DISCONTINUOUS PWM TECHNIQUES FOR OPEN-END WINDING INDUCTION MOTOR DRIVE FOR ZERO SEQUENCE VOLTAGE ELIMINATION

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Abstract— In now a days modern multi level inverters have emerged to overcome the drawbacks due to the conventional inverters. In various industries inverters with different PWM techniques have been employed to achieve good performance in the context of variable speed drives. But in the conventional inverter instantaneous sum of all the phase voltages is not equal to zero this results into zero sequence voltages in inverters. This zero sequence voltages will induce bearing currents inside the motor. If these currents exceed some permissible limits premature failure of motor bearings will occur. These are some drawbacks due to the usage of conventional inverters in industries. In this paper the techniques to overcome the drawbacks due to conventional inverter have been presented. The cascaded connection of asynchronous motor and two 2-level inverters at both ends of motor constitutes to open end winding induction motor drive. The characteristics of dual inverter fed open end winding induction motor drive resembles to those of conventional three level inverter . In this paper the performance characteristics of Induction motor with different PWM techniques like SPWM, CSVPWM,DPWMMAX, DPWMMIN have been analysed and the harmonic analysis has been carried out using MATLAB/SIMULINK environment.

Index Terms—Bearing currents, zero sequence voltage, CSVPWM, Open end winding induction motor drive Modulation index.

I. INTRODUCTION

Conventional two level inverters are extensively used in medium voltage and high power variable speed drive systems because of their inherent switching operation but however have some limitations in operating at high frequency mainly due to switching losses and constraints of device rating. These switching converters can also provokes high dv/dt caused due to the switching transients[1-2]. These zero sequence voltages results into various adverse effects on motors named as bearing currents, conducted electromagnetic interference, ground currents through stray capacitors. In consequence to this premature motor bearing failures will occur. The clear indication of flowing of hazardous bearing currents in the context of motors inside the motors can be shown in the Fig.1.

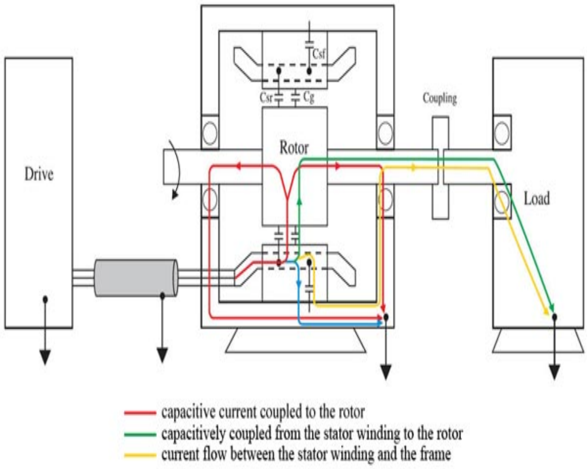


Fig.1 Flow of bearing currents inside the motor

So concerning to this the hazardous common mode voltages in the context of variable speed motors has to be mitigated [4,10].

The numerous methods for mitigating common mode voltage in inverters can be classified as[4]:

[A].Using isolation transformers, Common mode choke, Using hybrid active and passive filters, Using dual inverter fed open end winding induction motor drive, Using four phase inverter.

[B].Using some advanced modulation techniques like carrier based SVPWM scheme for dual inverter fed open end winding IM drive.

The methods proposed in [A] above increases the system cost as it employs some extra hardware circuitiry and complexity in control. So this is mainly focused on the implementation of SVPWM technique for dual inverter fed open end winding induction motor. A schematic of dual inverter fed open end winding induction motor can be represented as shown in the Fig.2.

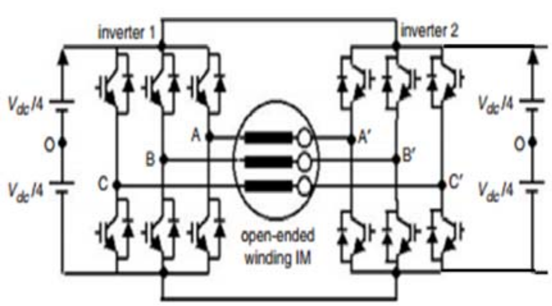


Fig.2 Dual inverter fed open end winding Induction motor drive

As dual inverter fed open end winding induction motor drive resembles the performance of three level inverter thus we can achieve multilevel inverter operation using this configuration. Hence the harmonic content of the output voltage waveform decreases significantly, dv/dt stresses are reduced, Produces smaller zero sequence voltages therefore stress in the bearings of motor can be reduced, Provides low switching losses and higher efficiency[5-8].

II.SPWM(SINUSOIDAL PULSE WIDTH MODULATION TECHNIQUE)

The sinusoidal pulse width modulation technique produces a sinusoidal waveform by filtering an output pulse waveform with varying width. A high switching frequency assures a better filtered sinusoidal output waveform. The desired output voltage is achieved by varying the frequency and amplitude of a reference or modulating voltage i.e. by varying the modulation index. The variations in the amplitude and frequency of the reference voltage can change the pulse width pattern of the output voltage.

The gate pulses to the inverter switches generated by comparing a low frequency sinusoidal modulating waveform with a high frequency triangular waveform [11]. The switching state is changed when the sine waveform intersects the triangular waveform. The crossing positions determine the variable switching times between states.

In three phase inverter for switching of devices of the inverter, a triangular wave is compared with three sinusoidal voltages which are 120^0 out of phase with each other.

