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Reduction Of Current Ripple and THD In VSI Fed Induction Motor Using Fuzzy Based SVPWM

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Abstract : The simple stepper wave inverted has low level harmonics which are not eliminated by filters. But by using SVPWM technique we can filter the low level harmonics. In this SVPWM technique, when compared to PWM this SVPWM technique as 15% increment in voltage; hence it enables efficient use of DC voltage. SVM provides excellent optimized efficiency, high reliability, and output performance compared to similar Inverters with conventional PWM. This paper proposes three different sequences, and identifies all possible sequences, which result in the same average switching frequency as conventional space vector PWM (CSVPWM) at a given sampling frequency and FSVPWM at variable speed conditions. The proposed FUZZY based SVPWM lead to a significant reduction in THD over CSVPWM at high line voltages and can be implemented with variable speed applications. The harmonic, variable speed performance of the proposed techniques over CSVPWM techniques is established by using Matlab/Simulink

Keywords : Fuzzy, Speed control, induction motor drive, pulse width modulation (PWM), PWM inverters, space vector, switching sequences, space vector modulation.

1. INTRODUCTION

Current in the induction motor is induced in the rotor by means of electromagnetic induction, it act as an AC synchronous motor. In an electrical motor electrical power is converted into mechanical power. In an induction motor the power conversion is done in rotating parts with the help of commutators or brushes and is directly conducted in case of dc motor but in case of induction motor does not get any electrical power through conduction, so it comes by mutual induction between stator and rotor . The same principle is followed by 2-widing transformer [1]. It is also called as a rotating transformer because it has stationery stator winding and moving rotor winding. In case of AC motors rotating magnetic field is setup when 3-phase supply is applied to the stator windings. The rotor bars cuts the rotating magnetic field and emf induced in it which is transferred through the rings connected at the end. It is difficult to control the speed of an induction motor as compared to dc motors. Speed control of an induction motor can be done by different schemes. By using V/*f* control strategy maximum torque can be developed in the motor. A constant flux is maintained in an ideal induction motor by fixing the V/*f* ratio constant while in practice the induction motor contains series resistance and inductance. The stator resistance drop R_1 is significant at low speed/frequencies compared to reactance drop X_1 because of this effect the torque will become lower at low frequencies.

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Mostly AC induction motors are controlled by using Vector control method. As in DC motor the expression for torque in the smooth air gap is almost equal the expression for the electromagnetic torque of the smooth-air-gap machine in special frame of reference. *d-q* frame of reference is attached to the rotor flux space vector in induction motor. So, to implement vector control it necessary requires information on modulus and space angle of the rotor flux space vector. By using *d-q* co-ordinate system stator currents are separated into flux and torque producing components whose direct axis (*d*) is assigned with rotor flux space vector.

2. SWITCHING SEQUENCES

A 3-phase VSI has eight switching states which as shown in Fig. 1.

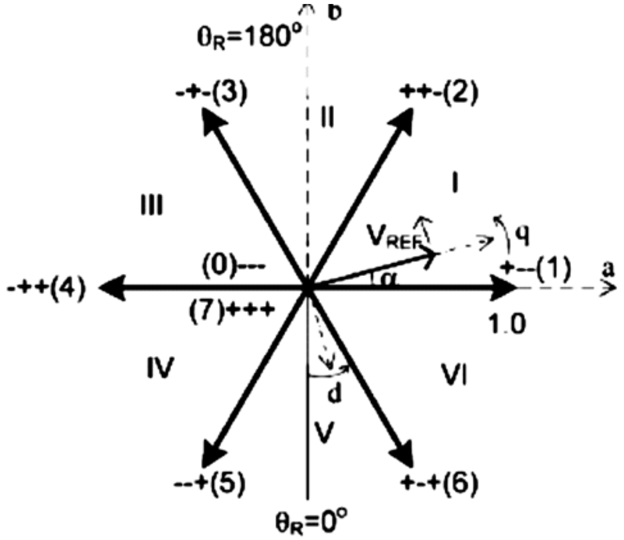

Fig. 1. Inverter voltage vectors and states.

