Hybrid Asymmetric Space Vector Modulation for inverter based direct torque control induction motor drive

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Abstract— This paper proposes novel hybrid asymmetric space vector modulation technique for inverter operated direct torque control induction motor drive. The hybridization process is performed by the combination of continuous asymmetric space vector modulation pulse width technique (ASVPWM) and fuzzy operated discontinuous ASVPWM technique. Combination process is based on pulse mismatching technique. Pulse mismatching technique helps to reduce the active region of the switch. Finally, optimal pulses are applied to control the inverter. The optimal hybrid pulse condense switching losses of the inverter and also improves the operating performance of the direct torque control (DTC) based drive system like smooth dynamic response in speed reversal, minimum torque error, settling time of speed. Simulation results of proposed hybrid asymmetric space vector pulse width modulation technique to direct torque control (HASVPWM-DTC) approach has been carried out by using Matlab-Simulink environment. .

Keyword- HASVPWM, DTC, Fuzzy Logic.

I. INTRODUCTION

Variable speed drives are extensively used in Electrical application such as pumps, fans, elevators etc. In Earlier stages, DC separate excited motors has been used in many variable speed drives, especially where there was a need of fast response & four quadrant operation with high performance close to zero speed. But these DC motors has some disadvantages such as higher cost, higher rotor inertia, existence of commutator & brushes, limited commutator capability under high speed & high voltage operational conditions, require periodic maintenance and difficult to use in explosive & corrosive environment. These problems can be eliminated by using AC machine which have simple & rugged structure, good self-starting capability, high maintain ability, economical and reliability. Small dimension compared with DC machine allows AC machine to be designed with substantially higher output rating for low weight and low rotating mass [1]-[4],[16]. Among various AC drive systems, cage induction motor has great attention in industrial applications because it is one of the cheapest machines available in all power ratings. In DC motor flux and torque can be controlled independently, so the control algorithm can be implemented easily with the help of proportional integral (PI) regulators. But in an induction motor, independent control of flux and torque is only possible in the case of coordinate system is connected with rotor flux vector [1]. In vector control of AC machines, both the torque & flux producing current components can be decoupled and also maintain the transient response characteristics; which are similar to separately excited DC machines and system will accept to any load disturbances. In addition to that vector control technique allows an Induction motor to be driven with high dynamic performance than DC motors [1]. Scalar control methods are only suitable for adjustable speed applications in which load speed (or) position is not controlled like servo system. Vector controlled drives are one particular type of torque controlled drive. The other type of high performance torque controlled drive is called Direct Torque Controlled(DTC) drive which is achieved by direct & independent control of flux linkages & Electromagnetic torque through the selection of optimal inverter switching modes which give fast torque response, low inverter switching frequency and low harmonic losses [1]. DTC system operates to control the stator flux and the torque directly by selecting the appropriate inverter switching state. DTC is also very simple to implementation because it needs only two comparators and switching vector table for both flux and torque control. A new space vector modulation based on direct torque control (SVM-DTC) based control of induction motor drive was discussed in paper [6]. According to this method, an inverter switch position is selected combining with the situation of torque error, current error and the position of stator flux angle. The rotor flux is estimated from induction motor currents and speed information [6]. Many papers discussed about maintaining constant switching frequency in DTC and to reduce torque, flux, current, and speed pulsations during the steady state condition. The most preferred PWM technique today is space vector modulation which offers 15% better bus utilization and 33% fewer commutations per cycle than conventional PWM. In [7], space vector modulation based on direct torque control (SVM-DTC) protect DTC transient merits and furthermore, create better quality steady-state performance in a wide speed range. The modified method of DTC using SVM improves the electrical magnitudes of asynchronous machine, such as minimizing stator current distortion, stator flux with electromagnetic torque without ripple, fast response of rotor speed, and constant switching frequency. PI controller to minimizing the torque error and to achieve constant switching frequency. In this scheme, the switching capability of inverter is fully utilized as a result improves the system performance [7].The classical control DTC algorithm is based on the instantaneous values and it can be directly calculated the digital control signals for the inverter. The control algorithm in DTC SVM methods are based on averaged values whereas the switching signals for the inverter are calculated by space vector modulator. This is the main difference between classical DTC and SVM-DTC control methods [8], [15].

In DTC hysteresis based induction motor, the applied stator voltage depends on voltage vectors, which are selected from lookup table. The selections based on requirement of torque and flux demands obtained from the hysteresis comparators. On the other hand, in SVM-DTC, a stator voltage reference is calculated or generated within a sampling period, which is then synthesized using space vector modulator. The stator voltage reference vector is calculated based on the requirement of torque and flux demands. Due to the regular sampling in SVM, SVM-DTC produces constant switching frequency, as opposed to the variable switching frequency in hysteresis based DTC, however at the expense of more complex implementation [8]. Problems of conventional DTC technique discussed in [9] such as the pulse duration of output voltage vector is determined by the torque-ripple minimum condition. These improvements can significantly decrease the torque ripple, but they raise the difficulty of DTC algorithm and suggested an alternative method to reduce torque ripples in DTC using space vector modulation (SVM) technique. The space vector based control algorithm which gives a constant inverter switching frequency & minimize flux with torque ripple. Space Vector Pulse Width Modulation (SVPWM) method is an advanced; computation intensive PWM method and possibly the best techniques for variable frequency drive applications etc. Space vector Modulation (SVM) has recently grown as a very popular PWM for voltage fed converter AC drives because of its superior harmonic quality and extended linear range of operation.

Minimum switching loss PWM technique has proposed, which reduces the inverter switching loss. For best reduction in switching loss, the choice of switching sequences are essential that should be based on the spatial angle (α) of the reference vector and also discussed about how to select optimal spatial angle (α) of the reference vector[10]. Asymmetrical modulating function and randomly varied pulse rate within consecutive sub cycles of the inverter output voltage, results in an improved power spectrum of this voltage and significantly reduced switching losses[11]. Switching losses are optimized using a suitable discontinuous modulation technique. Basic rule for adjusting the discontinuous PWM appropriately with special focus on the semiconductor switching losses. An adjustment rule to achieve minimal semiconductor switching losses[12]. By adding additional switching pulses for each phase in one fundamental cycle near the voltage zero crossings, the Total harmonic distortion (THD) of output current can be reduced to as low as 50%. Additional pulses are added near the fundamental voltage zero crossings, the resulted extra power loss is very limited [13]. The switching loss characteristics of sequences that involving division of active state duration in space vector modulation has analyzed and introduced new hybrid PWM techniques for induction motor drives, which result in simultaneous reduction in both THD as well as inverter switching losses. New sequences involving division of active state time fully exploit the advantages of space vector based PWM compared to triangle comparison methods, and can result in simultaneous reduction in THD and switching losses [14]. From the above discussion, reduction of switching losses and harmonic distortion mainly depends upon optimal switching angle that can be achieved by selection of optimal spatial angle in reference vector, proper division of active switching state. These performance can be done by introduce additional subsectors in conventional space vector plane. Discontinuous modulation is an another important technique for reducing switching loss but creates poor harmonic profile. Adding additional sectors in symmetrical space vector converts asymmetrical space vector plane. If there is more number of sectors in the hexagon, it allows more degrees of freedom which help to find the optimal reference voltage and angle.