The relative levels of the waveforms are used to control the switching of the devices in each leg of the inverter. The sinusoidal pulse width modulation technique can be well explained with the comparison of triangular wave & modulating (sinusoidal) wave as shown in the Fig.3

The modulation ratio(ρ) is the ration between frequency of carrier wave to that of the modulating wave i.e. reference wave & is represented by the eqn(1).

$$\rho = \frac{\mathrm{fc}}{\mathrm{fm}} \tag{1}$$

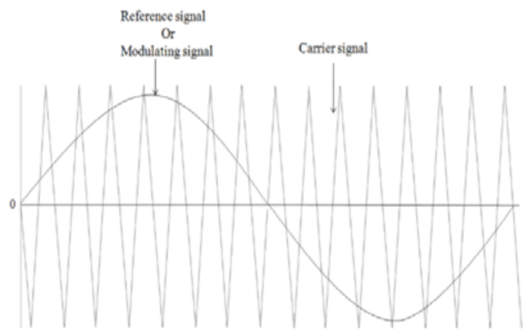


Fig.3 Carrier and reference wave comparison for SPWM control technique

The modulation index(M) is the ratio between the amplitude of modulating wave to that of the carrier wave & is represented by eqn(2).

$$M = \frac{Am}{Ac} \qquad (2)$$

The modulation ratio (ρ) is related to harmonic frequency as

$$f = k\, \rho\, f_m \qquad (3)$$

Generally the magnitude of modulation index is limited below one(i.e. 0<m<1)

Drawbacks due to SPWM:

1. Precise & flexible control of voltage is not possible.
2. Generates more Harmonic distortion in output.
3. DC bus utilization is not that much effective.

To overcome these drawbacks due to conventional SPWM control technique an advanced control technique is proposed known as Space Vector Pulse Width Modulation Technique.

III.SVPWM CONTROL TECHNIQUE

SVPWM control technique is an advanced modulation technique abbreviated as Space Vector Pulse Width Modulation Technique has several advantages over other pulse width modulation techniques like superior performance in terms of better harmonic spectra, ease of implementation and advanced & enhanced dc bus utilization[12].The concept of SVPWM technique can be well explained with the help of a rotating voltage vector as shown in the Fig.4.

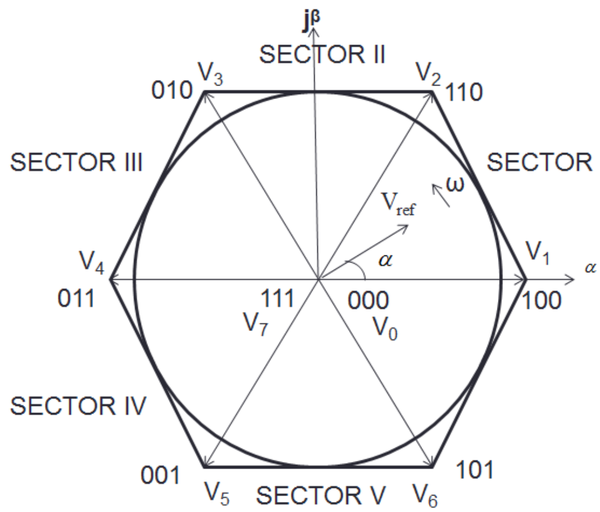


Fig.4 SPACE VECTOR

1).Principle of Space vector:

A typical two level inverter has 6 power switches (S_1 to S_6) that generates three phase voltages. The six switching power device can be constructed using power BJTs, GTOs, IGBTs the choice of switching devices is based on the desired operating power level, required switching frequency & acceptable invertible power losses. When the upper transistor is switched on, the corresponding lower transistor is switched off. The on & off states of lower power devices are complementary to the upper power devices.

The basic principle of SVPWM is based on the eight switching combinations of three phase inverter. The eight(8) switching combinations of a three phase inverter can be represented in the Table.1.

S.NO.	Switching State	ON state devices
1	000	4,6,2
2	100	1,6,2
3	110	1,3,2
4	010	4,3,2
5	011	4,3,5
6	001	4,6,5
7	101	1,6,5
8	111	1,3,5

Table.1:Switching states and ON State Power devices

The switching combinations are represented in binary form. In this '1' indicates the on state of upper switching device in the corresponding phase leg & '0' indicates the on state of lower device in the corresponding phase leg.

The instantaneous sum of all the phase voltages is calculated & they deduce six(6) active vectors and two(2) zero vectors lies on the diagonals of hexagon. And the two zero vectors lies at the centre of the hexagon.

The reference vector which represents the 3φ sinusoidal voltages can be synthesised using SVPWM by switching between two nearest active vectors & zero vectors. The switching of reference vector with active and zero vectors can be represented as shown in the fig(5).

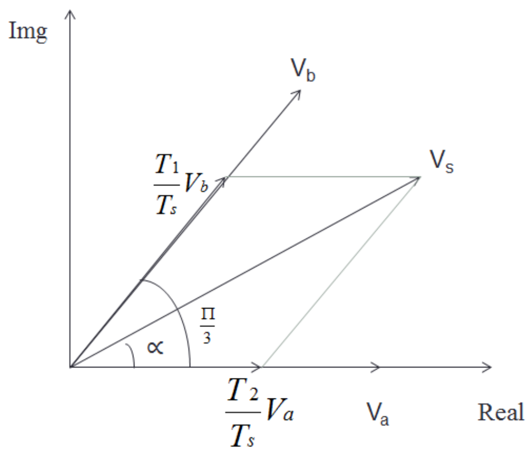


Fig.5 Synthesizing of reference vector from active and zero vectors

The time of application of these vectors can be calculated by volt second balancing as

$$\int_0^{T_z} V_{ref} = \int_0^{T_1} V_1\,dt + \int_0^{T_1+T_2} V_2\,dt + \int_{T_1+T_2}^{T_z} V_2\,dt \quad (4)$$

By solving the above equation we get

$$T_z V_{ref} = T_1V_1 + T_2V_2 \quad (5)$$

$$\left.\begin{aligned} T_1 &= 3\frac{V_{ref}}{V_{dc}}\left[\frac{\sin(60-\alpha)}{\sin(60)}\right]*T_s \\ T_2 &= 3\frac{V_{ref}}{2V_{dc}}\left[\frac{\sin(\alpha)}{\sin(60)}\right]*T_s \\ T_0 &= T_z-(T_1+T_2) \end{aligned}\right\} \quad (6)$$

Where V_{ref}= reference voltage vector magnitude

α = is the angle or position of the reference vector

T_1, T_2, T_0= are the time of application of vector V1,

vector V_2, zero vector V_0 respectively.