Where , I, II, III, IV, V, and VI are sectors and θ_R is angle of R-phase fundamental voltage

The two zero states (+++ and ---) of motor short terminals produce a zero magnitude of voltage vector. The other six active states produce an active voltage vector for each state. These six active vectors divides space vector plane into six sectors with an equal magnitude.The magnitudes are normalized with respect to the dc bus voltage V_{dc}. From Fig.1 V_{ref} is given by revolving reference vector whose sampling is done in every sub cycle is known as T_s and is given by sampled reference vector magnitude V_{ref} with angle $\propto$. From sector-I , the active power 1 has sub cycle T_1 active vector 2 has sub cycle T_2 and zero vector in sub cycle Tz respectively.

$$T_1 = \left(\frac{3V_{ref}}{2V_{dc}}\right)\left[\frac{(\sin(60° - \theta)}{\sin(60°)}\right]T_S \tag{1}$$

$$T_1 = \left(\frac{3V_{ref}}{2V_{dc}}\right)\left[\frac{(\sin(\theta)}{\sin(60°)}\right]T_S \tag{2}$$

$$T_z = T_s - T_1 - T_2$$

The CSVPWM divides T_Z equally between 0 and 7, and utilizes the switching sequence 7-2-1-0 or 0-7-2-1 in a sub cycle in sector I. However, multiple sequences are possible since the zero vector can be applied either using 7 or 0, and also an active state can be applied more than once in a sub cycle. The valid switching sequences in sector I, which have three switching's per sub cycle as in CSVPWM which satisfy the conditions:

(*a*) In each sub cycle both active states 1&2 must be applied once.
(*b*) In each sub cycle either a both zero states 7&0 must be applied once.
(*c*) Must satisfy multiple application of an active state (*a*).
(*d*) In a sub cycle must satisfy (*a*) when applied The total duration for the zero vector (either using zero state 7 or 0).
(*e*) Only one state transition one phase is applied.
(*f*) The total number of switching's should not present in a sub cycle only

Conditions (*a*) prevents (*d*) ensure voltage–sec, balance ,condition (*e*) for low switching avoid losses unwanted switches and condition (*f*) for a given sampling frequency ensures that the CSVPWM is greater than or equal to average switching frequency. At any arbitrary instant in sector I, the initial state or start of a sub cycle can be applied inverter state is 0, 1, 2, or 7. Let the initial state be zero and all possible sequences satisfying conditions (*a*) to (*f*) are illustrated in Fig. 2(*a*). Only those sequences which result in exactly 3 switching's in a sub cycle are considered. Sequences 0127 and 0121 are valid sequences, while sequence 0101 is invalid, since active state 2 never gets applied.

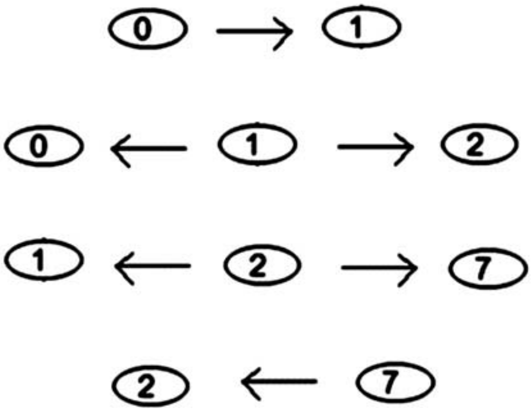

Fig. 2. (*a*) Initial state of a sub cycle.

Similarly, the active stages 1, 2, and 7 as the initial states have illustrated in Fig. 2(*b*)–(*d*), respectively. Ten valid sequences are taken emerge in Fig. 2, which can be grouped into 5- pairs of sequences, *i.e*;

(0127, 7210),(0121, 1210),(1012, 2101),(2721, 1272)(7212, 2127).

In sector-1 out of the above 10 valid sequences CSVPWM uses (0127, 7210) in alternate sub cycles in sector I. the remaining 4 conventional sequences are employed in other sub cycles of sector-1 caller as special sequences resulting in double switching of one phase to another and clamping of third phase.