The proposed hybridization process is performed by the combination of continuous ASVPWM and fuzzy operated Discontinuous ASVPWM technique. Fuzzy rules help to select the optimal switching angle in discontinuous modulation. Finally, the mismatching pulses of both PWM techniques are applied as input to the inverter. The paper is all about hybridized asymmetric space vector modulation based direct torque control (HASVPWM – DTC) induction motor drive. Hybridized ASVPWM-DTC is to improve the efficiency of switching condition which leads to condense losses in inverter and also a better operating performance on drive.

II. MATHEMATICAL MODEL OF INDUCTION MOTOR

The dynamic model of induction motor can be represented in the synchronous reference frame. We need to represent both d^s-q^s and d^r –q^r circuits and their variables in a synchronously rotating d^e – q^e frame. We can write the following stator circuit equations [2],[4].

$$V_{qs}^{S} = R_s i_{qs}^{S} + \frac{d}{dt}\psi_{qs}^{S} \tag{1}$$

$$V_{ds}^{S} = R_s i_{ds}^{S} + \frac{d}{dt}\psi_{ds}^{S} \tag{2}$$

$$V_{qs} = R_s i_{qs} + \frac{d}{dt}\psi_{qs} + \omega_e \psi_{ds} \tag{3}$$

$$V_{ds} = R_s i_{ds} + \frac{d}{dt}\psi_{ds} - \omega_e \psi_{qs} \tag{4}$$

$$V_{qr} = R_r i_{qr} + \frac{d}{dt}\psi_{qr} + (\omega_e - \omega_r)\psi_{dr} \tag{5}$$

$$V_{dr} = R_r i_{dr} + \frac{d}{dt}\psi_{dr} - (\omega_e - \omega_r)\psi_{dr} \tag{6}$$

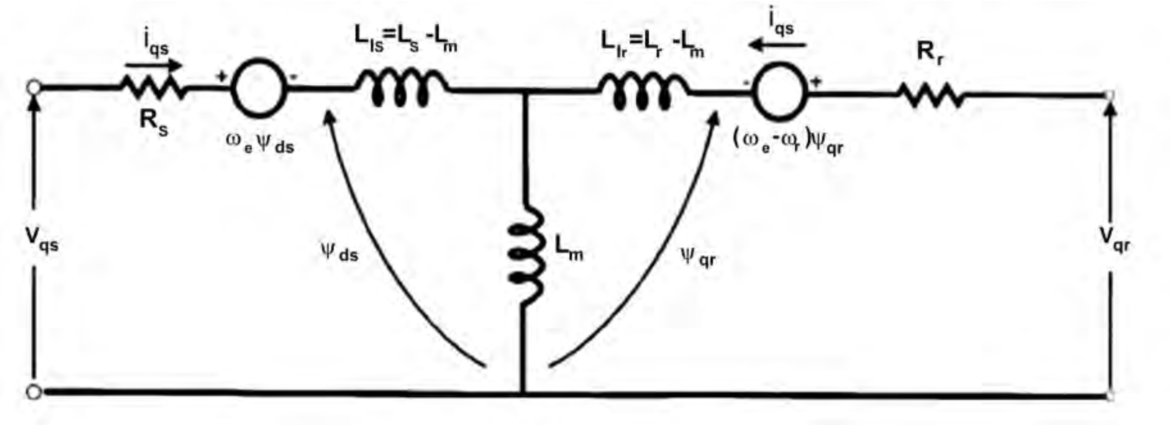

Fig. 1. Dynamic d^e - q^e equivalent circuit of Machine q^e -axis circuit

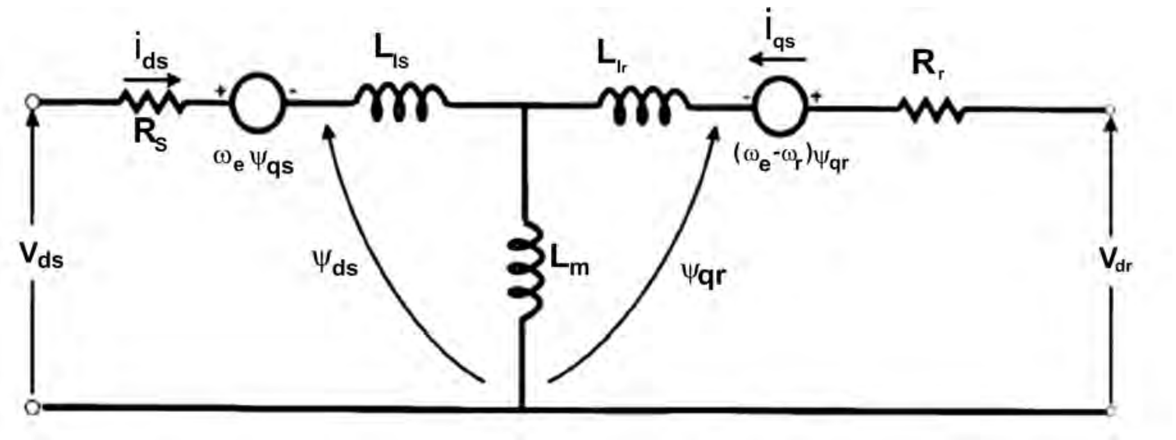

Fig. 2. Dynamic d^e - q^e equivalent circuit of Machine d^e -axis circuit.

Flux linkage expression in terms of the current can be written from Fig. 1 and Fig. 2

$$\psi_{qm} = L_m(i_{qs} + i_{qr}) \tag{7}$$

$$\psi_{dm} = L_m(i_{ds} + i_{dr}) \tag{8}$$

Speed ω_r can be related to the torques as

$$T_e = T_L + J\frac{d\omega_m}{dt} \Rightarrow T_L + \frac{2}{P}J\frac{d\omega_r}{dt} \quad (9)$$

Where, T_L = Load Torque, J = rotor inertia, ω_m = mechanical speed.

The development of torque is by the interaction of airgap flux and rotor MMF. Torque expressed in general vector form, relating the d-q components of variables.

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\bar{\psi}_m \bar{I}_r \quad (10)$$

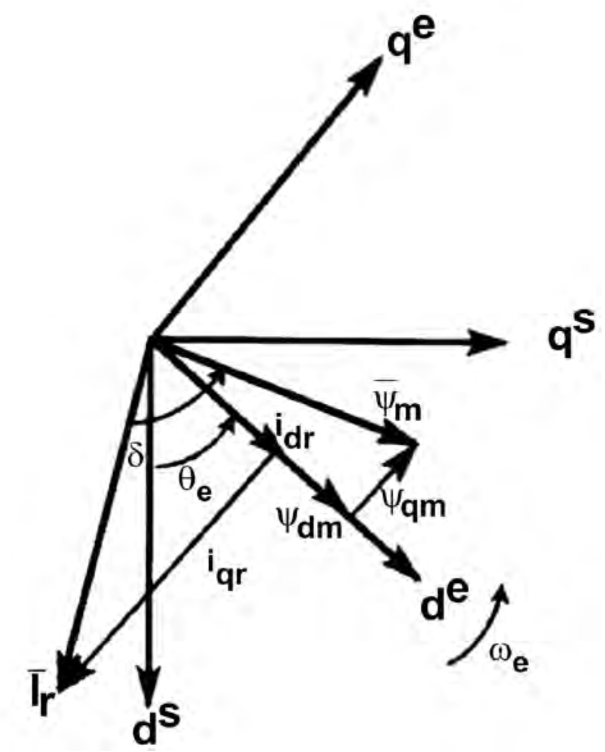

Fig. 3. Flux and Current vectors in d^e - q^e frame.