2)CSVPWM(Continuous Space Vector Pulse Width Modulation Technique):

In all PWM algorithms SVPWM gives good performance in terms of harmonics & effective control but the complexity is more due to angle calculations & sector identification. To reduce this complexity carrier based SVPWM algorithm is developed by adding offset voltage to the reference phase voltage. The switching pattern for the three phases using carrier based SVPWM can be represented as shown in theFig.6.

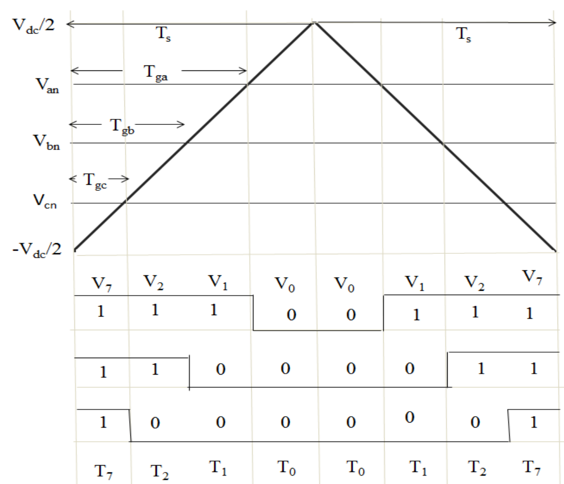


Fig.6 Switching pattern of power devices using carrier based SVPWM control technique

In order to achieve fixed switching frequency & optimum harmonic performance from SVPWM each branch should change its state only once in one switching period. This is achieved by applying zero vector followed by two adjacent active vectors in half switching period is the mirror image of the first half. The total switching period is thus divided into 7 parts. The zero vector is applied for 1/4th of the total zero vector time first. Followed by the application of active vectors for the half of their application times & then again zero vector is applied for 1/4th of the zero time. This is then repeated for the next half switching period.. This is how the symmetrical CSVPWM is achieved.

3) Discontinuous PWM technique(DPWM):

The main feature of space vector PWM is the freedom of explicit pulse placement in half of the carrier cycle. By using this degree of freedom alternative space vector PWM strategy can be formulated in which the active vectors in two successive half switching period are moved to join together, and zero space vector consequently vanishes resulting in Discontinuous Space vector PWM (Houdsworth and Grant, 1984). Due to this manipulation one branch of the inverter remain unmodulated during one switching interval. Switching takes place in two branches and one branch is either tied to the positive dc bus or negative dc bus. The number of switching is thus reduced to 2/3 compared to the continuous SVPWM, hence, the switching losses are reduced significantly. Six different schemes are available depending on the variation in the placement of the zero space vectors.

1. $T_0 = 0$ (DPWMMAX)
2. $T_7 = 0$ (DPWMMIN)
3. 0^0 Discontinuous modulation (DPWM 0)
4. 30^0 Discontinuous modulation (DPWM 1)
5. 60^0 Discontinuous modulation (DPWM 2)
6. 90^0 Discontinuous modulation (DPWM 3)

4) Zero sequence voltage elimination scheme with Open end winding configuration:

A remedy for the production of flowing of bearing currents inside the motors is open end winding induction motor. In this configuration Induction motor is feeded by two inverters from either side which are operated be isolated power supplies. A schematic diagram of dual inverter fed induction motor is represented as shown in Fig.7.

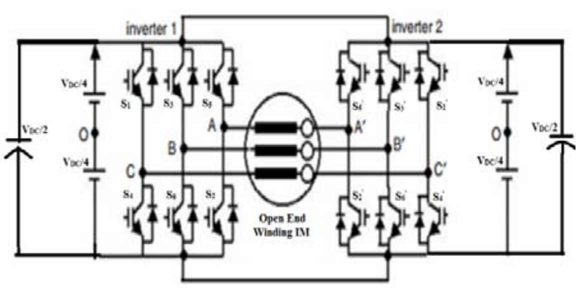


Fig.7 Dual inverter fed open end winding IM drive

Here S_1, S_2 , S_3 , S_4 , S_5, S_6 are the switches of inverter 1 and S_1', S_2' ,S_3' , S_4' , S_5', S_6' are the switches of inverter 2.The two inverters are supplied with isolated DC links, If the isolated DC link voltages are equal(i.e.$V_{S1}=V_{DC}/2$ & $V_{S2}=V_{DC}/2$) then the configuration resembles to that of three level inverter drive. If the Isolated DC link voltages are unequal (i.e. $V_{S1}=2V_{DC}/3$ & $V_{S2}=V_{DC}/3$) then the configuration resembles to that of four level inverter. In this 1& 0 represents on states of switches of inverter 1, 1' & 0' represents on states of switches of inverter2 .

Here V_{A0},V_{B0}, V_{C0} are the pole voltages of inverter 1, $V_{A0'}$, $V_{B0'}$, $V_{C0'}$ are the pole voltages of inverter 2.$V_{AA'}$, $V_{BB'}$, $V_{CC'}$ are the Phase voltages of the inverter which are supplied to the three phase induction motor but here the sum of all these phase voltages is not equal to zero, which results as zero sequence component in motor due

$$CMV\ or\ V_{ZS} = \frac{V'_{AA}+V'_{BB}+V'_{CC}}{3}$$

this the bearing currents will flow inside the motor . But here carrier based SVPWM algorithm is proposed to mitigate this Common mode voltage. The three phase voltages of dual inverter fed induction motor drive is given by

$$\left.\begin{aligned} V_{AA'} &= V_{A0}-V_{A0'} \\ V_{BB'} &= V_{B0}-V_{B0'} \\ V_{CC'} &= V_{C0}-V_{C0'} \end{aligned}\right\} \quad (7)$$

Where V_{A0},V_{B0},V_{C0} are the pole voltages of inverter 1,

$V_{A0'}$,$V_{B0'}$,$V_{C0'}$ are the pole voltages of inverter 2

&$V_{AA'}$,$V_{BB'}$,$V_{CC'}$ are the Phase voltages of the inverter

The common mode voltage or Zero sequence voltage is given by

$$CMV\ or\ V_{ZS} = \frac{V'_{AA}+V'_{BB}+V'_{CC}}{3} \quad (8)$$

The reference voltage in SVPWM modulation technique will be obtained as represented in equation (4)

$$V_{ref}=V_{AA'}+ V_{BB'}\, e^{j2\pi/3}+ V_{CC'}\, e^{j4\pi/3} \quad (9)$$

Hence by employing this open end winding configuration multilevel inverter operation can be achieved and the problems due to conventional inverters like common mode voltages can be overcome.

