International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

Performance Improvement of Sensorless Vector Controlled Induction Motor Drive for Medium Power Applications

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Abstract: ***This paper deals with sensorless vector controlled induction motor in which torque pulsations are reduced with improved input of induction motor. In proposed technique two multi winding transformers are used for generation of 18 sinusoidal signals given to rectifier unit and the rectifier output given as input to 9 level multi level inverter. In this proposed technique gating signals to the inverter switches will be provided through space vector pulse width modulation which considers speed as reference. This configuration was simulated in MATLAB/Simulink.and the simulation results are presented here with improvement in reduction of THD.***

Keywords: Multi Winding Transformer, Multi-Level Inverter, Power Quality, Modulation Techniques, VCIMD.Space vector pulse width modulation

I. INTRODUCTION

Rated voltage of the induction motor drive for industrial applications are in the range of several kV, and the feasible of AC power is 33/11 kV. Driving IMD, there is definite use of a set of step-down transformer at the grid side, which power is fed to a six-pulse diode bridge rectifier (DBR). This DBR current has high THD percentage. In order to overcome the above problems, secondary winding of multi-winding transformer is to be connected to AC- DC converter preferably at the grid side. The transformer steps down AC power to the desired level and connected to 6-pulse diode bridge rectifier device (DBR). Several DBR connections are done in such a manner that harmonics produced by one DBR will be cancelled by harmonics produced in other DBR. All these connections of DBRs will produce final DC supply which in turn given as input to the cascaded H bridge multi level inverter [4]. Multi Level inverters are good choice in giving input supply to Induction Motor Drives. These inverters possess low THD and dv/dt. Variable frequencies can be obtained by using these inverters. Two separate types of polygonal configuration Δ- polygon 18 pulse AC-DC converter is used in the grid side. Since the phase shift in the input winding of the two 18 pulse converter is reconfigured as 36-pulse AC-DC converter, which makes nearly sinusoidal grid current, reducing its THD. Three level (1: 3) based on 9 CHB inverter is used to drive the motor, to improve the performance of induction motor drive. As Sensorless vector control is used for the 3 phase induction motor (IM) and reference voltage signal is generated, which is used in accordance with an input modulation technology by using nine level CHB inverter. Here, the multi-pulse AC-DC converter is connected to CHB driving an induction motor drive for industrial applications. It has been pointed out that for applications of IMD, CHB operating frequency of the inverter is lower than 1kHz [8] to the limit. Thus, in this work, a new modification of the nearest level modulation techniques (NLMT) Presented at the fundamental frequency of operation of the inverter [9]. Since the basic operation of the inverter, the proposed IMD with very little switching loss is recommended for better efficiency results. Complete modeling, design, and operation of the suggested sensor less vector controlled induction motor drive response (SLVCIMD) mentioned in further sections. The switching frequency of CHB is less than 1kHz [8]. In this Paper, a new modification of the nearest level modulation techniques (NLMT) is Presented at the fundamental frequency of operation of the inverter [9]. By using CHB inverter in VCIMD the switching losses will be less with good efficiency than exiting VCIMD. The proposed system was simulated in matlab simulink platform to enhance the various load conditions and to analyze the output and to reduce the complexity of system. As the proposed system has components varying from existing configuration.The proposed system have the following blocks: i) 3 phase voltage source ii) two multi winding transformers, iii) ac to dc converter iv) 9 level multi level inverter v) speed estimator vi)space vector pulse width modulation and vii) Induction motor.

II. DESIGN OF PROPOSED SL-VCIMD

A 3 phase voltage is necessary to run a three phase induction motor drive but to control the induction motor drive we need so many components as shown in fig .1 we can get a glimpse of components .primarily the three phase voltage source is given to two multi winding transformer in those multi winding transformer secondary connections are in topology to generate three signal of each signal have phase difference of 20^o like +20^o , 0 ^{o}, - 20^o, from each of three phases so there are 9 signals at end for second transformer also there is a generation of 9

Revised Manuscript Received on December 30, 2019.
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signals both are together made 18 signal and these 18 signals given to rectifier and the rectifier made 18 signal of both positive and negative into positive side so then there is a dc voltage of 36 pulses.

The need of these 36 pulses is to reduce the harmonics.

Later these 36 pulses given to multi level inverter and the multilevel inverter output is given to induction motor drive .Now the control of induction motor drive can be achieved by changing the voltage of the multilevel inverter. For this the motor speed is need to be measured to compare with desire speed of motor as name indicates sensorless no mechanical measurement is needed but by measuring the induction motor current of three phases and transforming in to two phase by using clark transformations the we can find the speed by using speed estimator. After speed estimation there is a comparison of speed of motor and reference speed and the error signal given as input to the space vector pulse width modulation block and as SVPWM can generate triggering signal at every 60^{o} there is good improvement in THD reduction .by using the error signal there is reference signal generation and by using that reference signal the SVPWM block produces triggering pulses to MLI in this way the frequency and voltage of MLI can variable to desire and motor can be runs at desire speed and torque.