Resolving the variables into d^e - q^e components, as shown in Fig. 3

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\psi_{dm} i_{qr} - \psi_{qm} i_{dr}\right) \quad (11)$$

Several other torque expressions can be derived easily as follows

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\psi_{dm} i_{qs} - \psi_{qm} i_{ds}\right) \quad (12)$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\psi_{ds} i_{qs} - \psi_{qs} i_{ds}\right) \quad (13)$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)L_m\left(i_{qs} i_{dr} - i_{ds} i_{qr}\right) \quad (14)$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\psi_{dr} i_{qr} - \psi_{qr} i_{dr}\right) \quad (15)$$

III. HYBRID ASYMMETRIC SPACE VECTOR MODULATION

Space vector PWM (SVPWM) method is an advanced, computation intensive PWM method and possibly the best techniques for variable frequency drive application etc. Space vector Modulation (SVM) has recently grown as a very popular Pulse Width Modulation (PWM) for voltage fed inverter AC drives because of its superior harmonic quality and extended linear range of operation. Three-phase inverter voltage control by space vector modulation consists of switching between the two active and zero voltage vector in such a way that the time average switching between the two active and one zero voltage vector in such a way that the time average within each switching cycle corresponds to the voltage command [3],[10]. Generally, VSI has eight distinct switching states, where state 1 to 6 are active states, 0 and 7 are inactive switching states. Normally the switching states depend upon the voltage vectors. The PWM is incapable of generating pure sinusoidal voltages to the load, because of the switching states. So, additional switching states help to improve quality of the output. In Asymmetric Space Vector Modulation models with three additional sectors added in between the original sectors shown in Fig. 4. The additional three voltage vectors are added between 15° angle differences. Hence, the total numbers of vectors are 24 in the hexagon.

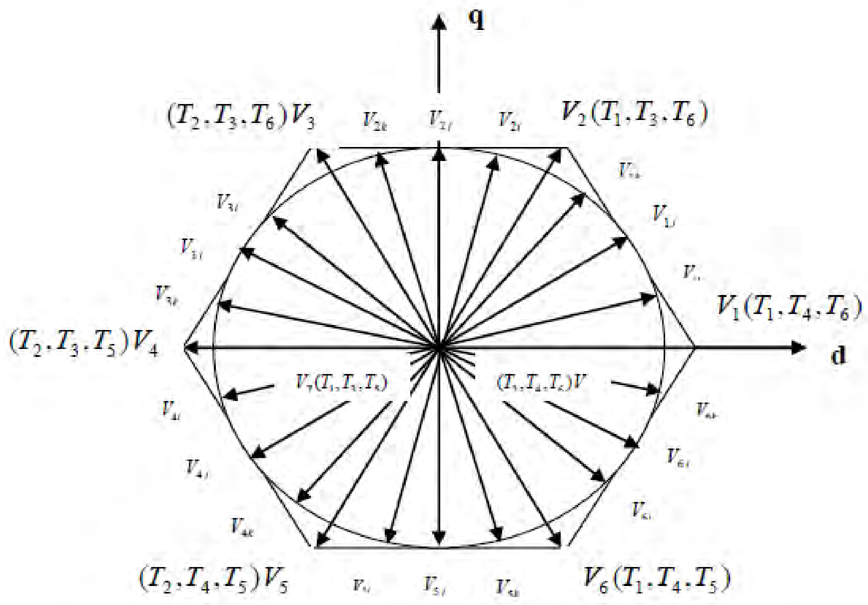

Fig .4. Asymmetric Space Vector Hexagon.

Space vector PWM can be implemented by the following steps:

(i) Determine d-q axis voltages (V_d ,V_q) and reference Voltage (V_{ref}) and angle (α).

(ii) Analyse the asymmetric voltage vectors

(iii) Determine the Time duration T_1,T_2 and T_0.

(iv) Determine the switching time of each switch of inverter (S_1 to S_6).

The proposed hybridization process is performed by the combination of continuous ASVPWM and fuzzy operated Discontinuous ASVPWM technique. Finally, the mismatching pulses of both PWM techniques are applied to control the inverter. Pulse mismatching technique helps to reduce the active region of the switch and achieve the optimal input pulse to the inverter. The optimal hybrid pulse reduces transition time of inverter switch and improves operating performance of the inverter. Fuzzy rules help to select the optimal switching sector for discontinuous modulation. If there is more number of sectors in the hexagon, it allows more degrees of freedom which help to find the optimal reference voltage and angle. If the inverter is operated under linear modulation index, then duration of sub cycle is higher than the sum of two active states. Then, in the lingering time, the switch is operated in two inactive regions.

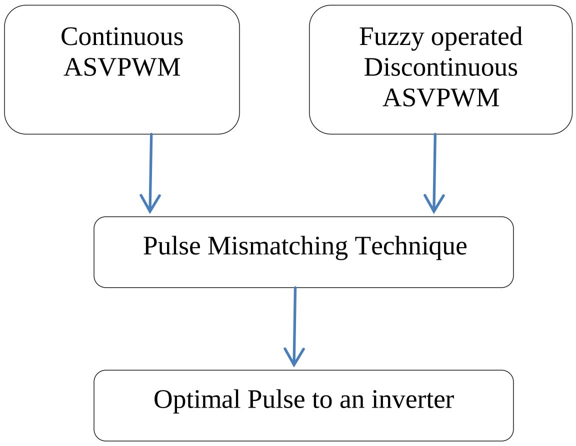

Fig .5. Pulse Generation Technique

The switching time of active state and inactive state is obtained by the following equation,

$$T_1 = \frac{\sqrt{3}.T_s}{V_{dc}}\left[\sin\left(\frac{\pi}{3}a\right).V_d^* - \cos\left(\frac{\pi}{3}a\right).V_q^*\right] \quad (16)$$

$$T_2 = \frac{\sqrt{3}.T_s}{V_{dc}}\left\{-\sin\left[\frac{\pi}{3}(a-1)\right].V_d^* + \cos\left[\frac{\pi}{3}(a-1)\right].V_q^*\right\} \quad (17)$$

The inactive (zero) switching time (T_z) output of above mentioned switching time T_1 and T_2 are given as follow which is represented as T_z,

$$T_z = T_s - T_1 - T_2 \quad (18)$$

$$V_d^* = \left|\vec{V}\right|\cos\theta \text{ and } V_q^* = \left|\vec{V}\right|\sin\theta \quad (19)$$

$$\theta = \alpha + \frac{\pi}{3}(a-1) \quad (20)$$

where, V_{dc} is the dc input voltage of the inverter,

V_d^* and V_q^* are the vector representations of voltage,

T_1 and T_2 are the active time of the switch,

T_z is the inactive time of the switch,

a is the different sector number (1,2....N)

θ is the angle in d-q coordinate system.