In special sequences of type I, there are 2 transitions between the active states 1 and 2. In special sequences of type II, there are 2 transitions between an active state and the 0 state closer to it (*i.e*., between 1 and 0 or between 2 and 7). Further there are also valid sequences with only 2 switching's, namely 012, 210, 721, 127. Sequence 012, for instance, can be viewed as a special case of 0127, 0121, or 1012. Similarly, the other 2-switching sequences can also be seen as special cases of certain 3-switching sequences. These sequences are termed "clamping sequences," and are employed by discontinuous modulation methods [2]–[4]. Sequences 012 and 210 or sequences 721 and 127 can be used in alternate sub cycles in sector-I. All the above sequences pertain to sector-I. Sequences pertaining to the other sectors are listed in Table-I. Of every pair of sequences, just one can be taken as a representative. While conventional and clamping sequences have been studied extensively , the special sequences have received only limited attention [5]. All seven sequences are analyzed and compared from the point of view of current ripple in the following section.

Considering zero to be the initial state, all possible sequences satisfying conditions one to six are shown below (only such sequences that result in exactly three switching's in a sub cycle are considered).

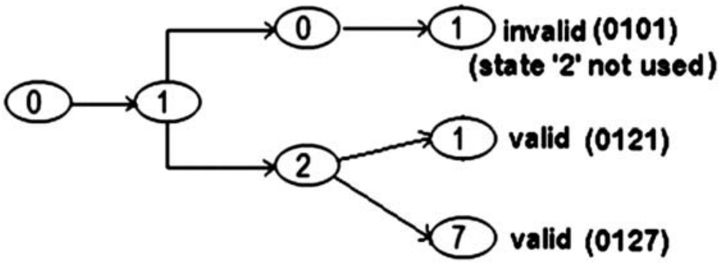

Fig. 2.(*b*) Switching sequences with '0' as the initial state.

Sequences 0121 and 0127 are valid sequences, while sequence 0101 is invalid since active state 2 never gets applied. Now, consider 1 as the initial state, the possible sequences are

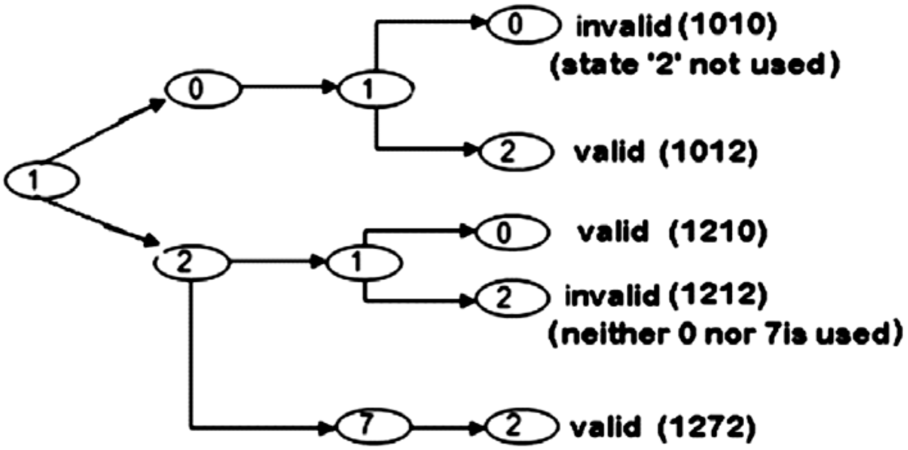

Fig. 2. (*c*) Switching sequences with '1' as the initial state.

If state 2 as the initial state, the possible sequences are

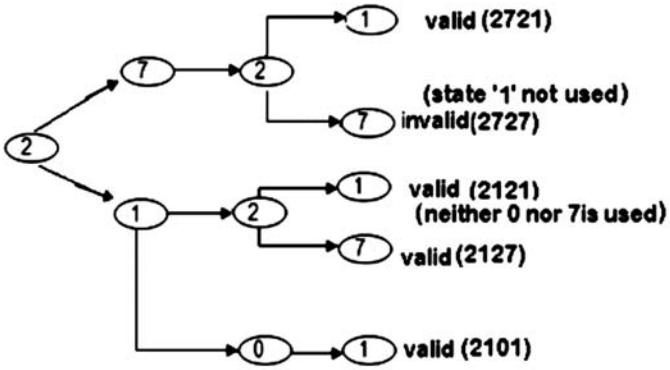

Fig. 2. (*d*). Switching sequences with '2' as the initial state.