IV.SIMULATION RESULTS

A) For single inverter Fed IM drive with SPWM control:

A two level inverter fed induction motor drive is modelled and is simulated by employing sinusoidal pulse width modulation(SPWM) control technique and the carrier and triangular comparison waveform, output pole, phase voltages of the inverter are shown in Fig.8

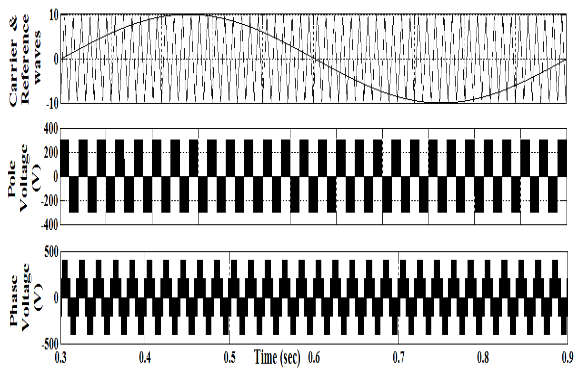


Fig.8 Carrier and reference wave comparison, Pole Voltage, Phase voltage of single inverter with SPWM

The performance characteristics of Induction motor drive i.e. Stator currents, Torque response, Speed response with no load and with the application of load of 20Nm at 0.5sec up to 0.7sec are as shown in Fig.9 and Fig.10 respectively .The motor achieves steady state at 0.3 sec. with the application of load at 0.5 sec the stator currents, Torque of the motor increases in proportion to load but the speed decreases in proportion to the load and after removal of load at 0.7 sec the motor comes to steady state position .

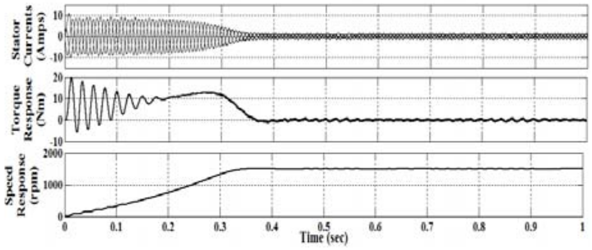


Fig.9 Performance characteristics of IM drive with single inverter(SPWM) at no load

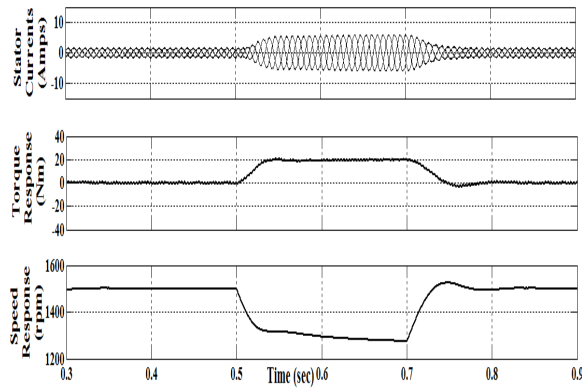


Fig.10 Performance characteristics of IM drive with single inverter(SPWM) under load condition with T_L=20Nm

B)For single inverter Fed IM drive with SVPWM control:

A two level inverter fed induction motor drive is modelled and is simulated by employing space vector pulse width modulation(SVPWM) control technique and the Modulated waveform, output pole, phase voltages and the common mode voltage of the inverter are shown in Fig.11

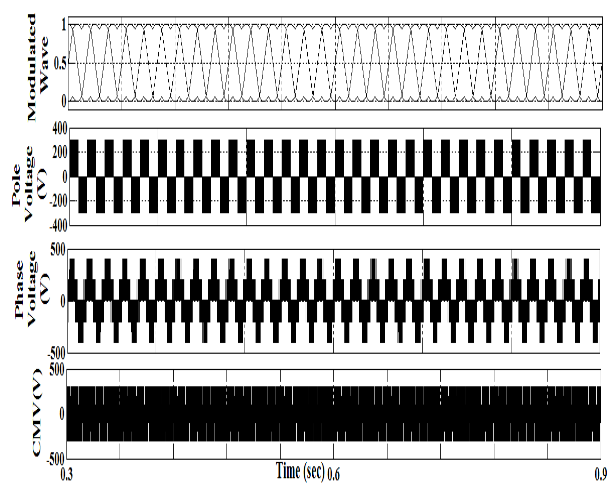
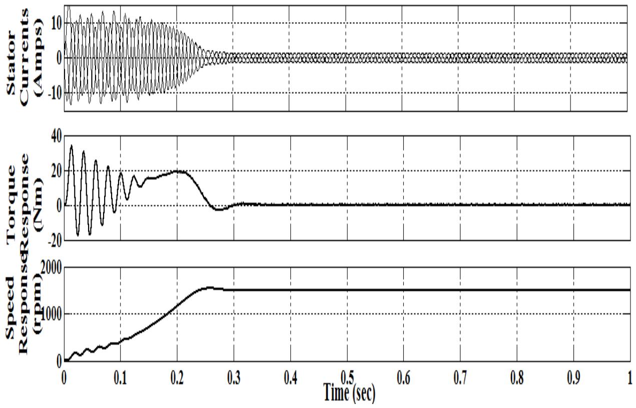


Fig.11 Modulated wave, Pole voltage, Phase Voltage, CMV for Single inverter with SVPWM

The performance characteristics of Induction motor drive i.e. Stator currents, Torque response, Speed response at no load and with the application of load of 20Nm at 0.5sec upto 0.7sec are as shown



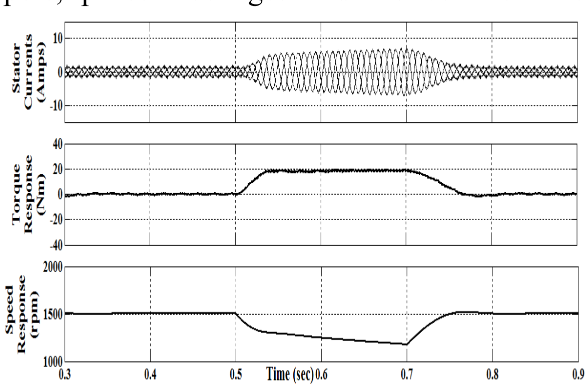
in Fig.12 and Fig.13 respectively. The motor achieves steady state at 0.3 sec. with the application of load at 0.5 sec the stator currents, Torque of the motor increases in proportion to load but the speed decreases in proportion to the load and after removal of load at 0.7 sec the motor comes to steady state position and the Total Harmonic Distortion(THD) for the stator currents is 7.26% for this model.