IV. FUZZY LOGIC TECHNIQUE FOR ASYMMETRIC SPACE VECTOR MODULATION

Recently, Fuzzy logic systems have generated a good deal of interest in certain applications. A Fuzzy logic system describes the control action of a process in terms of simple If –Then rules. Fuzzy logic control is the process of formulating the mapping from a given input to an output using fuzzy logic. A fuzzy logic system describes the algorithm for process control as a fuzzy relation between information on the process conditions to be controlled and control action. Hence, it gives a linguistic or fuzzy model that is developed based on human experience and expertise rather than mathematical model. Control action determined by simple set of linguistic rules. The development of the rules requires a thorough understanding of the process to be controlled, but it does not require a mathematical model of the system.[5]. The advantages over the conventional systems that it does not require accurate mathematical models, can be handle non linearity condition, more flexibility and easy to use or modify functions.[5][7]. Main components of the fuzzy logic systems are:

A. Fuzzification:

Fuzzy logic uses linguistic variables instead of Numerical variables. In the real world, measured quantities are crisp or real values. The process of converting a numerical variable (real number) into a linguistic variable (Fuzzy number) is called fuzzification. In the proposed scheme, we have used MAMDANI type fuzzification. It is the most commonly used implication method. In this method, the output MF is truncated to the degree of membership obtained from the IF-THEN rule. Output of each rule obtained by using AND (min) operator or using OR (max) operator. Hence it is called Min-Max implication [5][7].

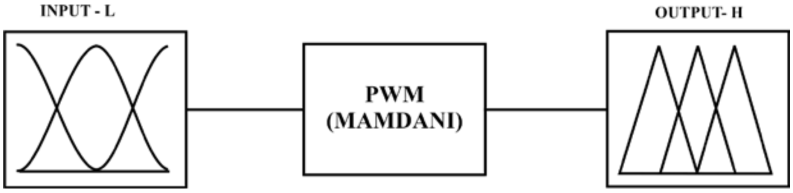

Fig.6 Input – Output Fuzzy logic controller

B. Rule base or Decision Making:

This is inferring fuzzy control action from knowledge of the control rules and the linguistic variable definition. In the proposed system, we used the following rule list to select the sector.

List of rules:

1. If (L is NB) then (T is NB) (1)
2. If (L is NB) then (T is NB) (1)
3. If (L is NB) then (T is NB) (1)
4. If (L is NB) then (T is NS) (1)
5. If (L is NB) then (T is ZO) (1)
6. If (L is NS) then (T is NB) (1)
7. If (L is NS) then (T is NB) (1)
8. If (L is NS) then (T is NS) (1)
9. If (L is NS) then (T is ZO) (1)
10. If (L is NS) then (T is PS) (1)
11. If (L is ZO) then (T is NB) (1)
12. If (L is ZO) then (T is NS) (1)
13. If (L is ZO) then (T is ZO) (1)
14. If (L is ZO) then (T is PS) (1)
15. If (L is ZO) then (T is PB) (1)
16. If (L is PS) then (T is NS) (1)
17. If (L is PS) then (T is ZO) (1)
18. If (L is PS) then (T is PS) (1)
19. If (L is PS) then (T is PB) (1)
20. If (L is PS) then (T is PB) (1)
21. If (L is PB) then (T is ZO) (1)
22. If (L is PB) then (T is PS) (1)
23. If (L is PB) then (T is PB) (1)
24. If (L is PB) then (T is PB) (1)
25. If (L is PB) then (T is PB) (1)

C. Defuzzification:

This is the conversion of the inferred fuzzy control action to a crisp or non-fuzzy control action. Centroid defuzzification used in proposed technique. In this method of defuzzification, the crispy output Z_{out} is taken as geometric center of the fuzzy area $\mu_{out}(Z)$ obtained after aggregation [5]. The general expression after defuzzified out in continuous system is

$$Z_{out} = \frac{\sum_{i=1}^{n} Z_i . \mu_{out}(Z_i)}{\sum_{i=1}^{n} \mu_{out}(Z_i)} \qquad (21)$$

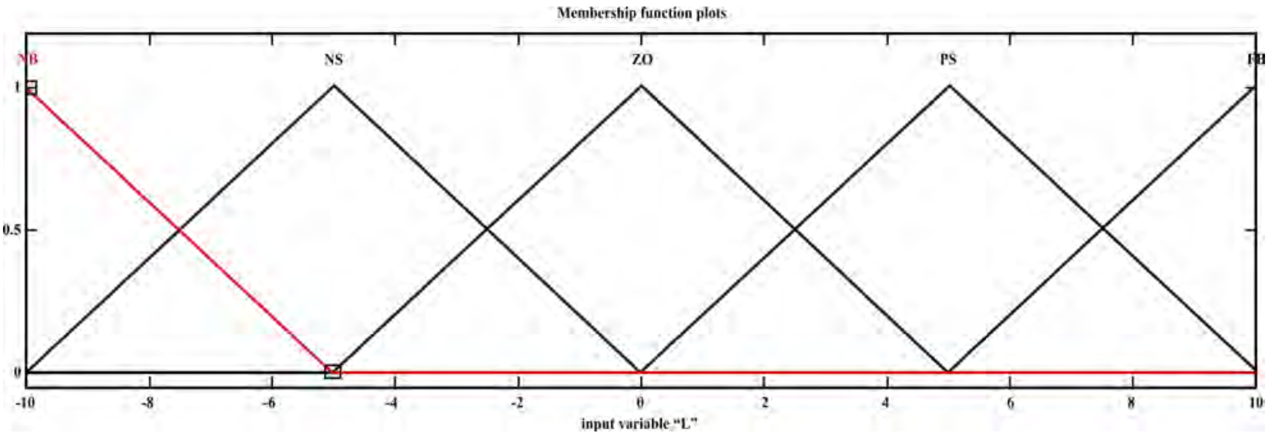

Fig.7. Input membership function

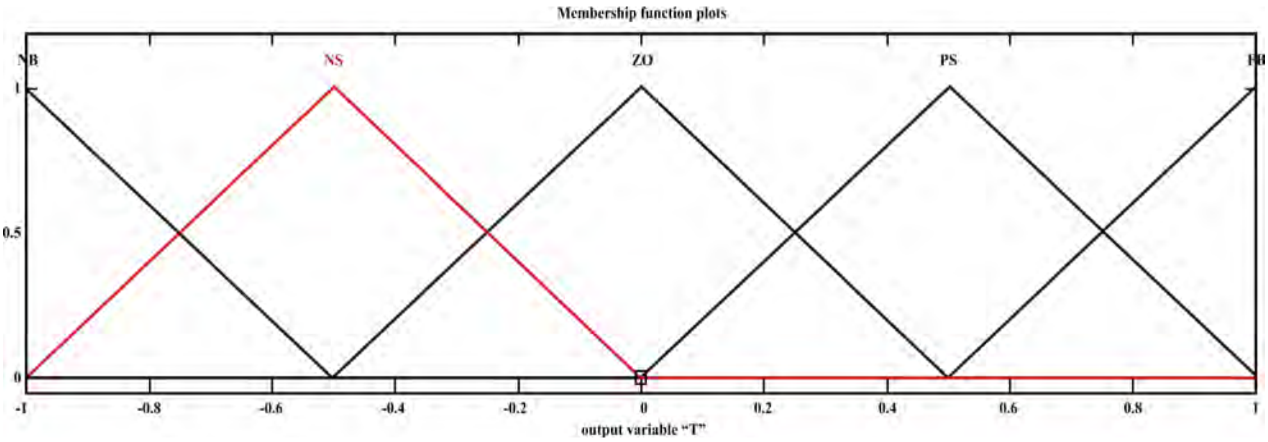

Fig 8. Output membership function

Fuzzy rules help to select the optimal switching sector for discontinuous modulation. If more number of sector in the hexagon, it allows more degrees of freedom which helps to find the optimal reference voltage and angle.

