

# Conventional and Artificial Intelligence based Control Techniques for Induction Motor Drive

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**Abstract:** Automation and motion control are important factors to run an industry. Induction motor is widely used in automation due to its various features. In past induction motor was used as fix speed motors but due to advancement in power electronics now a days it can be used as variable speed motors. This paper represent various control schemes like V/f control, Space Vector Control, Close loop control with PI controller, Vector Control, Direct Torque control (DTC) and artificial intelligence based V/f control by fuzzy logic control(FLC).In this paper various control schemes are discussed with its simulation result and all schemes are differentiate by comparing their torque-speed characteristics of speed control of an induction motor.

**Index Terms** - - induction motor, V/f ratio, scalar control, Space Vector PWM , vector control, Fuzzy logic control

## I. INTRODUCTION

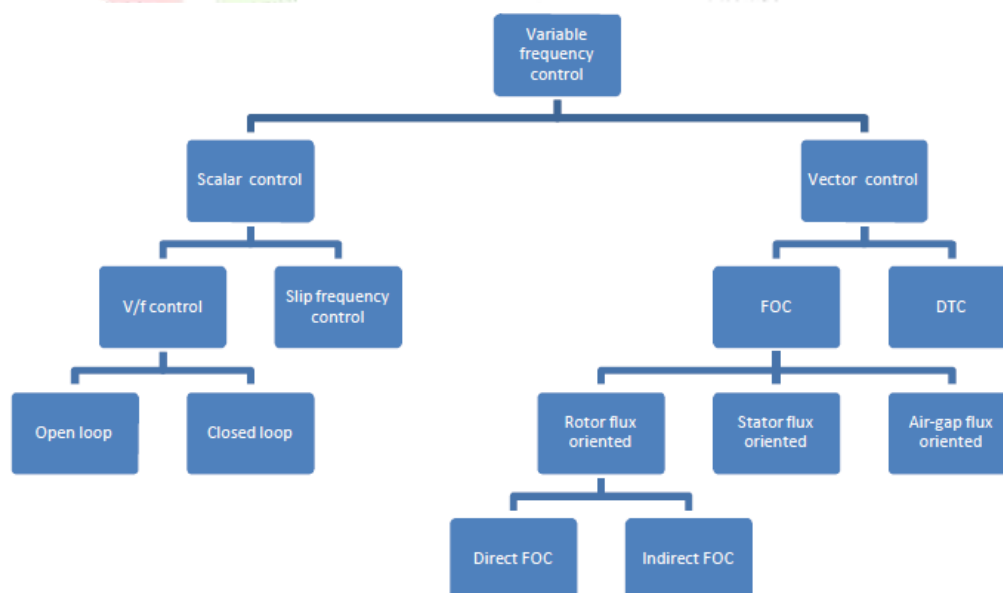
AC motors are invasive into the applying areas of motor drive, wherever DC motors are preponderantly used. Electrical machines are very in industrial and commercial applications. Electrical motors are an important part of any electrical system because they consume about 65% to 70% of all electricity generated. Their advantages are various merits like robust construction, very low maintains, good performance and stable operation under load and satisfactory efficiency. Advancements of electrical converter technique have created AC power supply very controllible. Now a days variable speed induction motor is widely used motors in many industrial applications. Among all the kinds of ac machines, the cage type induction motor is wide utilized in trade. The induction motor has various advantages like simple and robust construction and lustiness. Most induction motors are of the rotary kind with primarily a stationary stator coil and a rotating rotor.

However, the control of speed of the induction motor isn't easier in comparison with the dc motors. In associate adjustable speed drives, the machine usually established as part among a electrical circuit, and so its transient behavior has got to be taken into thought.