Fig.12 Performance characteristics of IM drive with single inverter(SVPWM) at no load

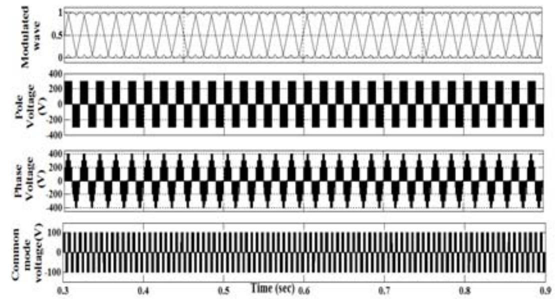
Fig.13 Performance characteristics of IM drive with single inverter(SVPWM) under load condition with T_L=20Nm

B)For dual inverter Fed IM drive(three level inverter operation) with CSVPWM, DPWMMAX,DPWMMIN control

A dual inverter fed induction motor drive is modelled and is simulated by employing space vector pulse width modulation(CSVPWM) control technique and the Modulated waveform, output pole, phase voltages and the common mode



voltage of the inverter which resembles the



characteristics of three level inverter characteristics are shown in Fig.14

Fig.14Modulating Wave, Pole voltage, Phase Voltage, Common mode voltage for dual inverter (Three level inverter operation)with CSVPWM control technique

The performance characteristics of Induction motor drive i.e. Stator currents, Torque response, Speed response at no load and with the application of load of 20Nm at 0.5sec upto 0.7sec are as shown in Fig.15 & Fig.16 respectively. The motor achieves steady state at 0.25 sec. with the application of load at 0.5 sec the stator currents, Torque of the motor increases in proportion to load but the speed decreases in proportion to the load and after removal of load at 0.7 sec the motor comes to steady state position and the Total Harmonic Distortion(THD) for the stator currents is 4.77% for this model & the common mode voltage is mitigated compared to single inverter fed IM drive.

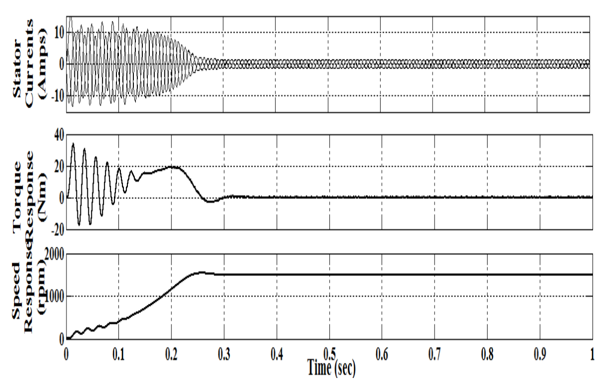


Fig.15 Performance characteristics of dual inverter (Three level inverter operation(CSVPWM))fed IM drive at no load

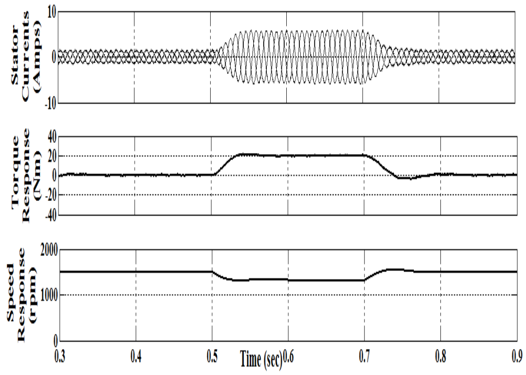


Fig.16 Performance characteristics of dual inverter (Three level inverter operation(CSVPWM))fed IM drive under load condition with T_L=20Nm

A dual inverter fed induction motor drive is modelled and is simulated by employing space vector pulse width modulation(DPWMMAX)control technique and the Modulated waveform, output pole, phase voltages and the common mode voltage of the inverter which resembles the characteristics of three level inverter characteristics are shown in Fig.17

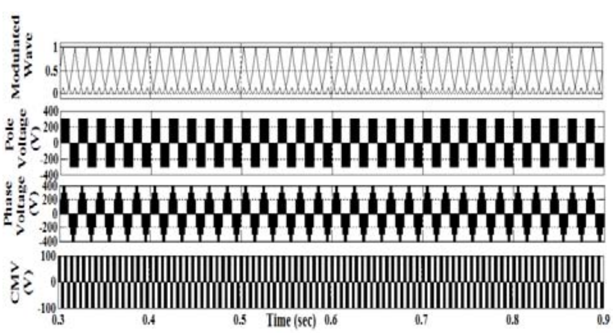


Fig.17 Modulating Wave, Pole voltage, Phase Voltage, common mode voltage for dual inverter (Three level inverter operation)with DPWMMAX control technique

The performance characteristics of of dual inverter fed Induction motor drive(three level inverter operation)with DPWMMAX control i.e. Stator currents, Torque response, Speed response at no load and with the application of load of 20Nm at 0.5sec upto 0.7sec are as shown in Fig.18 & Fig.19 respectively. The motor achieves steady state at 0.25 sec. with the application of load at 0.5 sec the stator currents, Torque of the motor increases in proportion to load but the speed decreases in proportion to the load and after removal of load at 0.7 sec the motor comes to steady state position and the Total Harmonic Distorsion(THD) for the stator currents is 3.97% for this model & the common mode voltage is mitigated compared to single inverter fed IM drive.