V. DIRECT TORQUE CONTROL

DTC technique introduced by Takahashi and Noguchi for low and medium power application and DTC technique introduced by Depenbrock for high power application are popular in industry. DTC strategy is quite different from that of the field orientation control (FOC), which does not need complicated coordination transformations and decoupling calculation. Direct Torque Control (DTC) is the first technology to control the real motor variables of torque and flux. In this method, the stator flux and the torque are controlled directly by selecting the appropriate inverter state [1],[4]. Direct torque control (DTC) is one method used in variable frequency drives to control the torque (and thus finally the speed) of three-phase AC electric motors. This involves calculating an estimate of the motor's magnetic flux and torque based on the measured voltage and current of the motor. Stator flux linkage is estimated by integrating the stator voltages. Torque is estimated as a cross product of estimated stator flux linkage vector and measured motor current vector. The estimated flux magnitude and torque are then compared with their reference values. If either the estimated flux or torque deviates from the reference more than allowed tolerance, the transistors of the variable frequency drive are turned off and on in such a way that the flux and torque will return in their tolerance level as fast as possible. PI comparators used for torque and flux comparator and switching's calculated by space vector modulation to improve the performance of system and achieved constant switching frequency. The magnitude of stator flux and electric torque calculated are compared with their reference values in the PI comparators and then the outputs of the comparators are fed to a switching table to select an appropriate inverter voltage vector. The switching table determines the voltage vector to apply based on the position of the stator flux and the required changes in stator flux magnitude and torque. The selected voltage vector will be applied to the induction motor at the end of the sample time. In VSI, there are six equally spaced voltage vectors having the same amplitude and two zero voltage vectors. SVM-DTC strategy depends on the applied flux and torque control algorithm. Basically, the controllers calculate the required stator voltage vector and then it is realized by space vector modulation technique. The classical DTC algorithm is based on the instantaneous values and directly calculated the digital control signals for the inverter. The control algorithm in DTC-SVM methods are based on averaged values whereas the switching signals for the inverter are calculated by space vector modulator[1],[2],[4],[15].

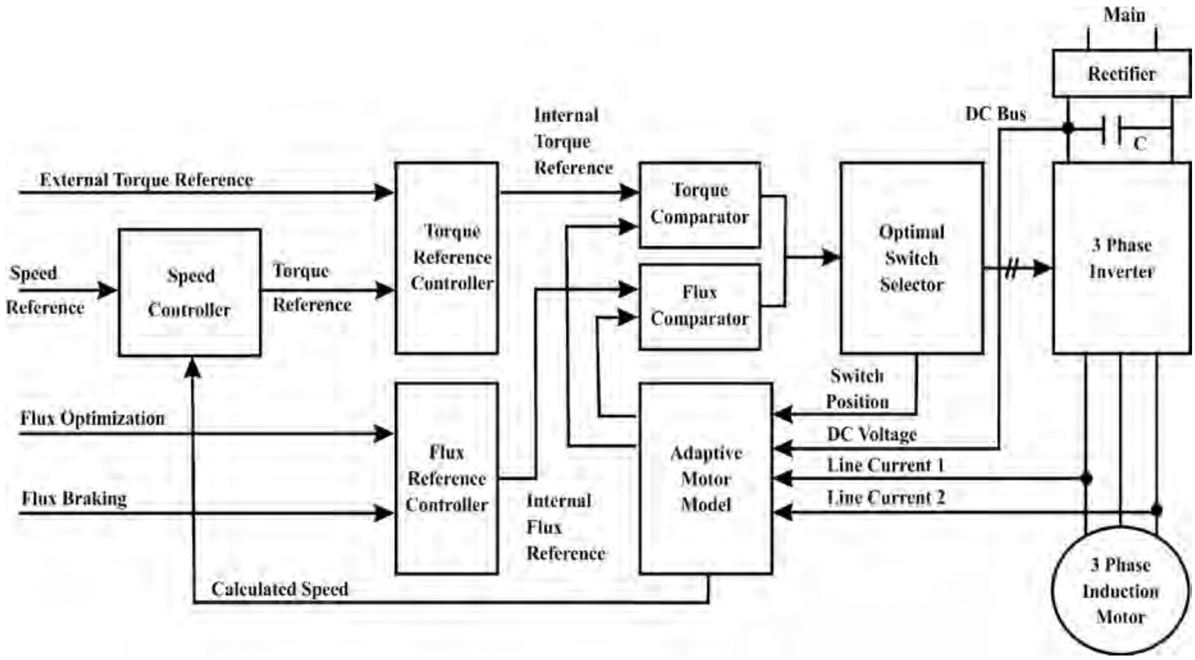

Fig.9 DTC based induction motor

A. Stator flux based calculation

By using terminal voltages, the air gap torque, flux and field angle can be computed with stator flux linkages. In stator flux based calculator, computational steps and dependence on many motor parameters could be very much reduced by using the stator flux linkages and stator currents. Then only stator resistance is employed in the computation of the stator flux linkages, thereby removing the dependence of mutual and rotor inductances of the machine on its calculation. This algorithm depends only on the stator resistance rather than on many other motor parameters. Sensitivity of the stator resistance will affect the accuracy of stator flux linkages. Dynamic operation at low speed is not efficient in stator flux linkage algorithm [4].

$$\lambda_{ds} = \int (V_{ds} - R_s i_{ds}) \cdot dt \tag{22}$$

$$\lambda_{qs} = \int (V_{qs} - R_s i_{qs}) \cdot dt \tag{23}$$

$$\lambda_s = \sqrt{(\lambda_{ds})^2} + \sqrt{(\lambda_{ds})^2} \angle \theta_{fs} \tag{24}$$

$$\theta_{fs} = \tan^{-1}(\lambda_{ds} / \lambda_{qs}) \tag{25}$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)(i_{qs}\lambda_{ds} - i_{ds}\lambda_{qs}) \tag{26}$$

B. Flux control

A uniform rotating stator flux is desirable, and it occupies one of the sextants at any time. The stator flux phasor has a magnitude of $\boldsymbol{\lambda_s}$, with an instantaneous position of $\theta_{fs.}$ The corresponding d and q axes components are λ_{ds} and λ_{qs}, respectively. Assuming that a feedback of stator flux is available. Its place in the sextant is identified from its position. Then the influencing voltage phasor is identified by giving a 90° phase shift.

$$V_d = \varphi_{ref} - \varphi_{estimated} \tag{27}$$

C. Torque control

Torque control is exercised by comparison of the command torque to the torque measured from the stator flux linkages and stator currents as T_e. The error torque is processed through a window comparator to produce digital outputs S_T.