A. 9-Level CHB Inverter

In this work, the ternary (1: 3) design of the basic CHB inverter is driven the AMD. The Switching sequence of the CHB inverter is reflected in the table -I. For every power cell the voltage can calculated as by using the DC link capacitor CHB inverter as [8],

$$V_{mab1} = 0.612a_i\left(L-1\right) V_{DC} \qquad (1)$$

Here, Vmab1 substantially line voltage of a motor, modulation index is A_1 , L is the number and state of the voltage of DC link Vdc. From equation one we can write as , A_l = 0.920, DC voltage are found as V_{dc1}=888.040 Volts, and V_{dc3}=2664.120 Volts.

In this paper 9 level inverter was considered for better performance for which Dc supply has been connected as input . Dc supply was obtained by using diode bridge rectifier. The same rectifier can be bult by MOSFET, GTO and others but its just need a fixed dc out put voltage not more than that so we need not to go to controlled device to reduce the cost of the system and to minimize the complexity of the circuit and we need to give extra supply to the rectifier and for firing circuits also uncontrolled devices are used .

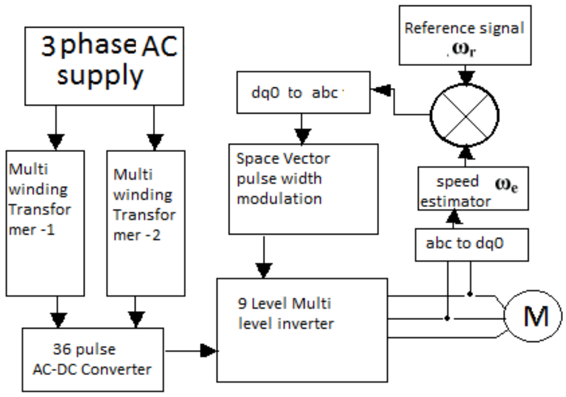

Fig. 1. Block diagram of proposed SL-VCIMD.

Series connected inverters are used in this system because the individual connection of inverter does not give much performance and when we add those inverter in series we can get 9 level output as the the each of on inverter can give three level output ac wave form . this can done by dividing those inverters and creating angular deviation among the inverter to generate 9 level output. For this inverter the output can be controlled by change the PWM. The PWM technique used earlier is NLMT and now that is replace with the space vector pulse width modulation that is one among the most advanced technology of the now day electronics .the out put of inverter can be controlled by changing the reference signal given to the pwm this is can possible by changing the reference voltage and reference frequency .

B. A 36-Pulse AC-DC Conversion

For the thirty six pulse generation , there is a need of 2 multi winding transformers T1 and T2 and these can be use at the grid side. Those transformers T1 and T2 are connected in delta configuration having an input winding, output winding having three winding isolation. Having an output winding angle of 20° 0° -20° triangular configuration and a simple 2-δ- polygonal configuration, to obtain 20° as these angles are to force the pulse converter.

Table-I Sequence of Switching of A 9-Level Cascaded MLI.

(+) Levels		(-) Levels	
Levels	sequence of Switching	Levels	sequence of Switching
0	S_1S_3, S_5S_7	$-V_{dc}$	S_3S_4, S_5S_7
V_{dc}	S_1S_2, S_5S_7	$-2V_{dc}$	S_1S_2, S_8S_7
$2V_{dc}$	S_3S_4, S_5S_6	$-3V_{dc}$	S_1S_3, S_8S_7
$3V_{dc}$	S_1S_3, S_5S_6	$-4V_{dc}$	S_3S_4, S_8S_7
$4V_{dc}$	S_1S_2, S_5S_6		

As mentioned above , it can be seen that the output winding transformers T1 and T2 are connected as a 18-pulse converter. Input winding of T1 and T2 are arranged in a triangular extension 10° to obtain an angle of -10° .

III. CONROL ALGORITHM FOR PROPOSED SL-VCAMD

As the suggested project can implemented by using two controls of those are the SVPWM and SIVC to controlling the induction motor drive and to vary the voltage and frequency of multi level inverter to controlling the induction motor drive to run the motor at desire speed.

