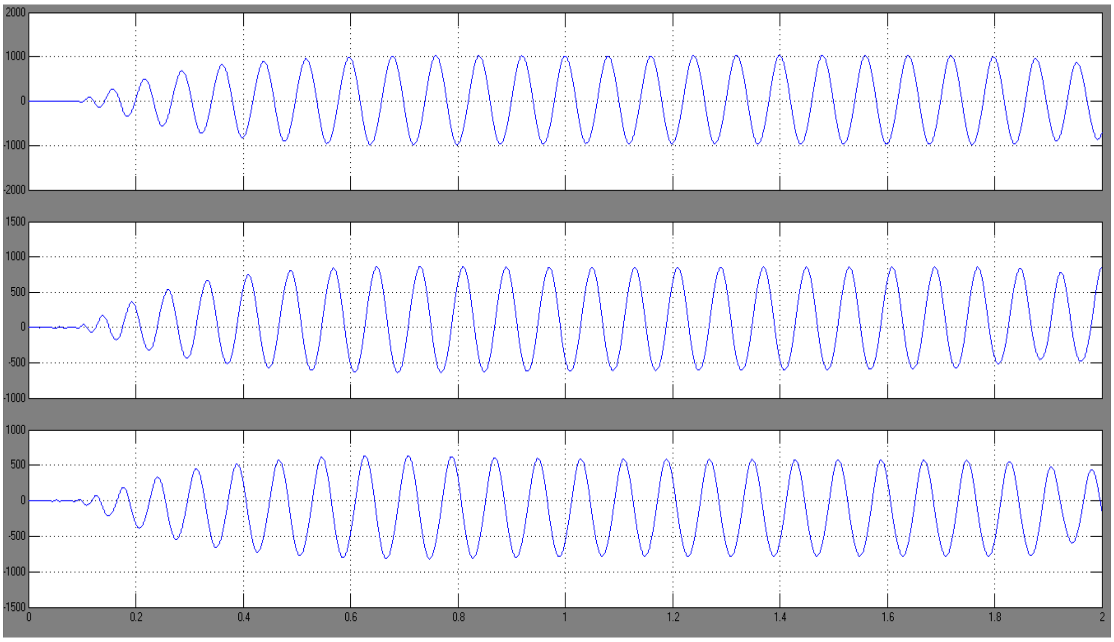

Fig.8 Output waveforms of ANPC phase voltages

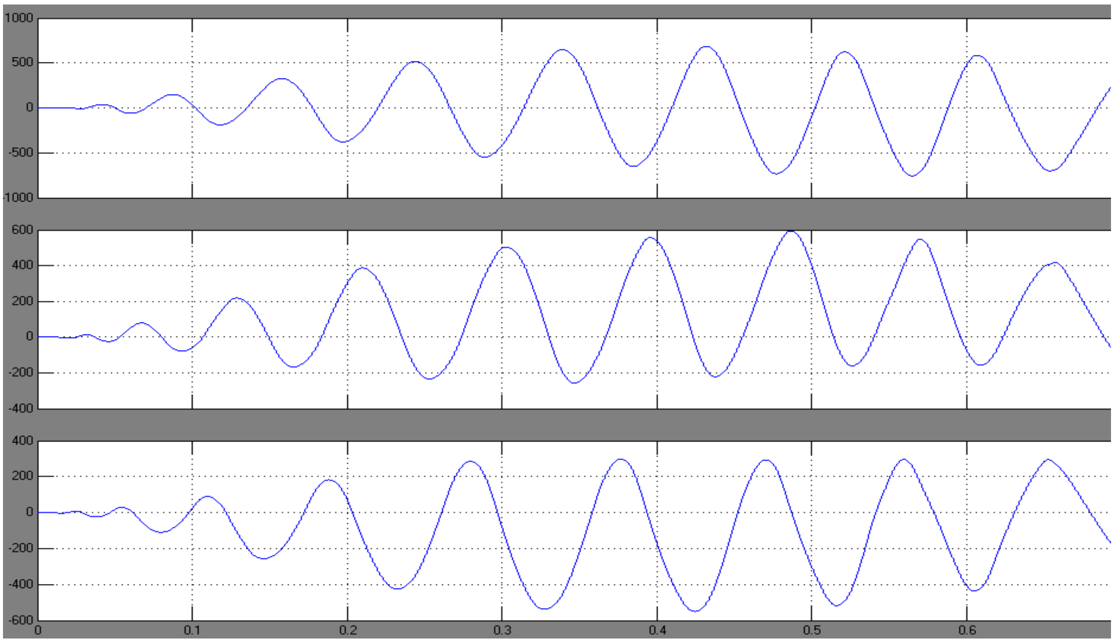

Fig.9 ANPC output current waveforms

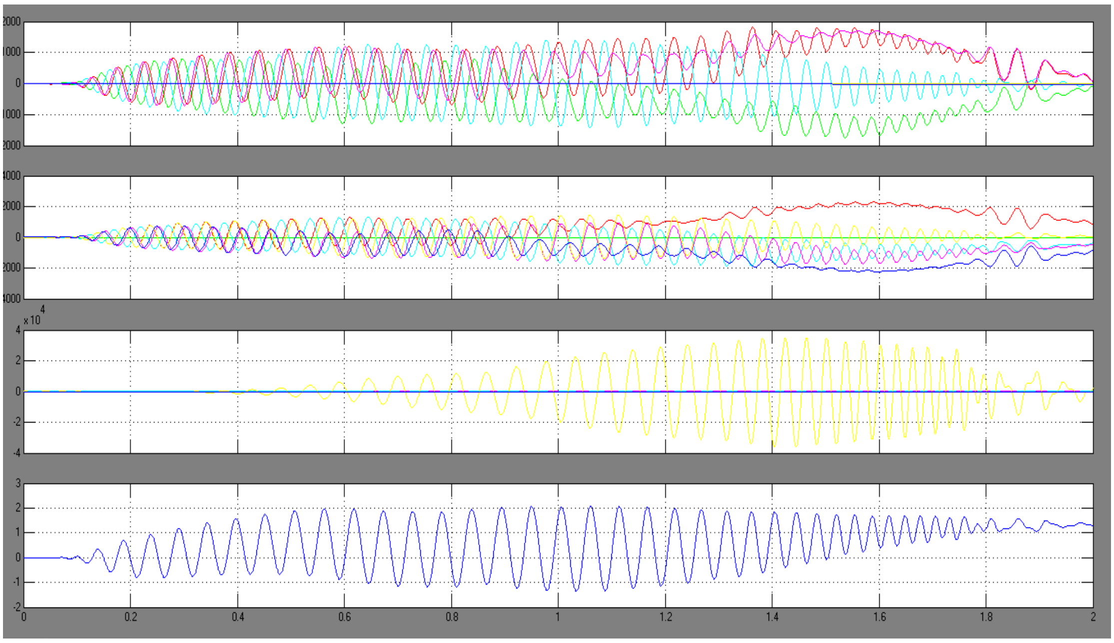

Fig. 10 Induction motor output

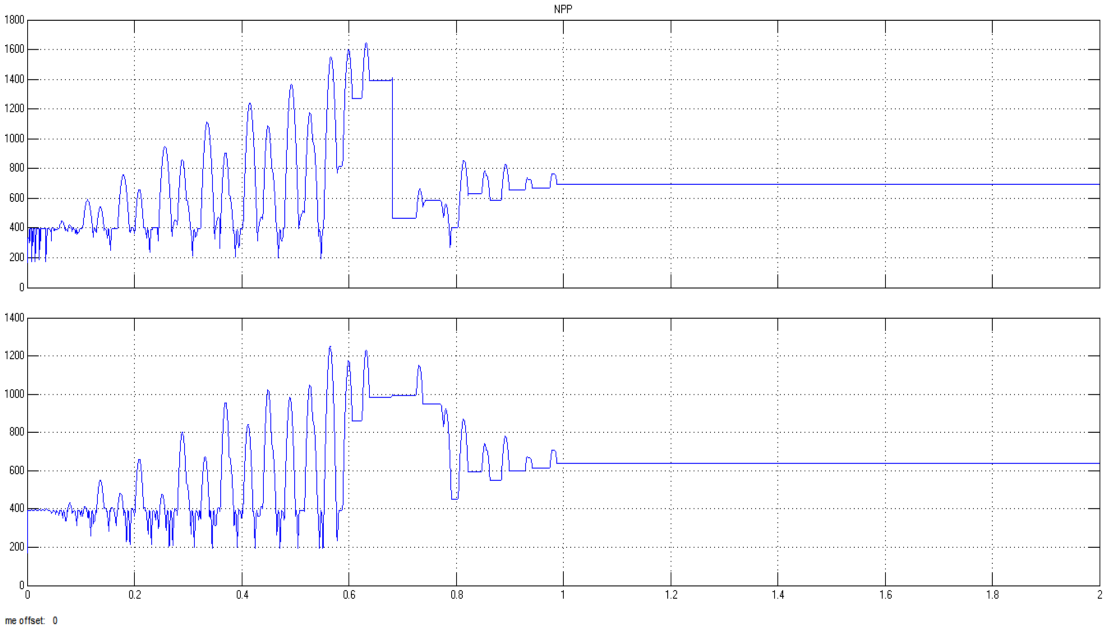

