Comparison between Scalar & Vector Control Technique for Induction Motor Drive

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Abstract - *This paper represent the modelling & simulation of scalar control & vector control technique for induction motor drive using two level inverter. To overcome the problem of increment in lower order harmonics, THD & speed torque characteristics of three phase squirrel cage induction motor. This paper provides the comparison between scalar control and vector control techniques for three phase Induction motor through Matlab / Simulink. A comparison and performance of scalar & vector control inverter are used in motor to control speed, current and torque. Matlab simulation environment are taken to simulate both scalar and vector control for induction motor drive. The torque ripple is minimized and thus lower order harmonics are reduced, constant speed, constant torque and variable speed variable torque are determined through simulation results for both scalar and vector to level inverter. The applications with two level inverter provides better power quality as compared to scalar due to reduction in harmonic content.*

Key words: MATLAB, Simulink, Scalar Control Technique, Vector Control Technique, Squirrel Cage Induction Motor.

1. INTRODUCTION

Induction motors have higher power densities and are mechanically more robust, which make them the ideal motor in many applications. Squirrel-cage induction motors fed VSI is standard in traction applications. Scalar control technique controls the parameter of Amplitude of voltage. Output torque of IM is dependent on the square of terminal voltage. Now to increase torque an increase in voltage is done in voltage control technique. The performance of both the speed and torque is promoted by a modified PI controller and V/F scalar control [1]. The most widely used IM is squirrel cage motor because of its advantages such as mechanical robustness, simple construction and less maintenance [2]. But the problem is that terminal voltage has a limit which is crossed will lead to a negative effect on insulation and operation of motor. Scalar control is a cheap, but stable control technique [3].

Scalar control method is easy to implement and a low price technique. Scalar control is a low performance but stable and simple control technique. Vector control is a complex and high price control technique [4].

Use of scalar control is limited to applications where the performance requirements in terms of dynamic behaviour of the system are less stringent, such as pumps, fans, centrifuges, conveyors, mixers, and some types of machine tools [5]. The speed of the motor cannot be controlled precisely, because the rotor speed will be slightly less than the synchronous speed and that in this scheme the stator frequency and hence the synchronous speed is the only control variable [6].

Rotor resistance method in which resistance is connected in rotor side externally such that when value of this resistance is altered it will change speed of motor. The main drawback of this method is its poor efficiency due to additional losses because of added resistance.

Another method of speed control is EMF Injection Method which is most popular for slip ring type IM. In this method, speed is controlled by supplying emf to the rotor circuit from external circuit. The main drawback of this technique is that the frequency of supply is equal to the speed of rotor, and rotor speed is dependent on slip. Hence is very difficult to supply EMF to the rotor and circuit is very complex.

Voltage Source Inverter is generally used for speed control by varying frequency and voltage [7]. Scalar control techniques were found to give poor dynamic responses for inverter-fed induction motor speed control.

PWM inverters are quite popular in industrial applications. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is however modulated to obtain inverter output voltage control and to reduce its harmonic content.

To improve speed control performance of the scalar control method, an encoder or speed tachometer is required to feedback the rotor angle or rotor speed signal and compensate the slip frequency. However, it is expensive and destroys the mechanical robustness of the induction motor. So these are the limitation of scalar control which is overcome by Field orientated control (FOC) for induction motor drive.

2. Different Techniques of Speed Control

There are different speed control techniques used to control the speed of Induction Motor. The speed variation or controlling is done by varying the load of Induction Motor. The Scalar Control Technique is widely used for such purpose. Figure 1 shows the system configuration of Squirrel Cage Induction Motor Drive using scalar Control Techniques.