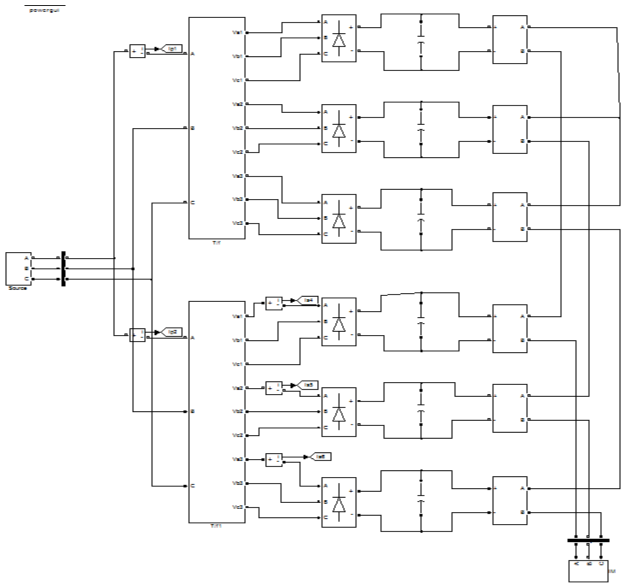

Fig. 2. Simulink model of proposed VCIMD

As it is needed to give ac input to the ac-dc converter 3 phase supply is given to the converter but when there exists more number of pulses then its is considered to be more advantageous system which results in harmonics reduction and utilizing the system efficiently. For this purpose multi winding transformer is used .Here two multi winding transformers are employed. primarily for a 3 phase supply we have 6 pulses and when we give it two multi winding transformers we can get 12 pulses of reduced amplitude and that when coming to secondary winding of multi winding transformer can be built of using different topology of connection as shown in simulation model below. this is for shift the angle of output as each single phase signal converted into three secondary signal of same frequency of reduced amplitude and much important thing of angle shift of signal of three output signal of each have 20^o phase shift among them of as one have -20^o and another have $+20^o$ to make the entire signal numbers to 36 .in this way the 36 pulses are generated. This method can also be called as multi level converting with split phase

A. Sensorless Indirect Vcetor Control

Herein, in the sensorless controlling uses flux of . 2 phase current IM, the current is sensed and the third phase is estimated as $I_C = -(I_A + I_B)$. The stator winding current, can be converted by using a conversion of abc as

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & \frac{-1}{3} & \frac{-1}{3} \\ 0 & \frac{1}{\sqrt{3}} & \frac{-1}{\sqrt{3}} \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix} \begin{bmatrix} i_{mta} \\ i_{mtb} \\ i_{mtc} \end{bmatrix}$$

In this scenario , a cascade MLI is can be used and a DC link voltage is measured . along with this , by using Kirchhoff's voltage law (KVL), we can calculate the voltage of switching pulse and dc bus as,

$$V_{ao} = V_{dc1}[S_{a1} + S_{a3} + 3S_{a5} - 3S_{a7}] \quad (2)$$

$$V_{bo} = V_{dc1}[S_{b1} + S_{b3} + 3S_{b5} - 3S_{b7}] \quad (3)$$

$$V_{co} = V_{dc1}[S_{c1} + S_{c3} + 3S_{c5} - 3S_{c7}] \quad (4)$$

Where S_{xy} are can be called as switching pulses and each of switching pulse can be accommodated on of the leg and those value can zero or one and those are called as pole voltages and these are transformed in to two phase form from three phase form with the help of matrix mentioned above .and by calculating the stator current and pole voltages by using these components we can find the torque and flux and along with this we can with find stator fluxes of both direct axis and quadrature axis

$$\psi_{\alpha s} = \int (V_\alpha - i_\alpha R_s)dt \quad (4)$$

$$\psi_{\beta s} = \int (V_\beta - i_\beta R_s)dt \quad (5)$$

And the flux of stator can calculated as ,

$$\psi_{es\_t} = \sqrt{\psi_{\alpha s}^2 + \psi_{\beta s}^2} \quad (6)$$

The synchronous speed can be found as,

$$\omega_s = \frac{\psi_{\alpha s}\frac{d}{dt}\psi_{\beta s} - \psi_{\beta s}\frac{d}{dt}\psi_{\alpha s}}{\psi_{s\_est}} \quad (7)$$

Slip speed of induction motor can be estimated as

Where L_m is mutual inductance and $T_r=L_r/R_r$, Rr is rotor resistance and $L_r=L_{lr}+L_m$.

$$\omega_{sl} = \frac{\psi_{\alpha s} i_\beta - \psi_{\beta s} i_\alpha}{\psi_{s\_est}} \frac{L_m}{T_r} \quad (8)$$

From (5) and (6), the speed of motor can be calculated as ,

$$\omega_m = \omega_s + \omega_{sl} \quad (9)$$

Voltage space vector of a different approach to SPWM is based on d, q plane representation. The d, q component of the Park transform is found, where the total power, and impedance, remain unchanged. Space representation Shows the voltage vector in phase from the inverter and switch position eight space vectors , V * by appropriate selection of vectors V1 and V2 adjacent to the center is obtained.