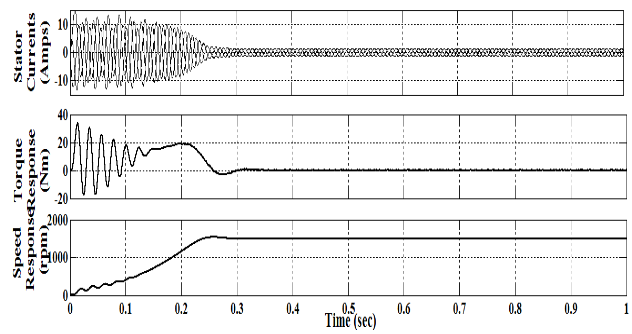


Fig.18 Performance characteristics of dual inverter (Three level inverter operation with DPWMMAX)fed IM drive at no load

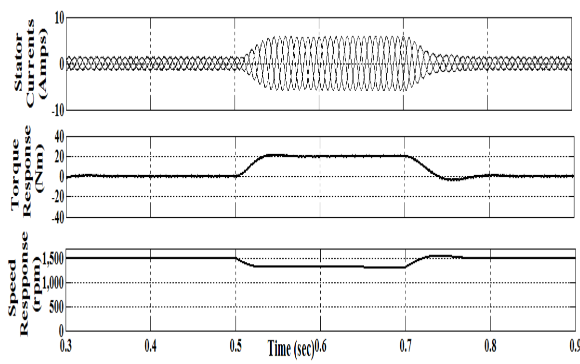


Fig.19 Performance characteristics of dual inverter (Three level inverter operation with DPWMMAX)fed IM drive under load condition with T_L=20Nm

A dual inverter fed induction motor drive is modelled and is simulated by employing space vector pulse width modulation(DPWMMIN)control technique and the Modulated waveform, output pole, phase voltages and the common mode voltage of the inverter which resembles the characteristics of three level inverter characteristics are shown in Fig.20

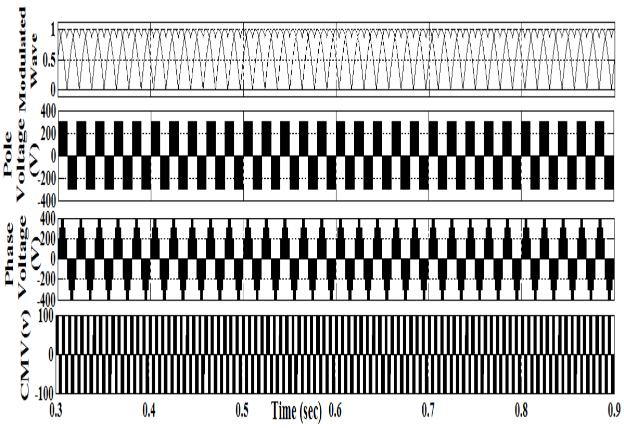


Fig.20 Modulating Wave, Pole voltage, Phase Voltage, common mode voltage for dual inverter (Three level inverter operation)with DPWMMIN control technique

The performance characteristics of of dual inverter fed Induction motor drive(three level inverter operation)with DPWMMIN control i.e. Stator currents, Torque response, Speed response at no load and with the application of load of 20Nm at 0.5sec upto 0.7sec are as shown in Fig.21 & Fig.22 respectively. The motor achieves steady state at 0.25 sec. with the application of load at 0.5 sec the stator currents, Torque of the motor increases in proportion to load but the speed decreases in proportion to the load and after removal of load at 0.7 sec .the motor comes to steady state position and the Total Harmonic Distortion (THD) for the stator currents is 3.85% for this model & the common mode voltage is mitigated compared to single inverter fed IM drive.

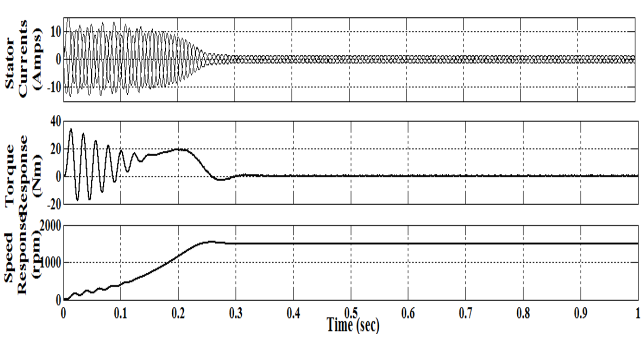


Fig.21 Performance characteristics of dual inverter (Three level inverter operation with DPWMMIN control)
fed IM drive at no load

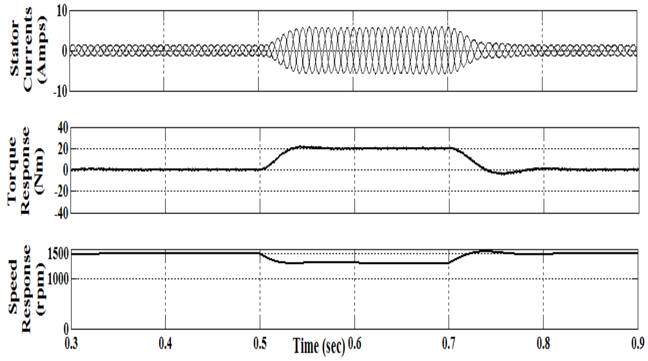


Fig.22 Performance characteristics of dual inverter (Three level inverter operation with DPWMMIN control)
fed IM drive under load condition with T_L=20Nm

C)For dual inverter Fed IM drive(Four level inverter operation)with CSVPWM, DPWMMAX,DPWMMIN control

A dual inverter fed induction motor drive is modelled and is simulated by employing space vector pulse width modulation(CSVPWM) control technique and the Modulated waveform, output pole, phase voltages and the common mode voltage of the inverter which resembles the characteristics of four level inverter characteristics are as shown in Fig.23