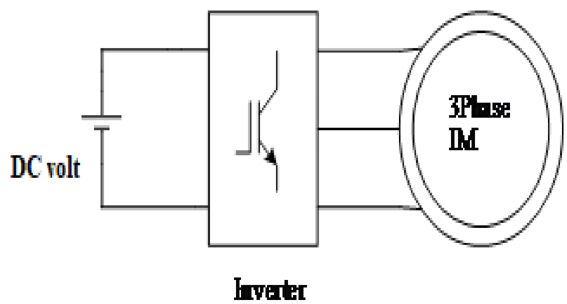

Figure 1 System Configuration of SCIM drive

Figure 2 shows the basic control scheme for SCIM based scalar control technique. The PWM scheme is used here to control the pulses in the Scalar Control Inverter. Parks Transformation & Inverse Parks Transformation is used basically to convert the d-q parameter into a-b-c parameters and vice versa. We have to calculate the phase angle from this and this will fed into Squirrel Cage Induction Motor.

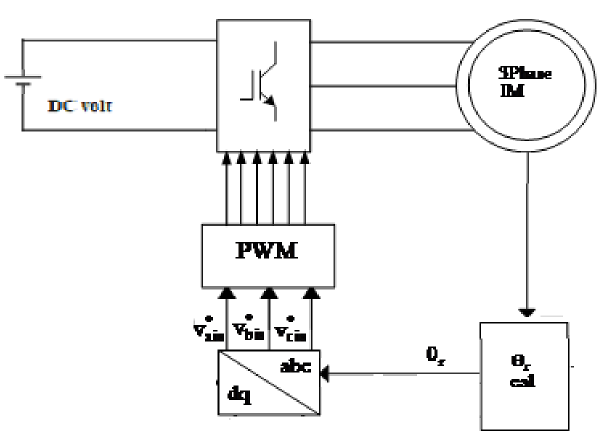

Figure 2 Control scheme for V/F of an SCIM

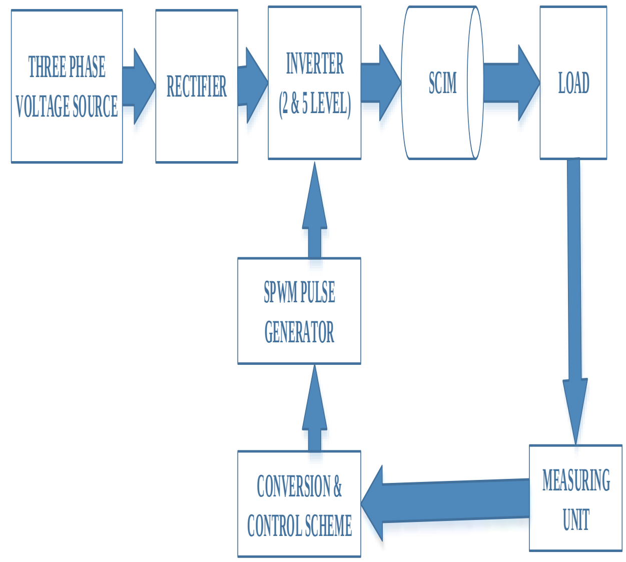

Figure 3 Block Diagram of Vector Control of Induction Motor Drive

Figure 3 shows the basic block diagram for vector control two level inverter of Induction Motor Drive. Here, AC Supply source is used to give voltage into Rectifier. Diode section and this will give the variable DC with LC Circuit. The LC circuit is used to filter the variable oscillating DC which will fed into Inverter (IGBTs). This IGBTs will convert the variable DC voltage into variable AC through Pulse Switching of SPWM technique.

3. PROPOSED METHODOLOGY

Figure 4 shows the proposed diagram for Scalar Control technique used to run the Induction Motor. Through SPWM fed Induction motor Drive, we will calculate the different parameters of IM such as rotor speed, electromagnetic torque, voltage and current. And after this calculation, one can do the d-q and a-b-c parameters of the system for PWM pulse generator. Now, compare obtained speed with the reference speed and if we get the desired speed which is equivalent to the obtained speed then we can calculate the THD.