For the project of sensorless vector control we need speed estimator .this estimator plays key role in determining the reference signal to the pwm as traditional method is use a measurement system to find the speed of the motor .but we are employing sensorless method so we draw the voltage and current from motor to measure the speed .this can done as the the voltage of and current are converted in clark transformations as the from a 3phase to 2 phase system and later the system mathematical calculation are done and the final we can generate the amplitude of angular velocity and angle of vector .in this way the speed estimator can function as the simulink model can easily indentify the flow of the speed estimation

IV. SPACE VECTOR PULSE WIDTH MODULATION

There are many modulation techniques are available for control of MLI. Preferably the real time digital modulation strategy for a VSI is controlled SVM. SVM DC link capacitor using the control voltage is simple and exact . there are Three switching states and those are [P] (positive electrode), [O] (zero), and [N] (negative),It is used to indicate the mechanism of every leg . Switch Status [P] is given voltage = + VDC / 2 [O] = 0 gives the voltage and [N] are given voltage = -Vdc / 2. As treating three of phases in to one course the 3 level NPC-VSI with a consensus sequence switching shown.the states of switchings can be categorized in to four models . The first model has three zero vector, the second model having a12 small carrier. These small carriers is later extended to six positive and negative six vectors. A third model having 6 medium carrier and a fourth model of six higher vectors. In the NPC inverter SVM can be useful to balance the voltage by using technical adjustments. The switching time for the negative and positive small vectors shown little effect on the vector of the neutral point voltage. the effect can be as small while running . the voltage at neutral point (VC2 of) may be increased the handover sequence when selected. Negative effects of the small vectors. During [ONN] is electrically operated instructions can reduce the neutral voltage switching sequence. it can be observed, the voltage of DC link capacitor may be increased or reduced by adjusting the positive and negative switching time small vectors. In this work, the modulated signal production from IVC. The size and angle of the modulation signal is calculated and given to improving SVM SVM modified strategy is variable than a existing NLMT. the area largely varies with respect to modulation index of the modulated signal. In the speed variable frequency of AMD, amplitude and frequency modulated signal proportional to the motor speed Reference vector Vref is synthesized at each sampling as two near positive vectors and null vector time period. This results in 6 similar parts department. Since V_{REF} in the complex plane corresponding to a circular trajectory sinusoidal signal voltage, the highest possible amplitude of the sinusoidal signal of output voltage. Thus, the modulation index MIcan explained on the basis of per unit values is used as a reference voltage output MI for example, when the reference voltage Vref is established by the first sector, although in the volt-second trajectory equals

$$T_S V_{ref} = t_{v1} V_{(1,0,0)} + t_{v2} V_{(1,1,0)} + t_{v0} V_{(0,0,0)} + t_{v7} V_{(1,1,1)} \quad (10)$$

$$T_s = t_{v1} + t_{v1} + t_{v1} + t_{v1} \quad (11)$$

$$t_{v1} = \frac{3}{4} T_s MI[\cos(\theta) - sin(\theta)] \quad (12)$$

$$t_{v2} = \frac{\sqrt{3}}{2} T_s MI \sin(\theta) \quad (13)$$

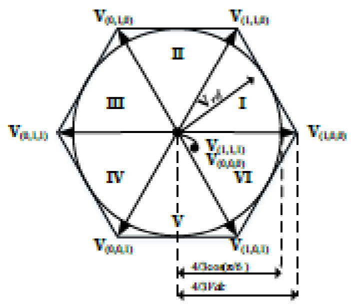

Fig.3 Eight stable vector in the complex plane for a VSL

$$t_{v0} = t_{v7} = T_S - t_{v1} - t_{v2} \quad (14)$$

The similar method may be a used for calculating the dwell times of the vector for sector 2 though 6 if the following enhanced θ_k is used

$$\theta_k = \theta - (k-1)\frac{\pi}{3} \quad (15)$$

In above equation sector number is denoted by k

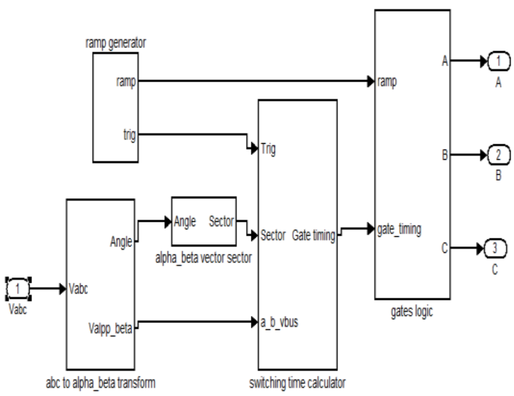

Fig. 4. Simulink model of SVPWM

As the significant module of the paper is space vector pulse width modulation SVPWM .The implementation of this can be as follows as we know the space vector have 8 signal in hexa gonal parameter as the six can as diagonal and other two are point measurement as the six side are sharing 360° and the each side can get 60° so we can have the conduction for every 60° earlier the NLMT method have conduction angle of 120° so we reduce the non conduction period that gives a better output as compare to the earlier one. so the SVPWM can be have more additional advantage of reducing the harmonics content this can observed at both input and output side that means source and load sides. The pulse generation through this can be as measuring the current and speed of the motor and comparing with reference speed and finding the error and the by using synchronous reference frame theory we did clark transformation and then converting the the 3 phase to 2 phase as dq axis.