Now, consider 7 as the initial state, the possible sequences are

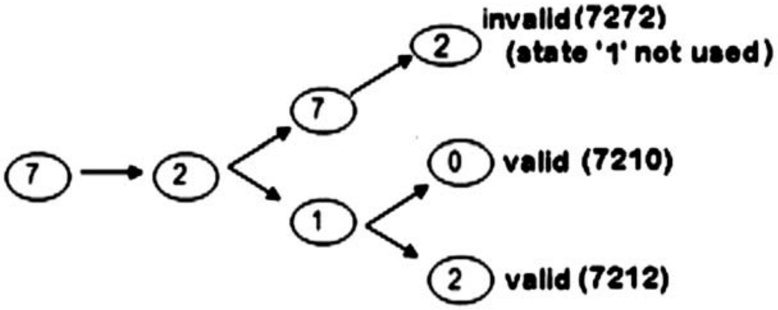

Fig. 2. (*e*). Switching sequences with '7' as the initial state

Table 1. Switching Sequences in Six Sectors.

Sector	*Conventional Sequence*	*Clamping Sequence Sequence*	*Special Sequence Type – I*	*Special Sequence Type – I*
I	(0127, 7210)	(012, 210),(721, 127)	(0121, 1210),(7212, 2127)	(1012, 2101),(2721, 1272)
II	(7230, 0327)	(723, 327),(032, 230)	(7232, 2327),(0323, 3230)	(2723, 3272),(3032, 2303)
III	(0347, 7430)	(034, 430),(743, 347)	(0343, 3430),(7434, 4347)	(3034, 4303),(4743, 3474)
IV	(7450, 0547)	(745, 547),(054, 450)	(7454, 4547),(0545, 5450)	(4745, 5474),(5054, 4505)
V	(0567, 7650)	(056, 650),(765, 567)	(0565, 5650),(7656, 6567)	(5056, 6505),(6765, 5676)
VI	(7610, 0167)	(761, 167),(016, 610)	(7616, 6167),(0161, 1610)	(6761, 1676),(1016, 6101)

Every pair of sequences, just one can be taken as a representative hence there are seven sequences as shown in fig 3

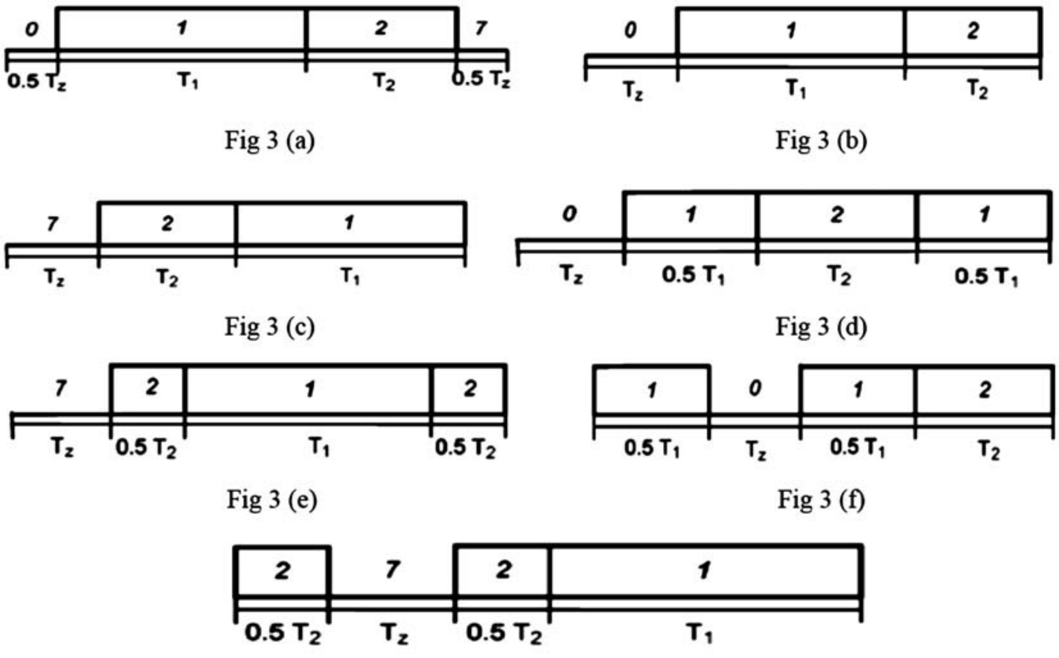

Fig 3 (a)

Fig 3 (b)

Fig 3 (c)

Fig 3 (d)

Fig 3 (e)

Fig 3 (f)

Fig 3 (g)

Fig. 3. Possible switching sequences in sector I (*a*) 0127, (*b*) 012, (*c*) 721, (*d*) 0121, (*e*) 7212, (*f*) 1012 and (*g*) 2721.