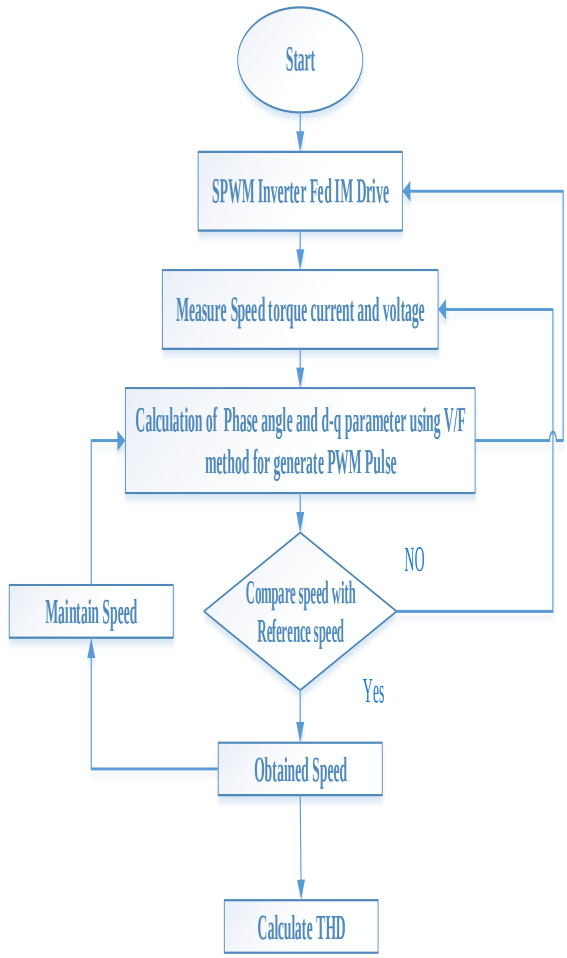

Figure 4 Flow Chart of Scalar Control Technique of an SCIM

E.m.f. equation for Induction Motor is given by

$$E = \sqrt[2]{2}\,\pi \phi_m f N \qquad (1)$$

$$\omega = \frac{d\theta}{dt} \qquad (2)$$

$$\begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta - 120^\circ) & \sin(\theta - 120^\circ) & 1 \\ \cos(\theta + 120^\circ) & \sin(\theta + 120^\circ) & 1 \end{bmatrix} \begin{bmatrix} V_{qs^s} \\ V_{ds^s} \\ V_{os^s} \end{bmatrix}$$
(3)

4. SIMULATION MODEL

The below figure 5 shows the Matlab Model for Scalar Control Techniques in IM drive. The scope shows the various outputs with respect to time. Here, the different motor parameters (rotor speed, electromagnetic torque, stator current and rotor current) will be obtained through Scope.

$$V_{qs^s} = \frac{2}{3}V_{as} - \frac{1}{3}V_{bs} - \frac{1}{3}V_{cs} \qquad (4)$$

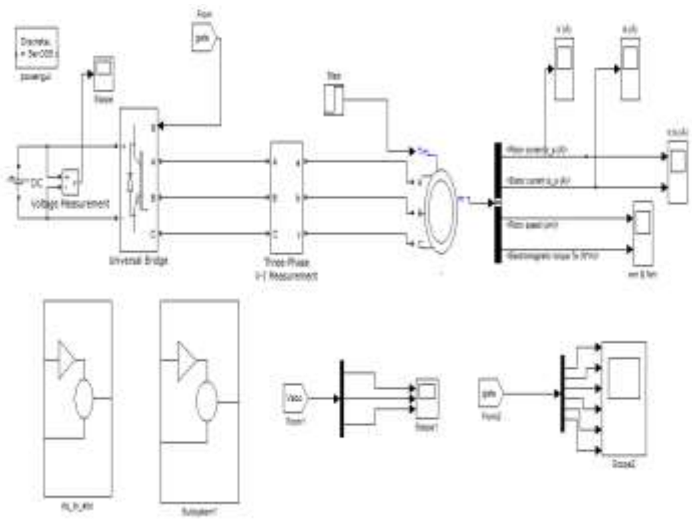

Figure 5 Matlab Model of Scalar Control Inverter Induction Motor Drive

$$V_{ds^s} = \frac{-1}{\sqrt{3}}V_{bs} + \frac{1}{\sqrt{3}}V_{cs} \qquad (5)$$

Figure 6 shows the subsystem for d-q to a-b-c transformation which is generally specified as Parks Transformation.