## II . SPEED CONTROL TECHNIQUES

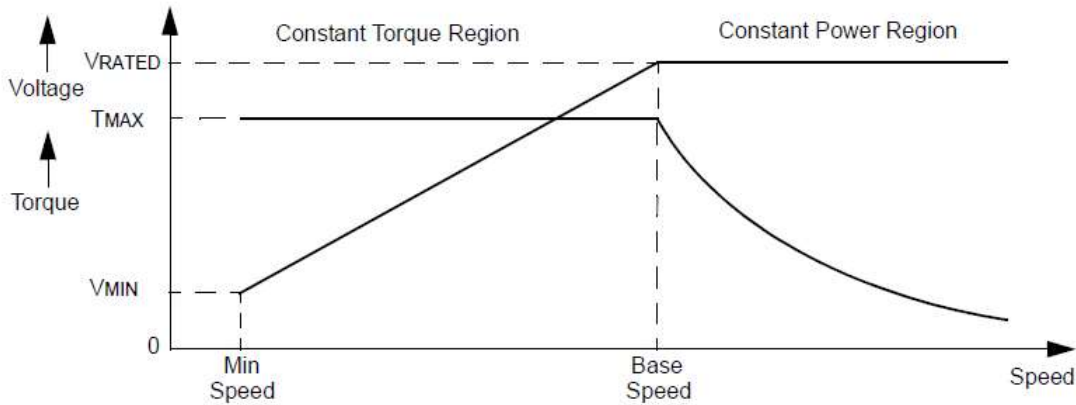
There are number of speed control techniques applied to modern induction machine drive , which are classified as scalar and vector control, shown in figure 1.

**Figure 1: Various Control Scheme**



**2.1 SCALAR CONTROL**

Due to advance technology in power electronics, it is possible to use for variable frequency and variable voltage (VVVF) scheme for speed control of induction motor. Scalar control scheme is easy to implement for speed control of induction motor. Speed control of induction motor is achieved by inverter with constant air gap flux. In order to avoid saturation the air gap flux is remain constant in throughout the control. This is because the induction motor is design to work as knee point of B-H curve. In this scheme both voltage and speed are very accordingly vary to keep flux constant.

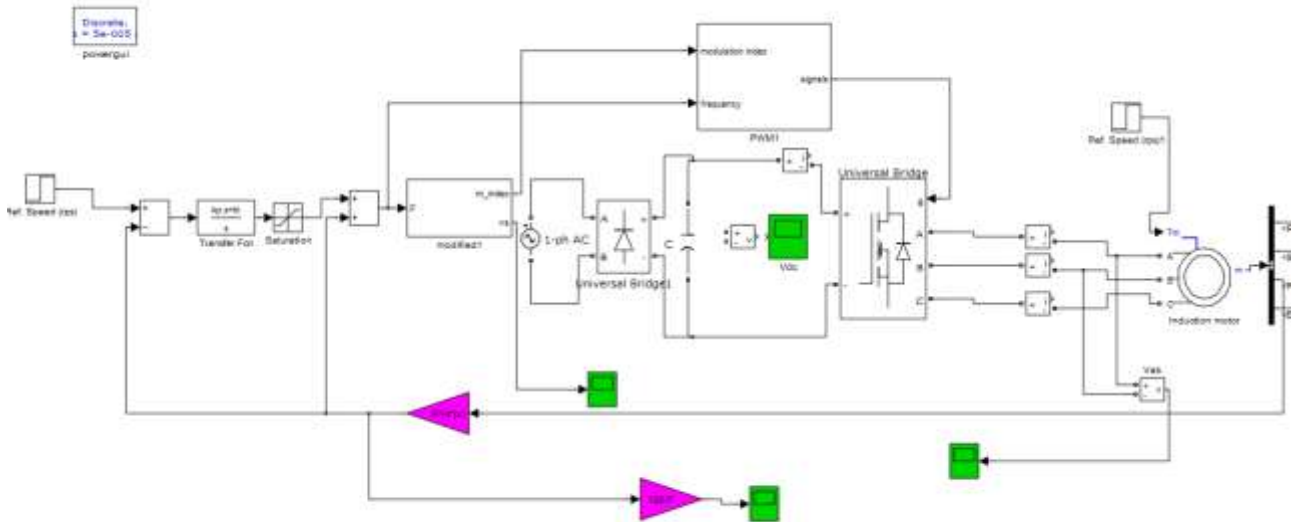


**Figure 2: V/f Control Scheme**

The above figure shows the torque and voltage characteristics for variable frequency and variable voltage (VVVF) scheme, where the first region is called as constant torque region which is up to base speed. Above base speed the power remain constant as speed increase.