3. MODELLING AND SIMULATION OF PROPOSED SYSTEM

The simulated model of the proposed system is shown in fig.4 , it consists the speed controlling mechanism of the induction motor drive with conventional Space vector PWM.

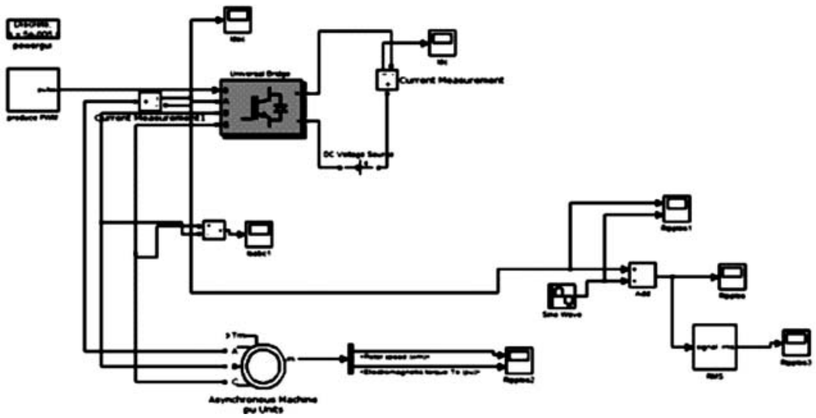

Fig. 4. Simulated model of Conventional Space vector PWM based Induction motor drive.

The fig.5 shows the simulated model of the proposed Space vector PWM based Induction motor speed control system. The SVPWM Space Vector locations are shown if fig.6.

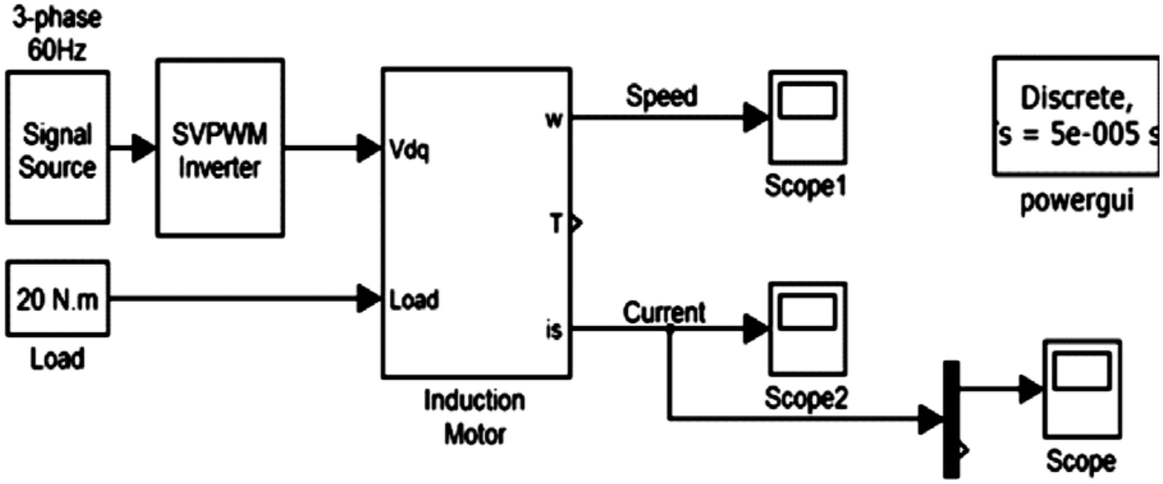

Fig. 5. Simulated model of proposed Space vector PWM based Induction motor drive.