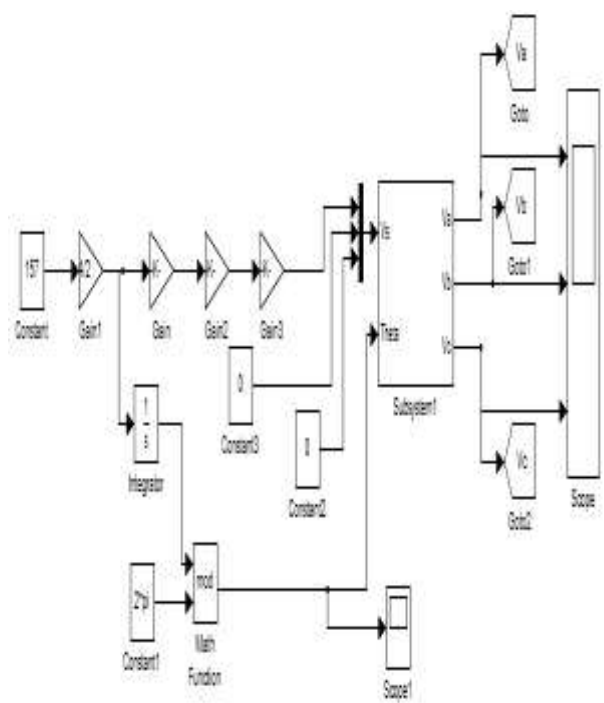

Figure 6 dq to abc transformation Subsystem

Figure 7 shows the SPWM Generator subsystem of Scalar Control Techniques used to control the speed of Induction Motor Drive.

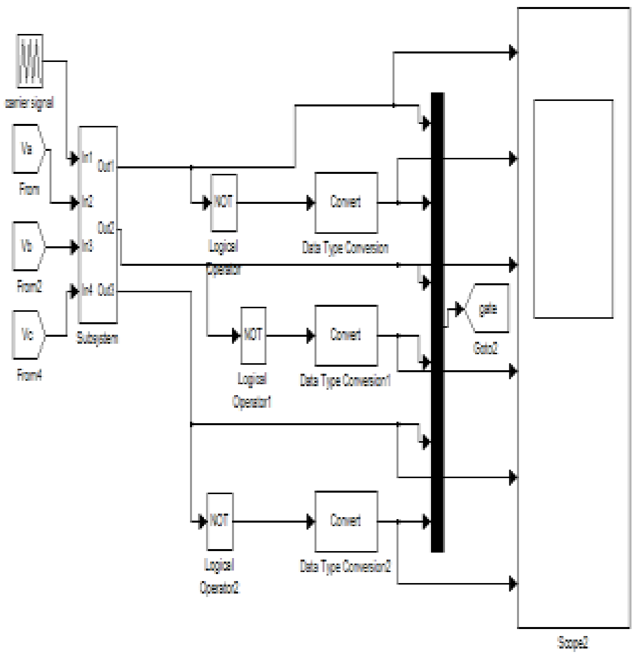

Figure 7 SPWM Generator Subsystem for Scalar Control SCIM drive

5. RESULTS ANALYSIS

The simulation model of an IM drive with Scalar control has been developed using MATLAB R2008a.The results obtained at VSC under steady condition and step change in both speed and load torque. These results are obtained in terms of SCIM Rotor currents (i_{ra}), Stator currents (i_{sa}), speed of IM (□) and electromagnetic torque (T_e) and phase to phase output voltage of inverter (V_{ab},V_{bc},V_{ca})