If Condition is $(T_e^* - T_e) < \delta T_e$,then digital outputs $S_T = 1$ (Increasing voltage)

If Condition is $-\delta T_e > (T_e^* - T_e) < \delta T_e$ then digital outputs $S_T = 0$ (Keep same level)

If Condition is $\left(T_e^* - T_e\right) < -\delta T_e$ then digital outputs S_T = -1 (Regeneration)

Where, δT_e is the torque window acceptable over the commanded torque. When the error exceeds $\delta T_{e,}$ it is time to increase the torque, denoting it with a +1 signal. If the torque error between +ve and –ve torque windows , then the voltage phasor could be at zero state. If the torque error is below –ve torque windows, its amount to calling for regeneration.(signed by -1 logic). Combining the flux error output S_λ, the torque error output S_T and the sextant of the flux phasor S_θ, a switching table can be realized to obtain the switching states of inverter [4].

$$V_q = T_{ref} - T_{estimated} \tag{28}$$

$$T_{ref} = \omega_{ref} - \omega_{estimated} \tag{29}$$

VI. SIMULATION RESULT AND DISCUSSION

To verify the proposed scheme, a simulation has been carried out by using MATLAB/SIMULINK. The fuzzy rules based hybrid asymmetric space vector modulation was designed and simulated. The proposed method is developed by using fuzzy Toolbox. The parameters of induction motor that are used in this simulation are given No of Pair poles=2, R_s=0.5Ω; R_r=0.25Ω;L_s=0.0415H; L_r=0.0412H; L_m=0.0403H; L_{sc}=0.0018H; Output Power= 4KW; V=400v; frequency =50 Hz,3 phase induction motor.