**2.1.1 OPEN LOOP V/F CONTROL SCHEME**

The analysis of scalar control technique called as variable voltage and variable frequency is carried out by MATLAB simulink model which is shown in below figure.



**Figure:3 Simulation of Open Loop V/f Control**

The simulation result of V/f control induction motor is shown in above figure. The result shows that the peak torque is 1100 N.m.

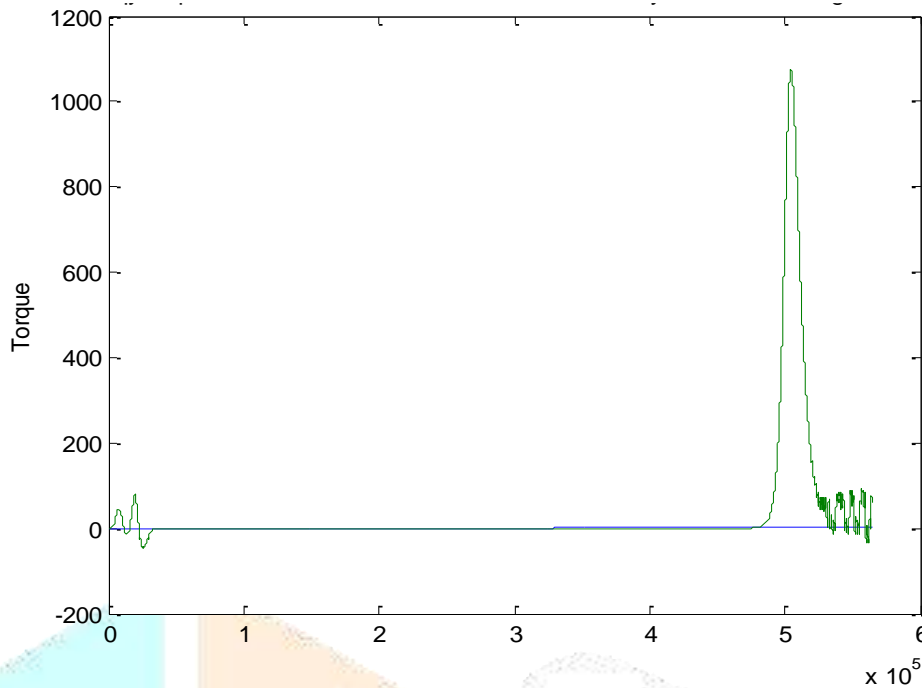


Figure:4 Torque-Speed Characteristics of V/f control

2.2 V/F CONTROL BY SPACE VECTOR MODULATION

Space vector modulation (SVM) is one in all the well-liked time period modulation techniques and is wide used for digital management of VSI (voltage source inverters). A three-phase electrical converter with two switches per electrical converter leg will turn out twenty three or eight shift states. Out of those eight shift states, (+++) and (---) states ((+++) implies all the highest switches area unit ON and (---) implies all all-time low switches area unit ON) area unit known as zero vector states. as a result of throughout these states the load is free-wheeling and there's no power transfer from the electrical converter to the load. From the eight distinct shift states, during a cycle of operation, six distinct positions for the voltage area phasor area unit attainable. For one electrical converter cycle of operation, the voltage area phasor locations akin to the electrical converter states area unit shown in Fig.1.1. The tips of the half-dozen area phasor locations kind a polygon. From the distinct area phasor locations, a circular mechanical phenomenon for the voltage area phasor is feasible by shift between the vertices and also the zero vector during a sector.