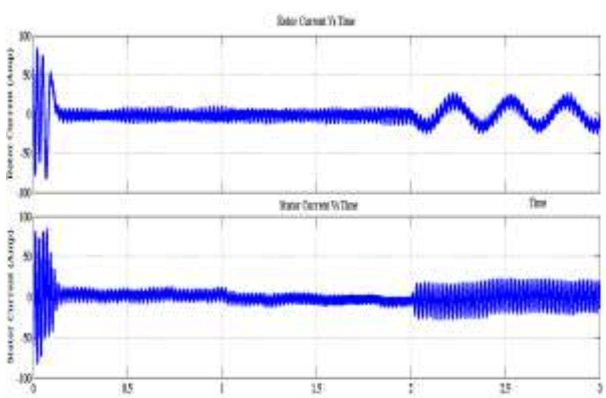

Figure 8 Rotor & Stator current of IM employ with scalar Technique

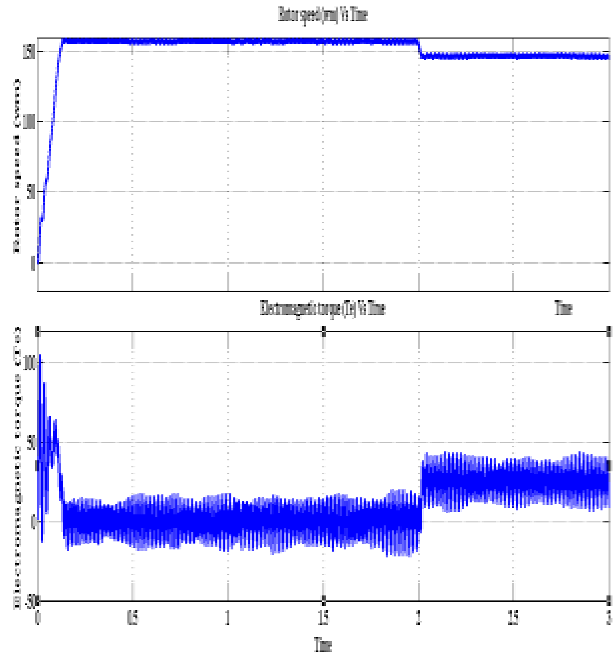

Figure 9 Speed & Electromagnetic Torque of IM using scalar control technique

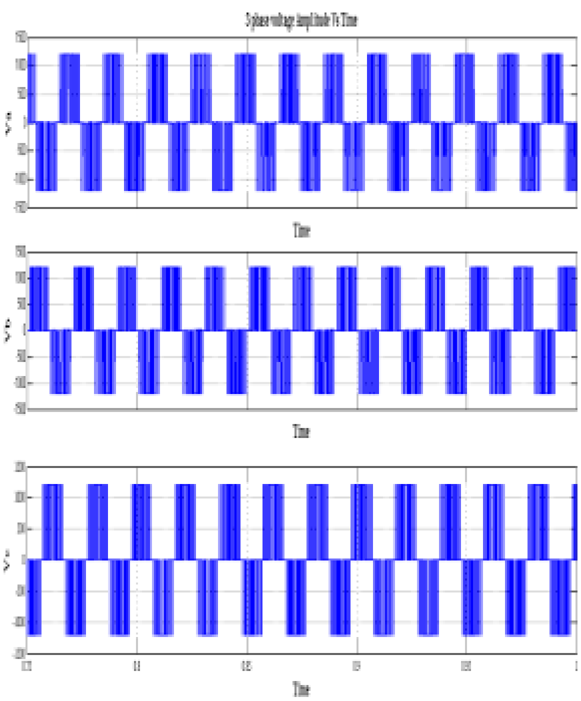

Figure 10 Three phase to phase voltage output waveform of VSI using scalar control technique

Figure 8 shows the rotor current and stator current for Scalar Control Induction Motor Drive. Similarly, Figure 9 shows the rotor speed and electromagnetic torque for

Scalar Control Technique fed Induction Motor Drive. Figure 10 shows the voltage waveforms for Scalar Control Technique.