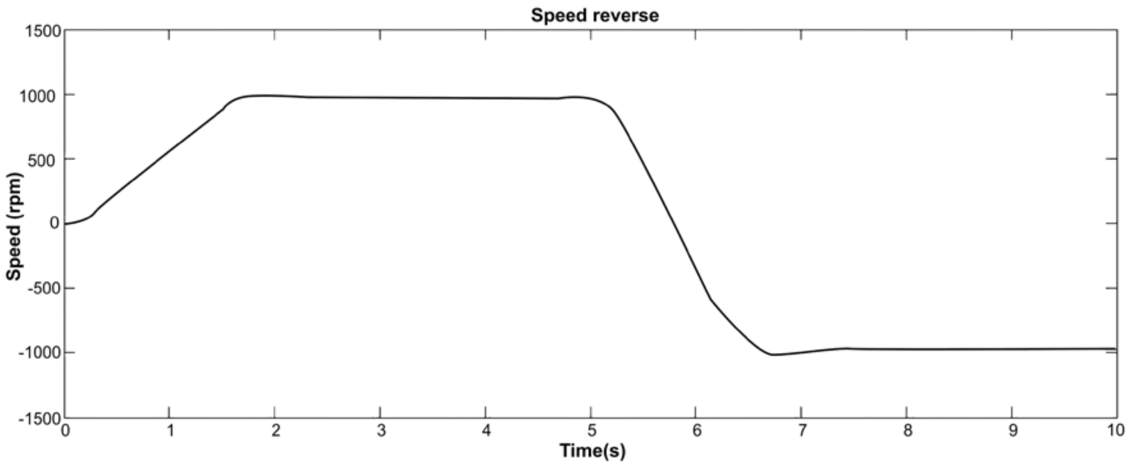

Fig. 10. Speed reversal

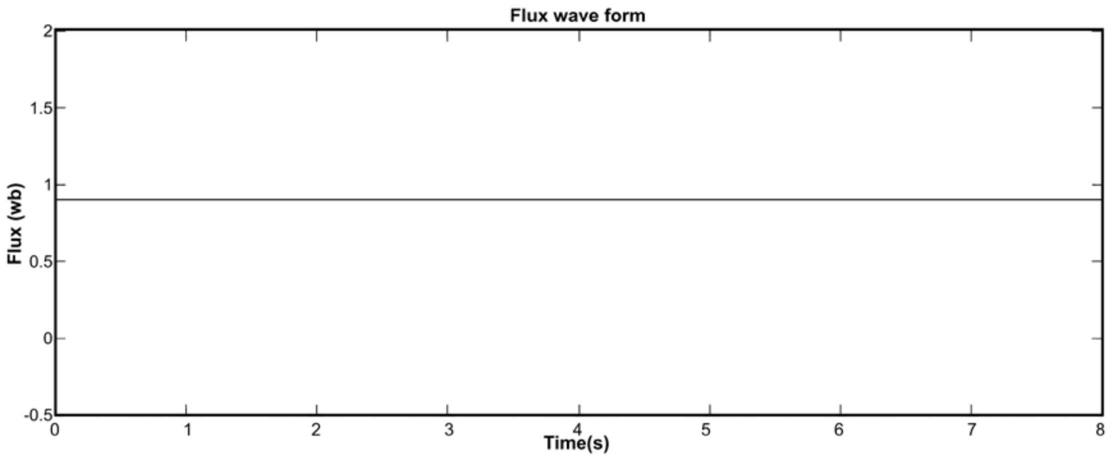

Fig.11. Flux condition

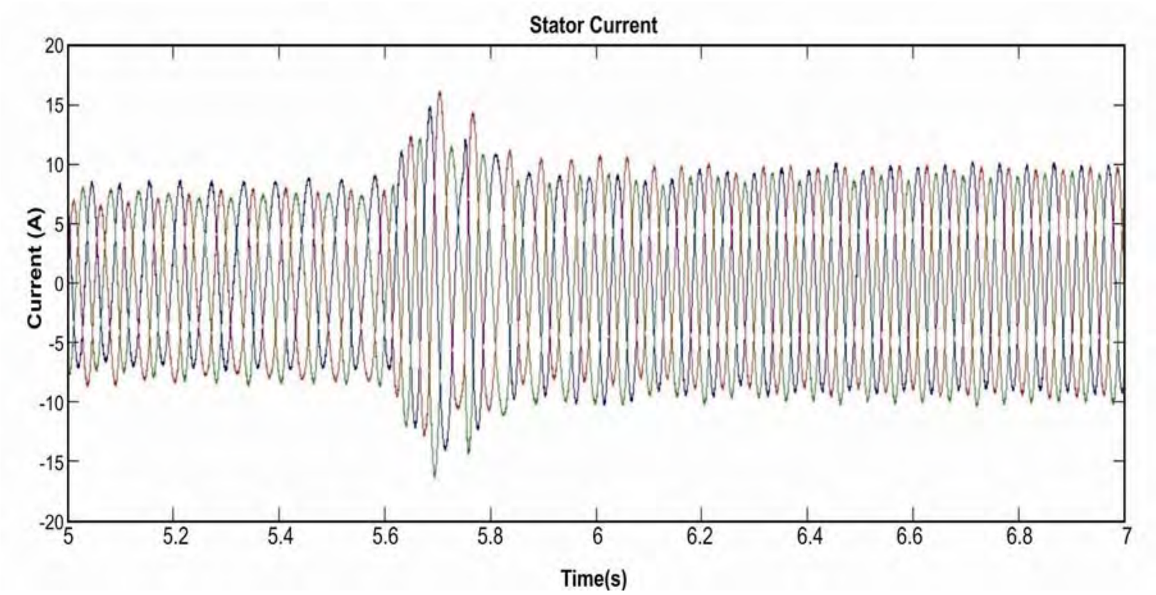

Fig.12. Stator current variation during speed reversal

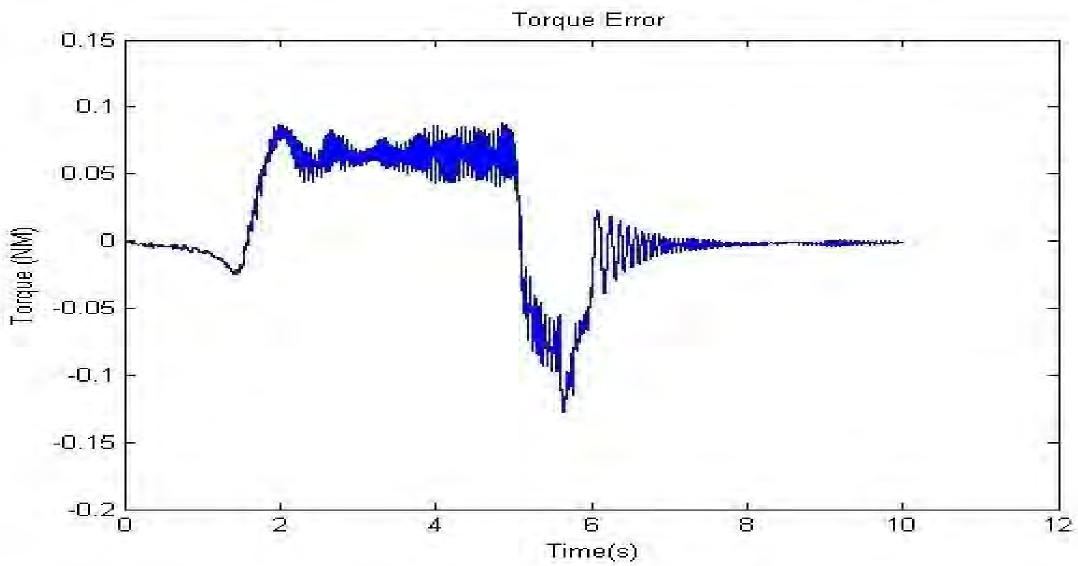

Fig.13. Torque error

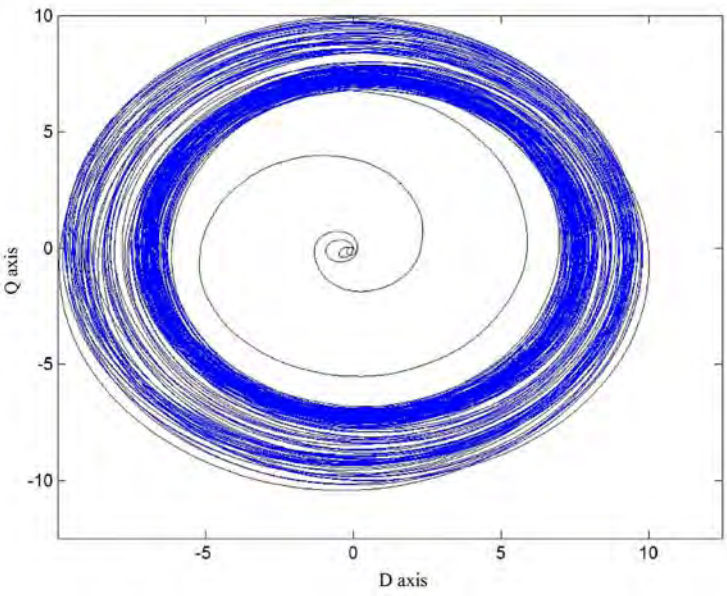

Fig.14 Circular flux pattern

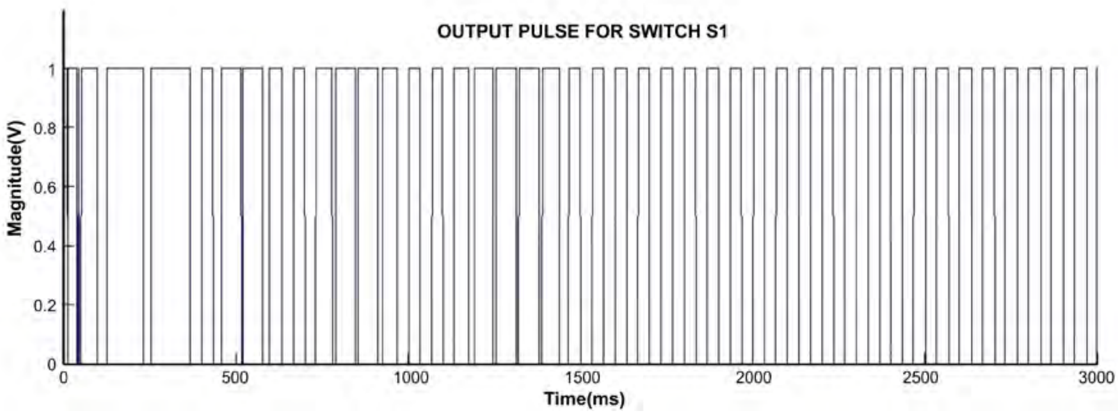

Fig.15. Switching output pulse across S_1

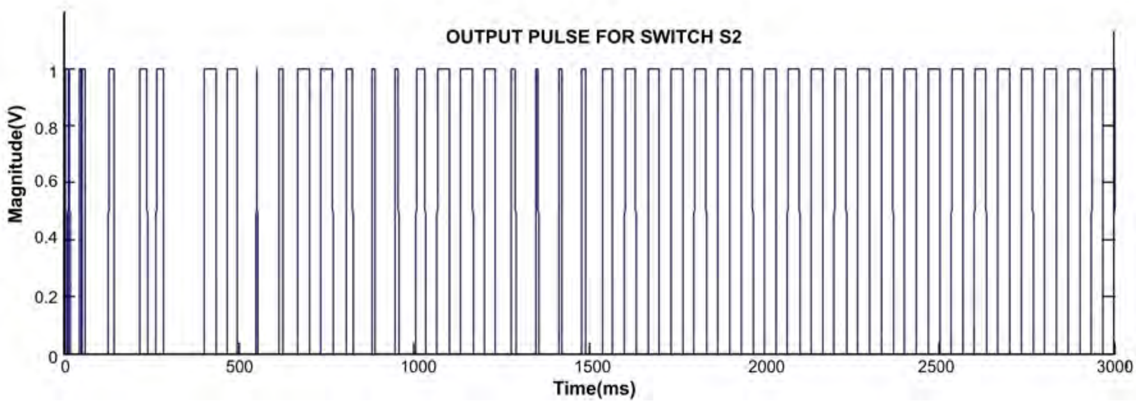

Fig.16. Switching output pulse across S_2

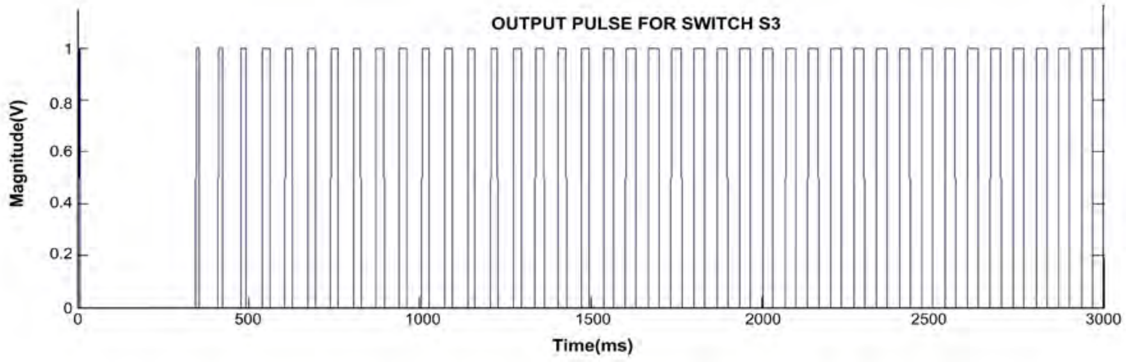

Fig.17. Switching output pulse across S_3

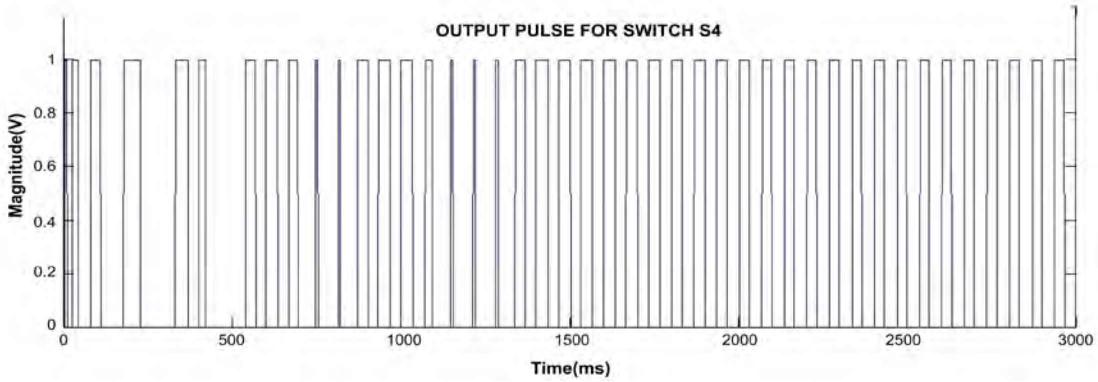

Fig.18. Switching output pulse across S_4

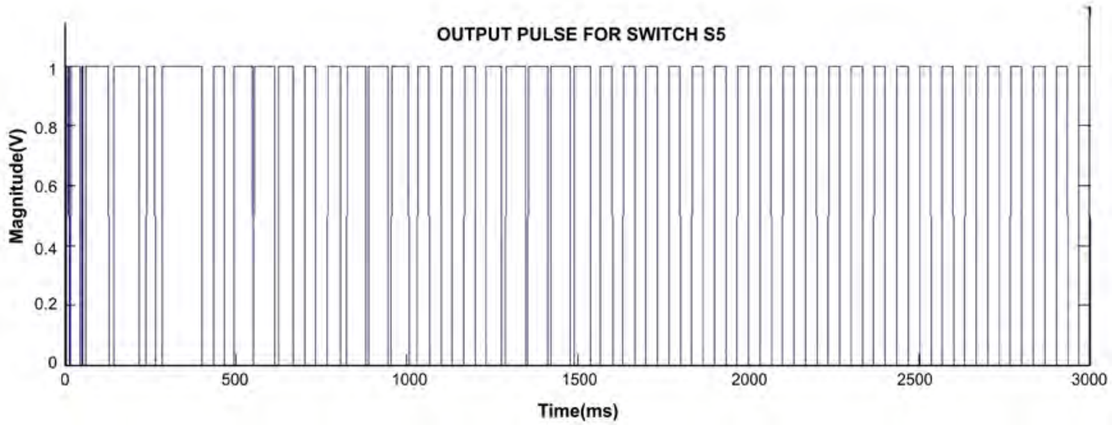

Fig.19. Switching output pulse across S_5

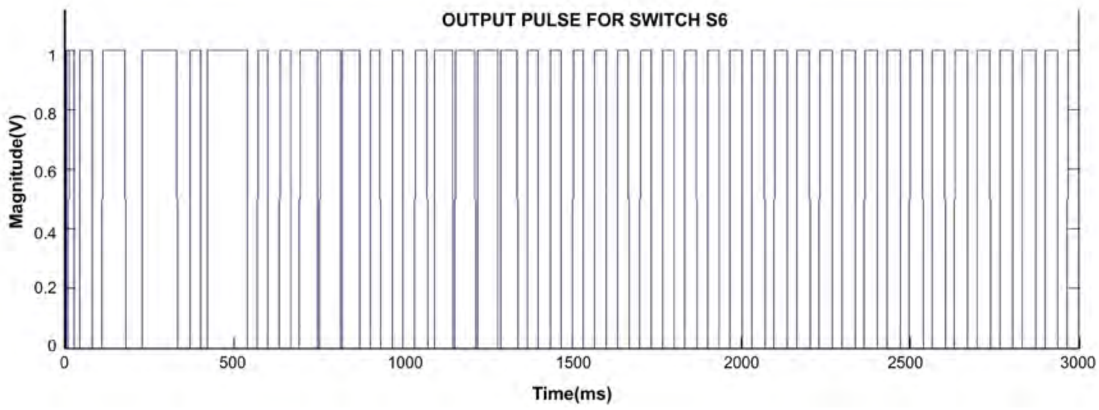

Fig.20. Switching output pulse across S_6

It is observed that the proposed scheme which condenses switching losses of an inverter around 16 watts but in conventional technique, it takes more than 20 watts. Consequently it helps to improve efficiency of an inverter. Moreover, asymmetric space vector technique which enables to condense harmonic distortion in an output voltage. The presented scheme further effects on drive parameters like settling time (steady state of rotor) of the machine, torque and flux ripples. This scheme delivers a smoother steady state performance in terms of torque and rotor speed. The dynamic responses of the machine have tested under positive and negative operating conditions with full-load torque and their results are illustrated in Fig 10 and Fig 12. The steady state of rotor speed in proposed method is achieved within a minimal time and ripple free stator flux at steady state condition in Fig 11.

VII. CONCLUSION

Thus, proposed method enhanced to condense the switching losses, torque error, variation of stator current, rotor flux ripples and also better dynamic response of the drive in terms of minimum peak overshoot in speed oscillation, thus settling time is very quick near to 1.5 ms. In the speed reversal of machine, smooth transition happened in the rotor of machine and corresponding torque error between reference torque and torque estimation in proposed method is very low and equal to ±0.15 NM as a result a constant switching frequency is achieved. The same helps to upgrade the performance of control system.

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