Retrieval Number: B3325129219/2019©BEIESP
DOI: 10.35940/ijeat.B3325.129219
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in this the direct axis related to the magnitude of the system and q axis is related to the angle of the system then comparing the both and generate a reference to pulse generator then pulses are produced

V. RESULTS AND DISCUSSION

The proposed induction motor drive fed from 9 level multi level inverter with space vector pulse width modulation and existing nearest location modulation technique is simulink modeled and the corresponding result comparison can explained as follows with FTT analysis

The FTT analysis can shown as the THD used existing method of NLMT and proposed method of SVPWM are arranged in way to get identify the improvement of reduction of THD side by side to compare quickly .

Simulated results of the both SVPWM and NLMT can shown in following figures , as the motor to analyze the performances we have to compare the parameters like input current and motor current and voltage and pulse current and torque .The THD analysis is shown in figures along with some wave forms of pulse signal and torque response.

From the results demonstrated in Table. II it is seen that the suggested SL-VCIMD have better power response at the grid side of supply the motor side.

A. Steady State Response

The steady state response of the proposed induction motor drive with SVPWM method is have good response compare to existing technology of NLMT this can be observed in diagrams .

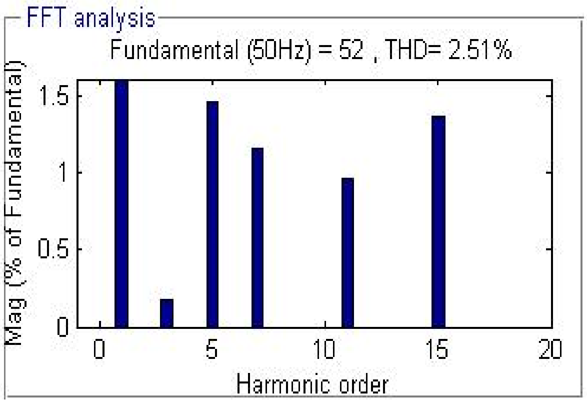

Fig. 5(a). Input current at steady state with NLMT

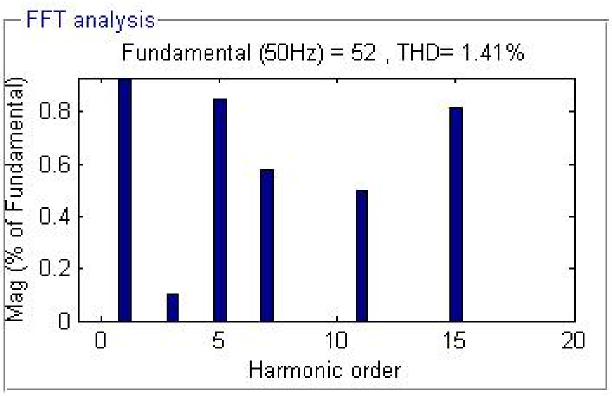

Fig. 6(a). Motor current at steady state with NLMT

B. Transient Response

The transient response of the induction motor drive can be explained as the improvement in THD reduction that can be shown in Fig.8(a)-(b). As the THD of existing system NLMT and proposed system SVPWM is reduced and the response of the speed and torque is also improved.

The power factor can also can be improved and this also can as follows and analysis is can be made from the table II . As per the below mentioned FTT analysis it can be justified that suggested technique is better than the exiting technique in terms of voltage, input current, motor current and torque In all the above said parameters the performance of proposed technique has been improved in terms of THD reduction .

C. Power Quality Response

The Fast Fourier transform (FFT) of i_s, v_m and i_m of suggested SL-VCIMD are explained in Figs. 5(a)-12(b), respectively. The FFT of *'i_s'* is shown in Fig. 5(a) and it depicts 2.51% THD in it and is reduced to 1.55%. The FFT of *'v_m'* is shown in Fig. 12(a) and it has 7.10% THD in it and it is reduced to 7.06% in proposed technique. The FFT of *'i_m'* is shown in Fig. 6(a), it is having 1.41% THD and it is reduced to 0.80%.