Table 1 THD for Scalar & Vector Control Technique

Inverter	THD %	1st Order Harmonic	3rd Order Harmonic	5th Order Harmonic	7th Order Harmonics
Scalar Control Inverter	152.1	100	24.25	25.65	20.38
2 level Inverter	34.89	100	21.16	8.33	3.92

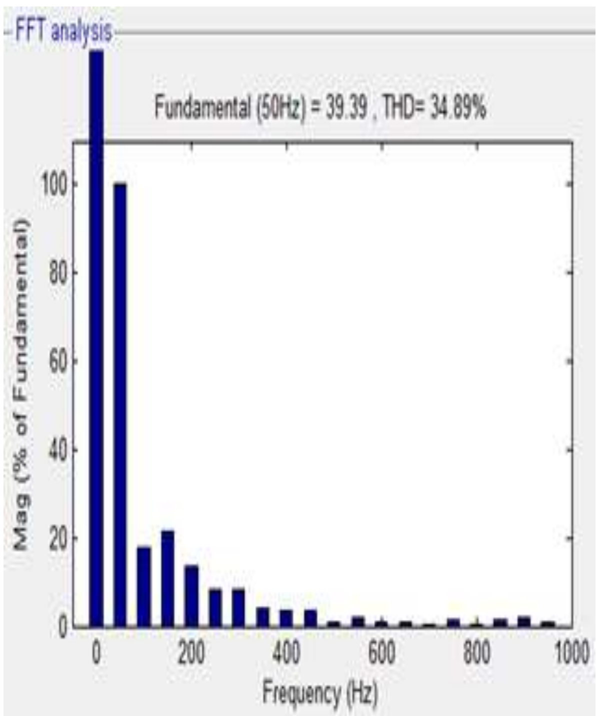

Figure 11 THD result analysis for two level vector control technique fed Induction Motor Drive

Figure 11 shows the THD result analysis for two level vector control technique fed Induction Motor Drive. Figure 12 shows the THD result analysis for scalar control technique fed Induction Motor Drive.

The two level vector control technique is good approach as compared to scalar control technique when load is applied frequently for controlling the IM because of the response of Induction motor is very quick and accurate. Control scheme has been studied for variable torque operation of an Induction Motor drive system.

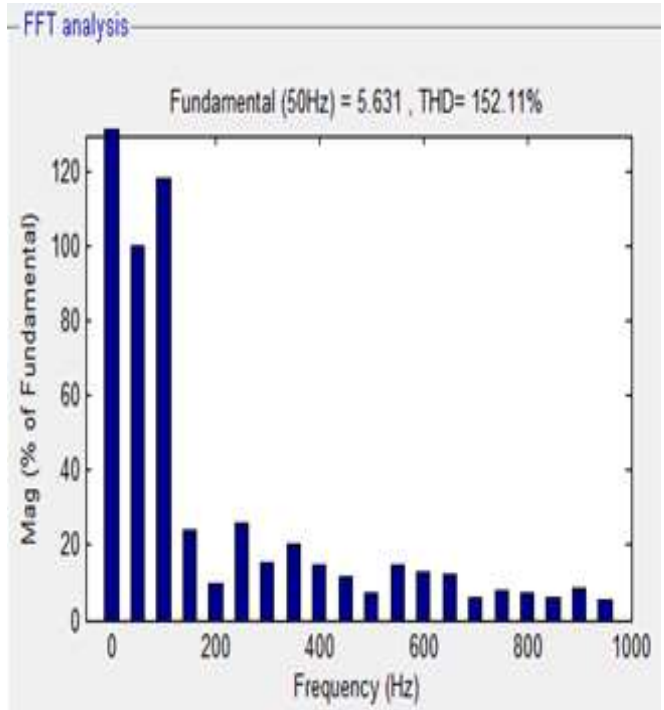

Figure 12 THD result analysis for scalar control technique fed Induction Motor Drive

6. CONCLUSION

From the above analysis it is clear that the two level vector control technique is far superior to scalar control technique as scalar control is having poor response issue and the stability of the system degrades. This will improves the efficiency of the Induction Motor and provides the saving at the customers end by smooth start up and stop, dynamic response, reduction in noise and improved power quality of the system.

Table 2 Comparison between Scalar & Vector Control Technique

S. No.	Scalar Control	Vector Control
1.	Simple	Complex
2.	Slow response to transient	Operate with fast response
3.	Low price technique	High Price Control Technique
4.	Low Performance but stable	Speed regulation is very good

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