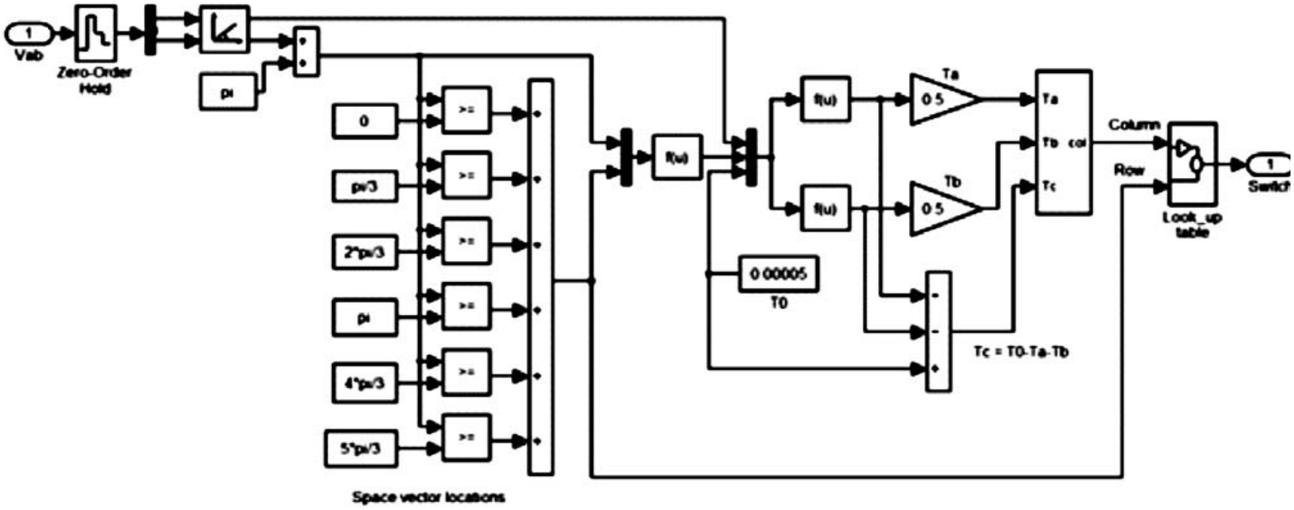

Fig. 6. Matlab/Simulink model of proposed SVPWM Space Vector locations.

The variation in speed of the induction motor using SVPWM is shown in fig.7. From the figure it can be observed that the speed rises constantly without any oscillations to the reference value and stays there with zero steady state error. The corresponding torque wave form is shown in fig.8 and it varies with damped oscillations before reaches to constant amplitude.

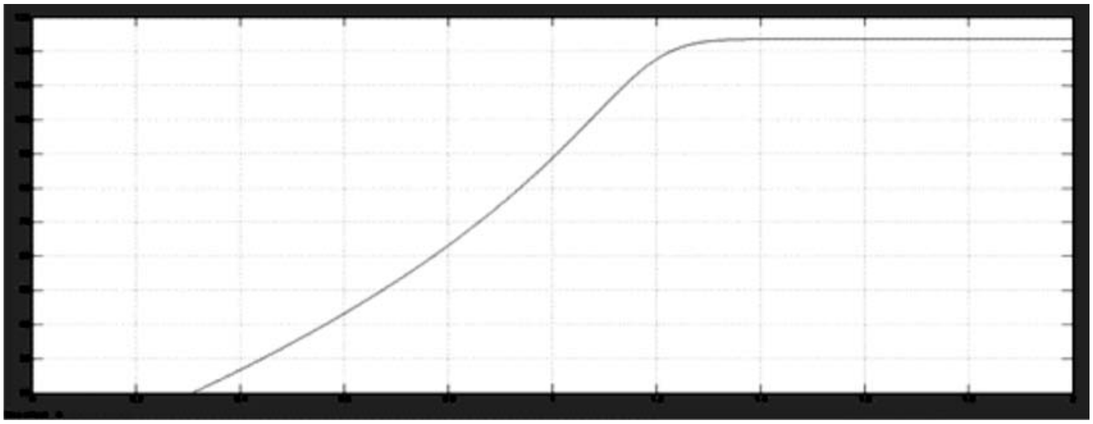

Fig. 7. Speed wave form of SVPWM based Induction motor drive.