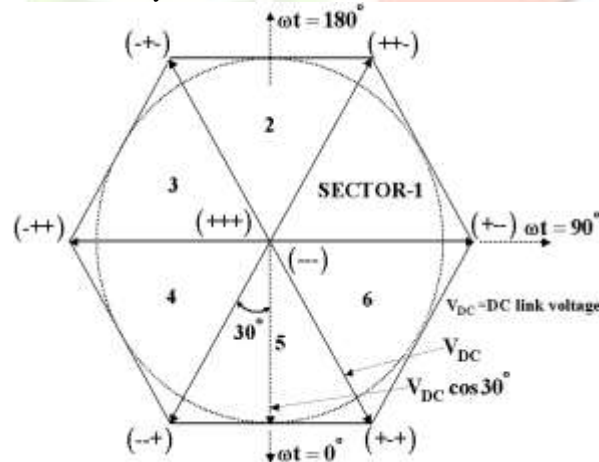
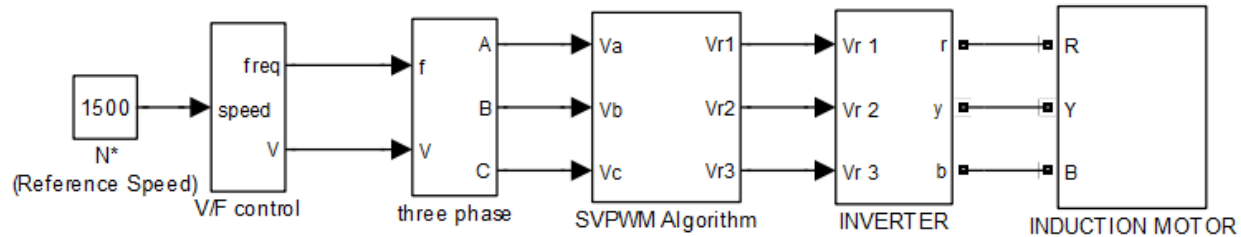


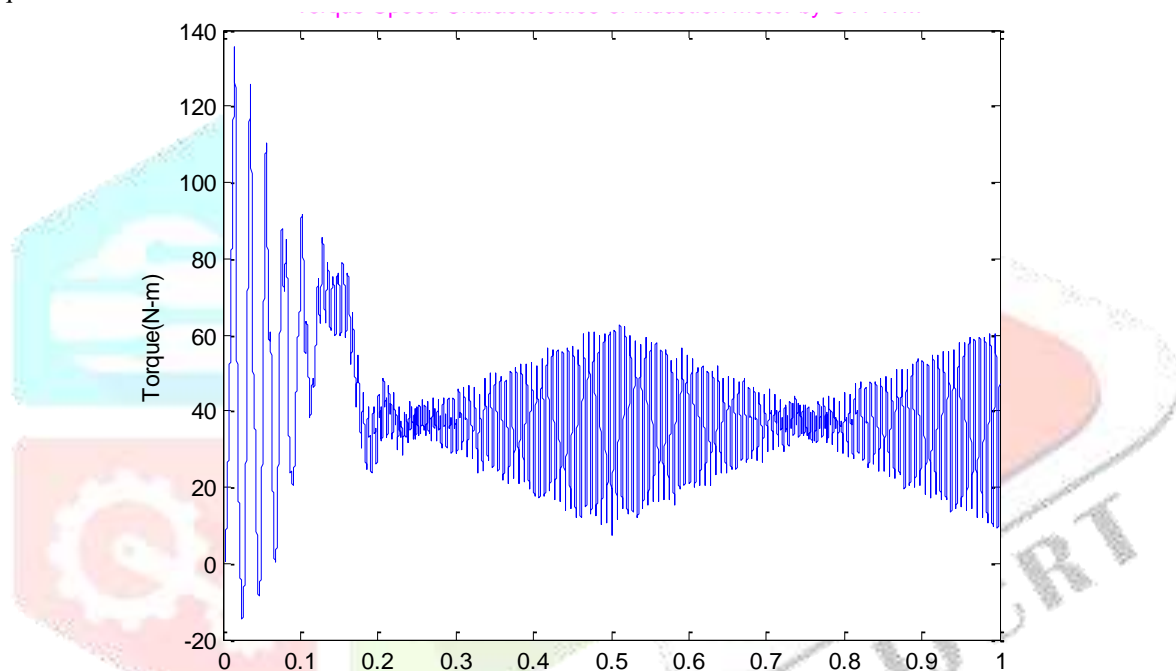
Figure 5: Voltage space phasor locations corresponding to switching states of a conventional three-phase inverter