Fig.10 Balancing of Capacitor Voltages at input

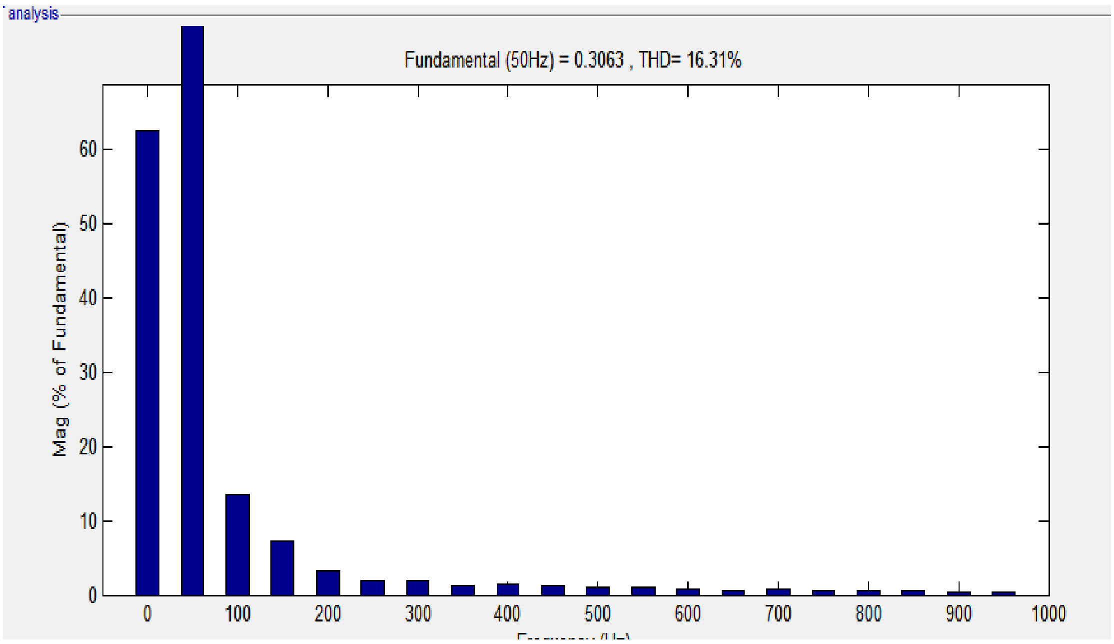

Fig.11 THD analysis of 1 phase (16.8%)

VII. CONCLUSION

This paper analyses different parameters of multilevel active NPC inverter like three level voltage, current, balancing dc link capacitor voltage, determination of current harmonics, and reduction of stress on switches. Loss calculation for the determined 3-level active NPC has also been analyzed and mentioned.

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