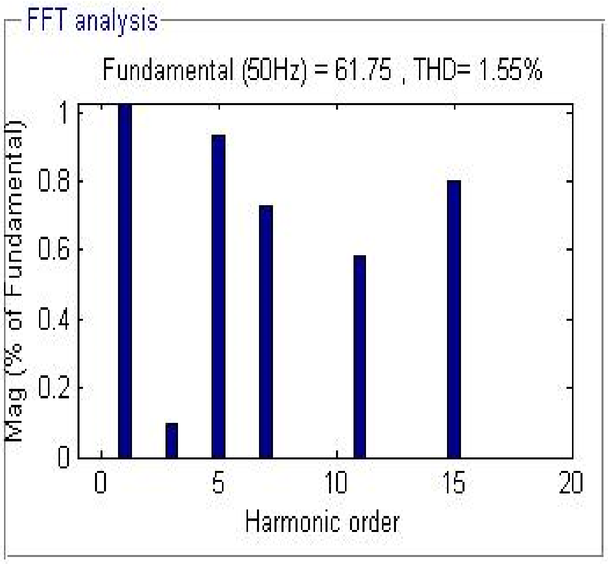

Fig. 5(b). Input current at steady state with SVPWM

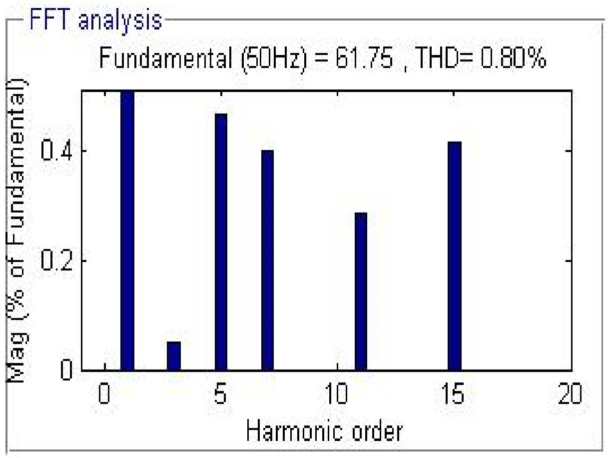

Fig .6(b). Motor current at steady state with SVPWM

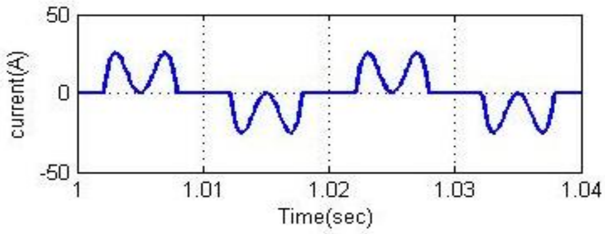

Fig. 7(a). Current pulse at steady state with NLMT

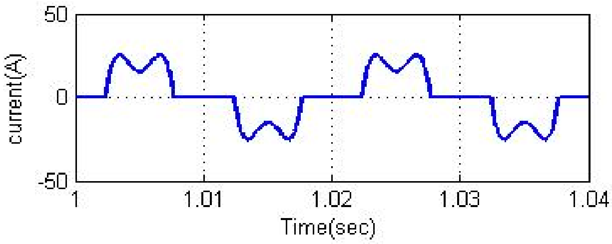

Fig. 7(b). Current pulse at steady state with SVPWM

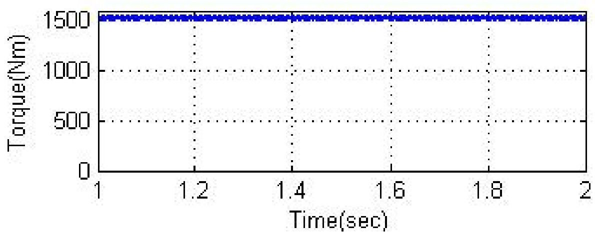

Fig. 8(a). Load torque at steady state with NLMT

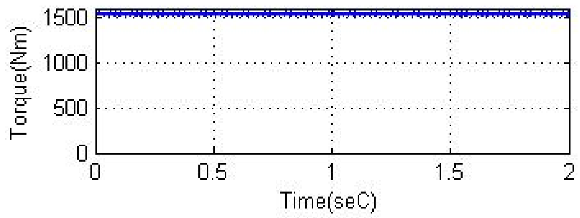

Fig.8(b) Load torque at steady state with SVPWM

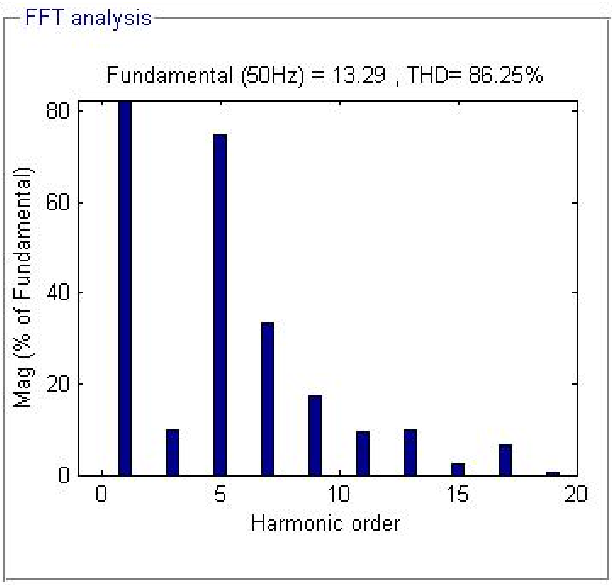

Fig. 9(a). Current pulse at steady state with NLMT

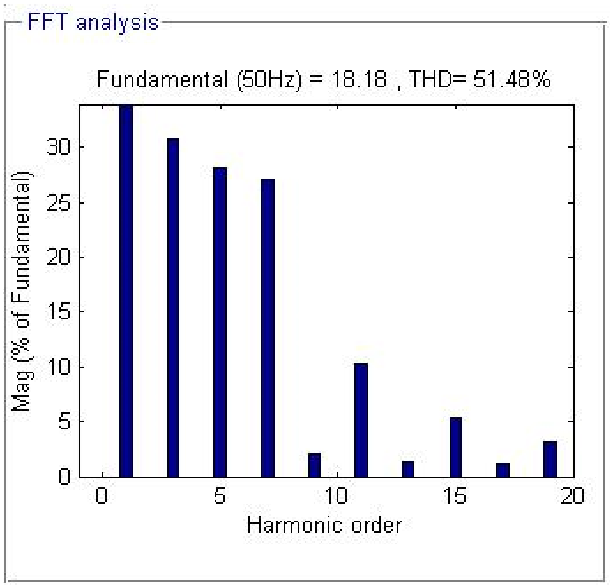

Fig. 9(b). Current pulse at steady state with SVPWM

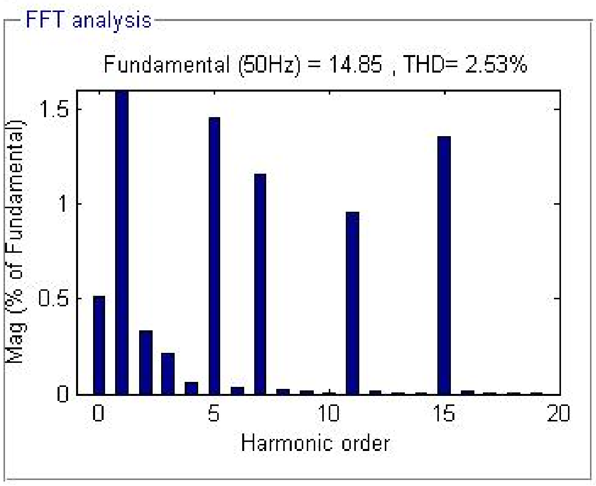

Fig. 10(a). Transient response of motor current with NLMT

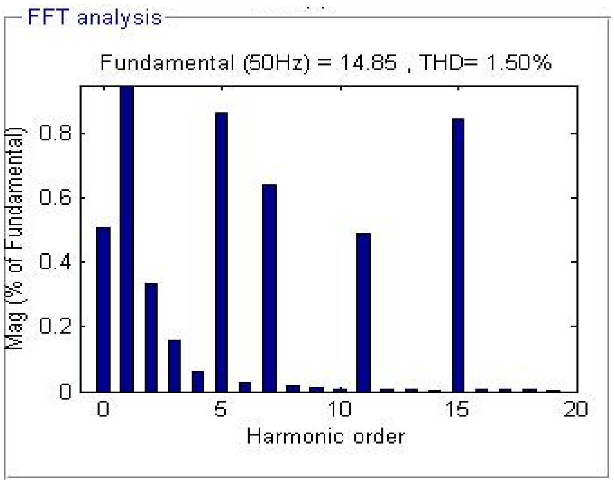

Fig. 10(b). Transient response of Input current with SVPWM