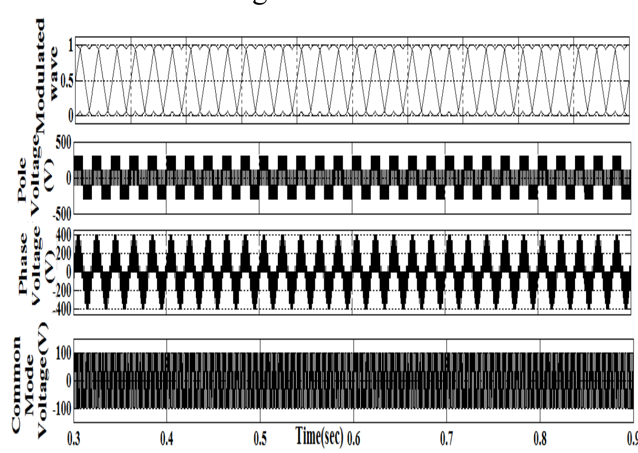


Fig.23 Modulated wave, Pole voltage, Phase voltage, Common mode voltage for dual inverter(Four level inverter operation with CSVPWM control)

The performance characteristics of of dual inverter fed Induction motor drive(four level inverter operation)with CSVPWM control i.e. Stator currents, Torque response, Speed response at no load and with the application of load of 20Nm at 0.5sec upto 0.7sec are as shown in Fig.24 &

Fig.25 respectively. The motor achieves steady state at 0.25 sec. with the application of load at 0.5 sec the stator currents, Torque of the motor increases in proportion to load but the speed decreases in proportion to the load and after removal of load at 0.7 sec the motor comes to steady state position and the Total Harmonic Distortion (THD) for the stator currents is 4.77% for this model & the common mode voltage is mitigated compared to dual inverter fed IM drive with three level inverter operation.

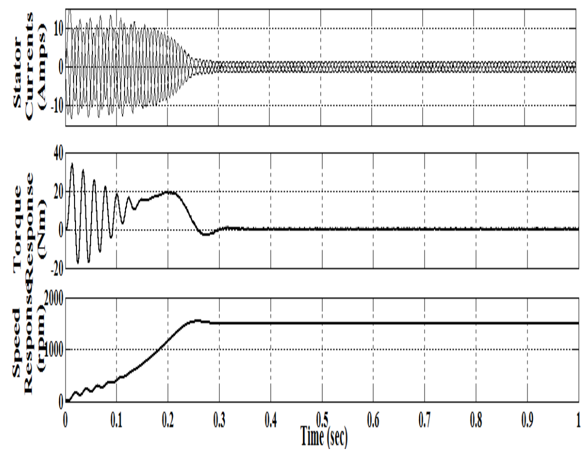


Fig.24 Performance characteristics of dual inverter
(Four level inverter operation(CSVPWM)) fed IM drive at no load

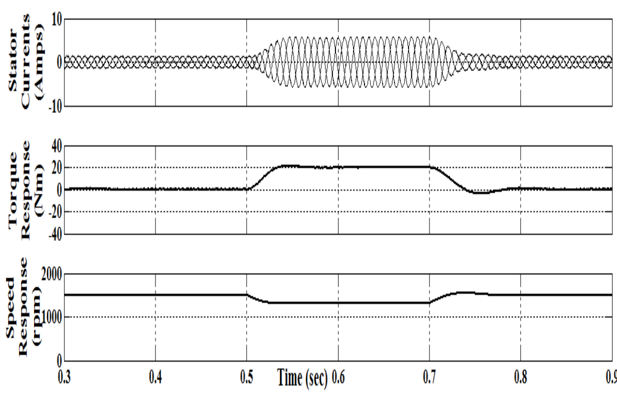
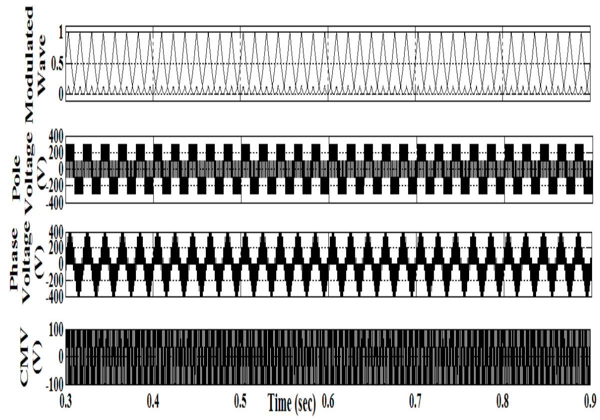


Fig.25 Performance characteristics of dual inverter
(Four level inverter operation(CSVPWM)) fed IM drive under load at TL=20Nm

A dual inverter fed induction motor drive is modelled and is simulated by employing space vector pulse width modulation(DPWMAX) control technique and the Modulated waveform, output pole, phase voltages and the common mode voltage of the inverter which resembles the characteristics of four level inverter characteristics are as shown in Fig.26

Fig.26 Modulated wave, Pole voltage, Phase



voltage, Common mode voltage for dual inverter(Four level inverter operation with DPWMMAX control)

The performance characteristics of of dual inverter fed Induction motor drive(four level inverter operation)with DPWMMAX control i.e. Stator currents, Torque response, Speed response at no load and with the application of load of 20Nm at 0.5sec upto 0.7sec are as shown in Fig.27 & Fig.28 respectively. The motor achieves steady state at 0.25 sec. with the application of load at 0.5 sec the stator currents, Torque of the motor increases in proportion to load but the speed decreases in proportion to the load and after removal of load at 0.7 sec the motor comes to steady state position and the Total Harmonic Distorsion(THD) for the stator currents is 3.85% for this model & the common mode voltage is mitigated compared to dual inverter fed IM drive with three level inverter operation.