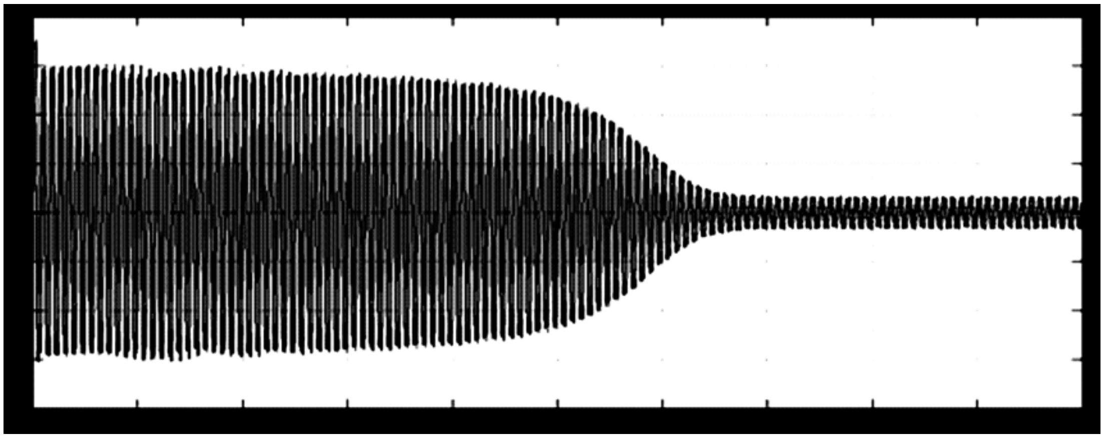

Fig 8: Torque wave form of SVPWM based Induction motor drive.

The simulated model of the proposed induction motor drive with the speed controlling mechanism using of fuzzy based Space vector PWM is shown in fig.9.

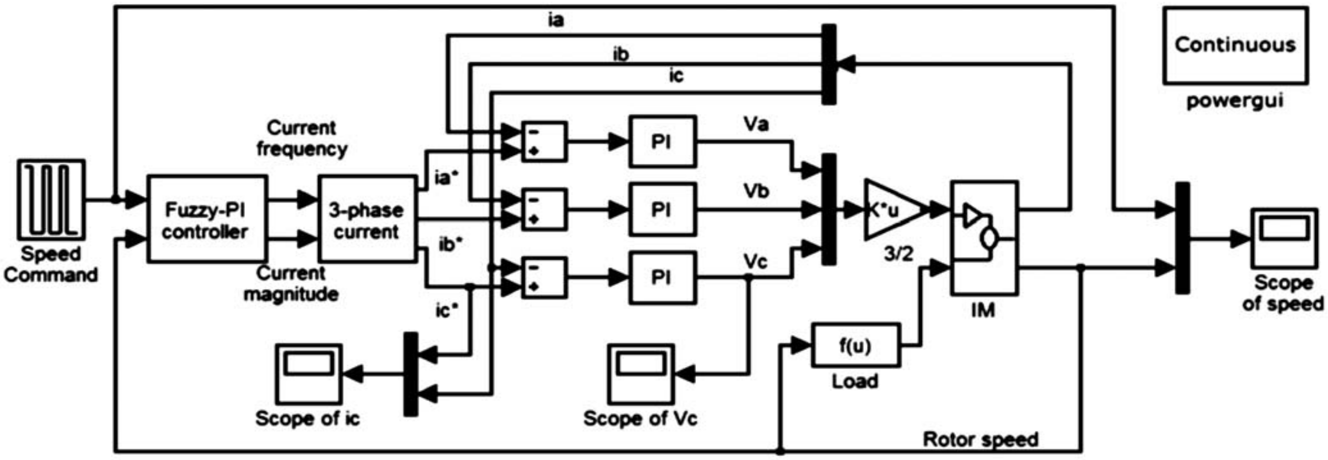

Fig. 9. Matlab/Simulink model of fuzzy based Space vector PWM for variable speed Induction motor drive.

The speed variation of the induction motor using fuzzy based Space vector PWM is shown in fig.10. From the figure it can be observed that the speed rises constantly without any oscillations to the reference value and stays there with zero steady state error.