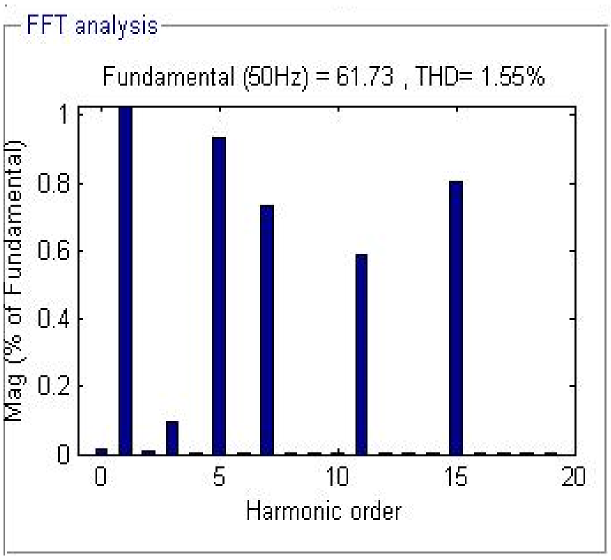

Fig. 11(a) Transient response of Input current with NLMT

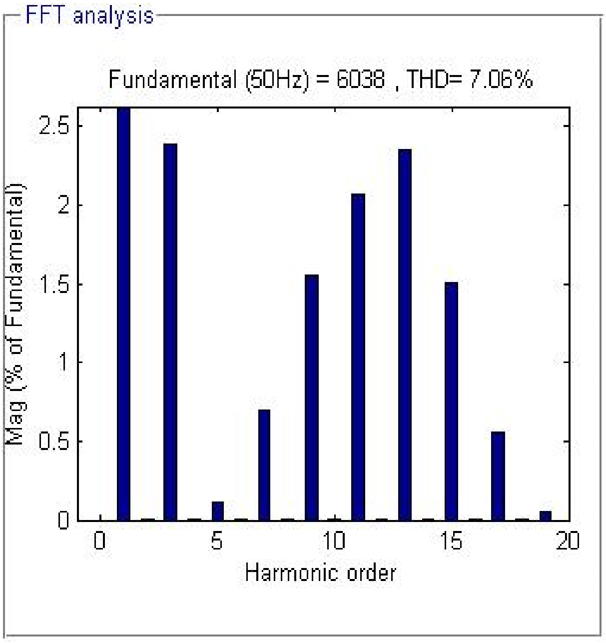

Fig .12(b) Voltage of motor with NLMT

Table-II: THD comparisons

Parameter	NLMT	SVPWM
STEADY STATE RESPONSE		
Input current	2.51	1.55
Motor current	1.41	0.80
Pulse current	86.25	51.48
TRANSIENT RESPONSE		
Voltage	7.10	7.06
Input current	2.53	1.50
Motor current	1.55	0.83

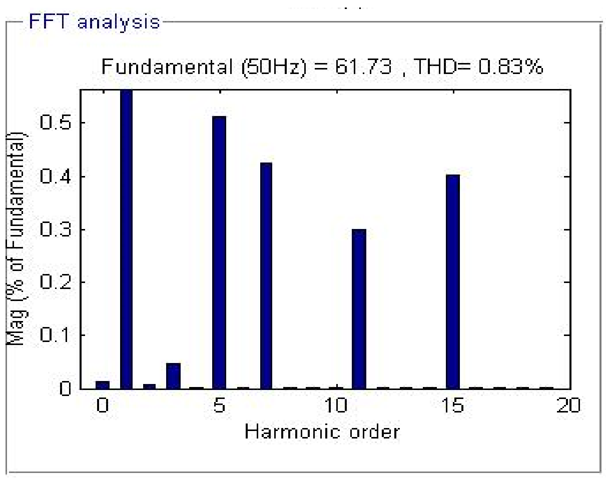

Fig .11 (b) Transient response of motor current with SVPWM

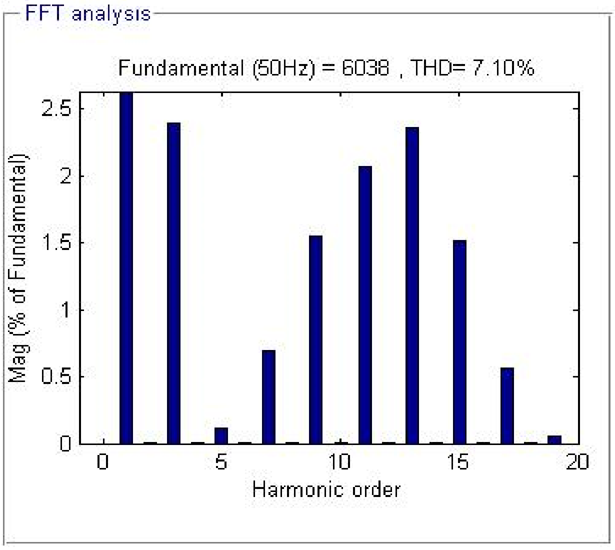

Fig .12.(a) Voltage of motor with SVPWM

VI. CONCLUSIONS

In this paper sensorless vector induction motor drive fed from multi level inverter has analyzed for utilizations of various applications. The suggested SLVCIMD will have better power response at the side of power supply along with drive side. From the simulations results it has been observed that suggested technique has superior performance when compared with existing NLMT during steady state and transient states of operation. Moreover good torques performance has been observed with proposed technology when compared with existing technology.

By using the 9-level CHB-inverter at input side of induction motor performance has been improvement IMD. To get good running state conditions indirect control of motor is used. SVPWM can be used to control multi level inverter at desired frequency along with improvement in steady state and dynamic of different loading conditions to analyze the motor drive for better performance.

INDUCTION MOTOR RATINGS

IM: 0.2984 MW (400 hp), Poles = 4, Frequency =60 Hz , Voltage=4000 V, Rotor resistance R_r =550.0 milli ohms, Stator resistance R_s=780.0 milliohm, Rotor leakage inductance L_{lr}=29 mH ,Stator leakage inductance L_{ls}=29 mH, , Mutual inductance L_m=530 mH and Momemt of interia J=50 kg-m^2.

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