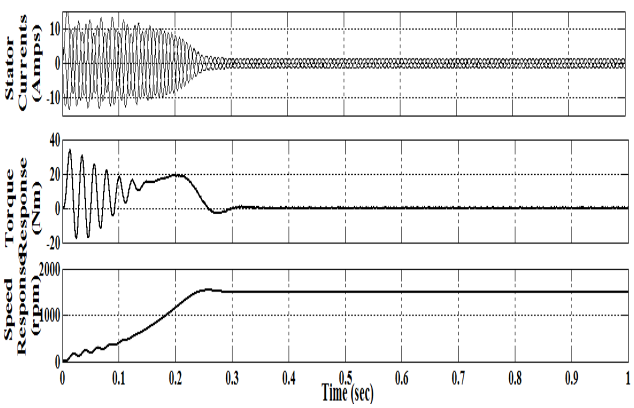


Fig.27 Performance characteristics of dual inverter
(Four level inverter operation(DPWMMAX control))
fed IM drive at no load

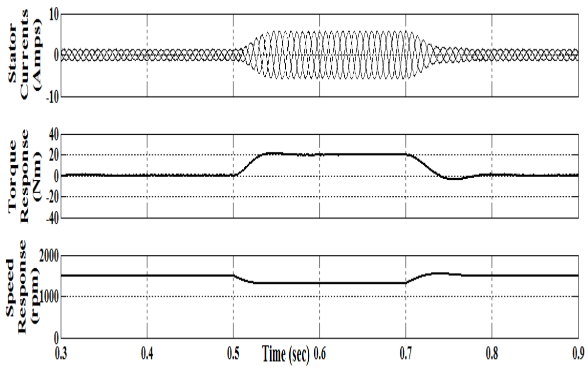


Fig.28 Performance characteristics of dual inverter
(Four level inverter operation(DPWMMAX control))
fed IM drive under load condition with T_L=20Nm

A dual inverter fed induction motor drive is modelled and is simulated by employing space vector pulse width modulation(DPWMMIN) control technique and the Modulated waveform, output pole, phase voltages and the common mode voltage of the inverter which resembles the characteristics of four level inverter characteristics are as shown in Fig.29

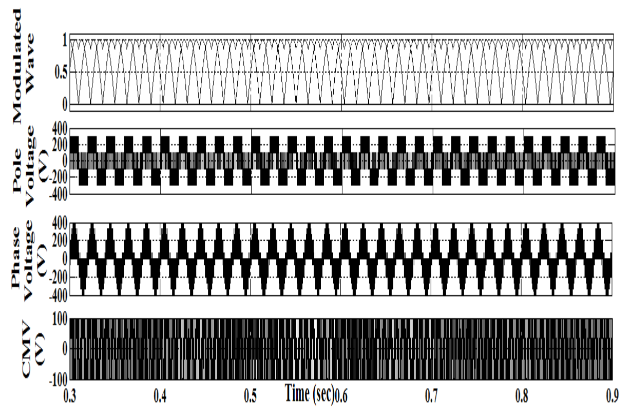


Fig.29 Modulated wave, Pole voltage, Phase voltage, Common mode voltage for dual inverter(Four level inverter operation with DPWMMIN control)

The performance characteristics of of dual inverter fed Induction motor drive(four level inverter operation)with DPWMMIN control i.e. Stator currents, Torque response, Speed response at no load and with the application of load of 20Nm at 0.5sec upto 0.7sec are as shown in Fig.30 & Fig.31 respectively. The motor achieves steady state at 0.25 sec. with the application of load at 0.5 sec the stator currents, Torque of the motor increases in proportion to load but the speed decreases in proportion to the load and after removal of load at 0.7 sec the motor comes to steady state position and the Total Harmonic Distortion(THD) for the stator currents is 3.43% for this model & the common mode voltage is mitigated compared to dual inverter fed IM drive with three level inverter operation.

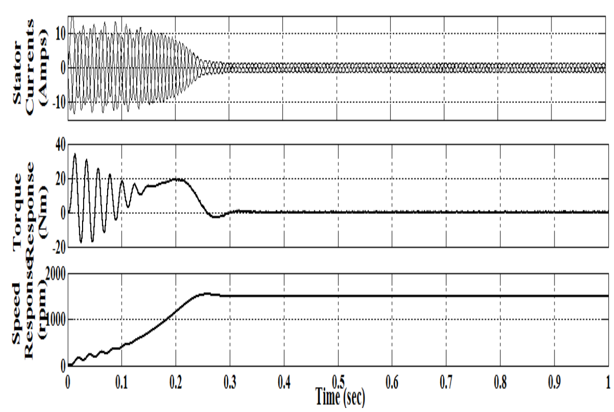


Fig.30 Performance characteristics of dual inverter
(Four level inverter operation (DPWMIN control))
fed IM drive at no load

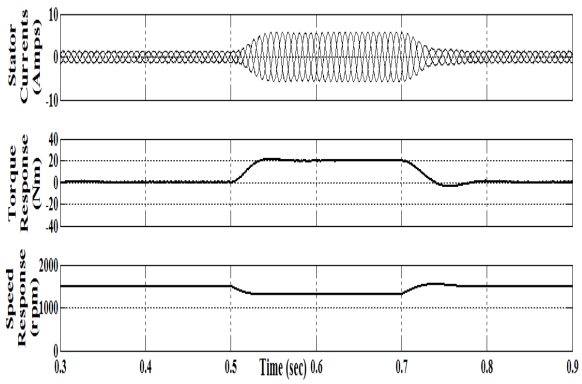


Fig.31 Performance characteristics of dual inverter
(Four level inverter operation(DPWMMIN control))
fed IM drive under load condition with T_L=20Nm

D)THD Comparison:

The THDs for stator currents of IM drive is listed out as shown in the Table.2.

Inverter Type	Control technique	THD of stator currents of the Motor(I_{THD})
2 level	SPWM	18.28%
	SVPWM	7.26%
3 level	CSVPWM	4.77%
	DPWMMAX	3.97%
	DPWMMIN	3.85%
4 level	CSVPWM	4.51%
	DPWMMAX	3.85%
	DPWMMIN	3.43%

Table.2 Comparison of stator currents THDs for various control techniques

IV.CONCLUSION

In this paper the implementation of dual inverter fed induction motor drive has been done. With the implementation of triangular based SVPWM the machine performance will be improved in the context of harmonic spectra and effective DC bus utilization over the conventional sinusoidal pulse width modulation technique. And the zero sequence voltage problem is also mitigated at a greater level compared to other mitigating techniques. This work can be extended with the implementation of SVPWM for higher level(5,6,7 levels) for dual inverter fed open end winding induction motor.

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