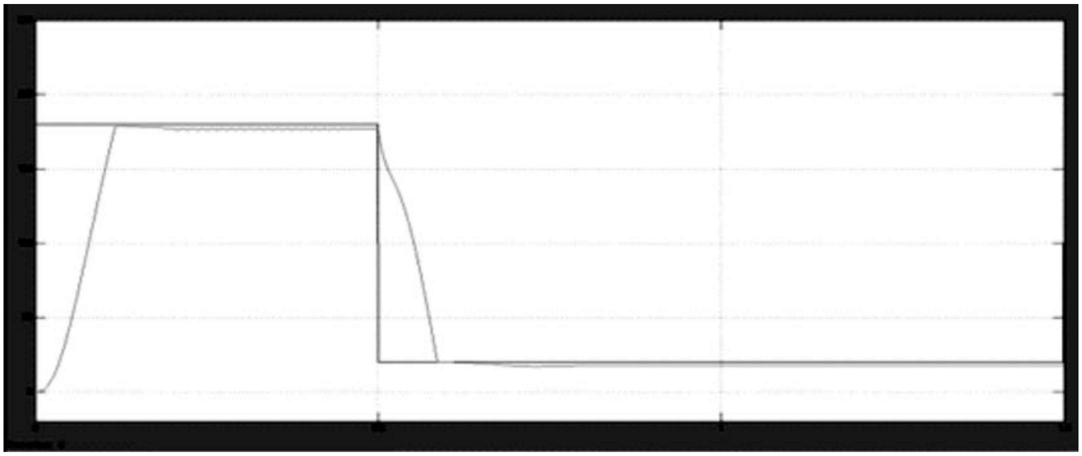

Fig. 10. Simulated Speed wave forms of Reference and actual speeds of the Induction motor.

The Total Harmonic Distortion of the Stator Current of Induction motor form is shown in fig.11 and it can be observed that the THD value is reduced to 1.61% using fuzzy based Space vector PWM.

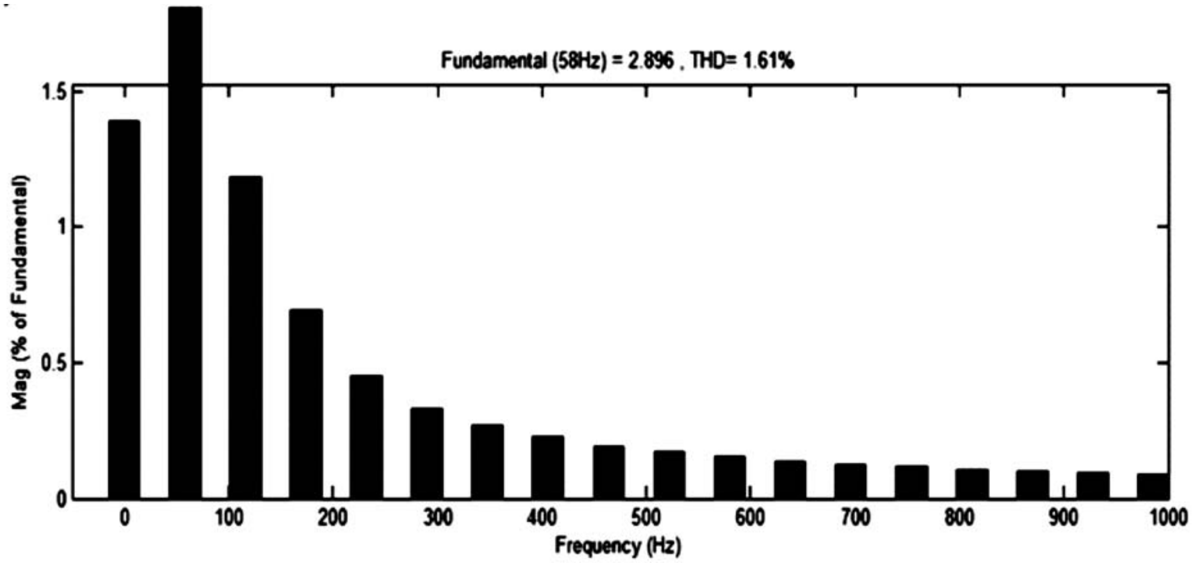

Fig. 11. Total Harmonic Distortion analysis of Stator Current of Induction motor .

4. CONCLUSION

Novel switching sequences, which can be employed in fuzzy based space vector PWM generation for variable speed control of induction motor drive is proposed and compared with the conventional SVPWM techniques for constant speed applications. Influence of the switching sequences on the rms current ripple over a subcycle is analyzed. A procedure is presented for designing hybrid PWM techniques involving multiple sequences for reduced current ripples and harmonics for variable speed conditions control technique based on fuzzy.

5. REFERENCES

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