**Figure:6 Simulation Model of Space Vector PWM**

The analysis of SPWM is carried out by MATLAB simulink model which is shown in above figure.

The simulation result of space vector based PWM control induction motor is shown in below figure. The result shows that the peak torque is 138 N.m.



**Figure7:Torque-Speed Characteristics of Open Loop V/f Control with SVPWM**

### 2.3 SVPWM BASED CLOSED LOOP SPEED CONTROL OF INDUCTION MOTOR

There are various PWM schemes are available and they are SIN- Triangle PWM, Sinusoidal PWM(SPWM) and Space vector PWM (SVPWM).Among all these PWM techniques the space vector PWM is latest and accurate PWM technique. Space Vector technique gives low harmonic distortion.

There are two type of space vector control scheme, one is open loop control and another is closed loop control. The open loop control is easy to implement but not give accurate control while closed loop control is accurate. In close loop control, the load output is compared with reference signal and error signal is generated which is given to PI control.

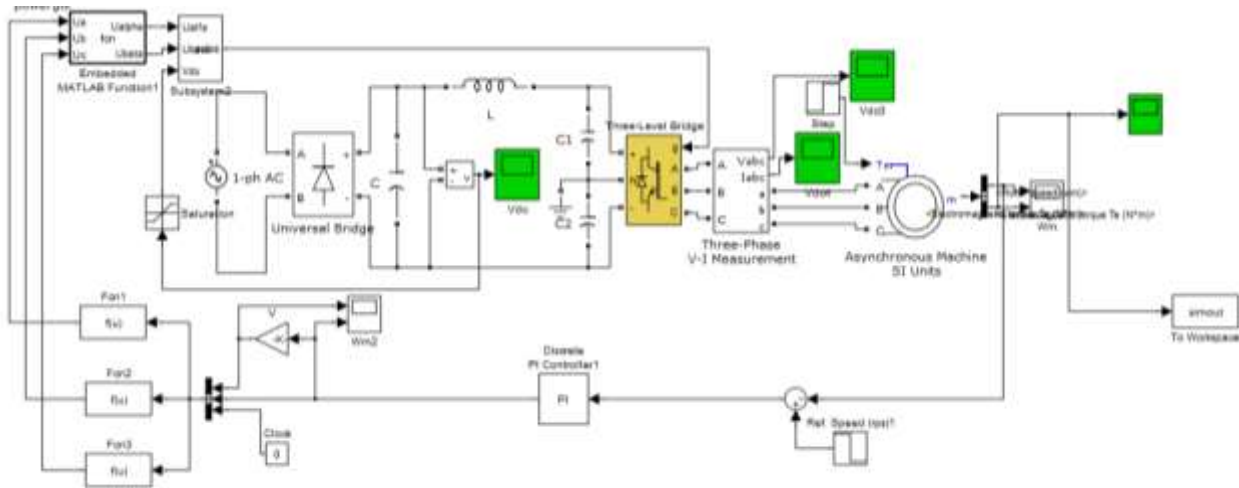


Figure:8 Simulation Model of Space Vector PWM with closed loop PI control

The simulation result of Space Vector PWM with Close loop PI control with induction motor is shown in below figure. The result shows that the peak torque is 70 N.m.

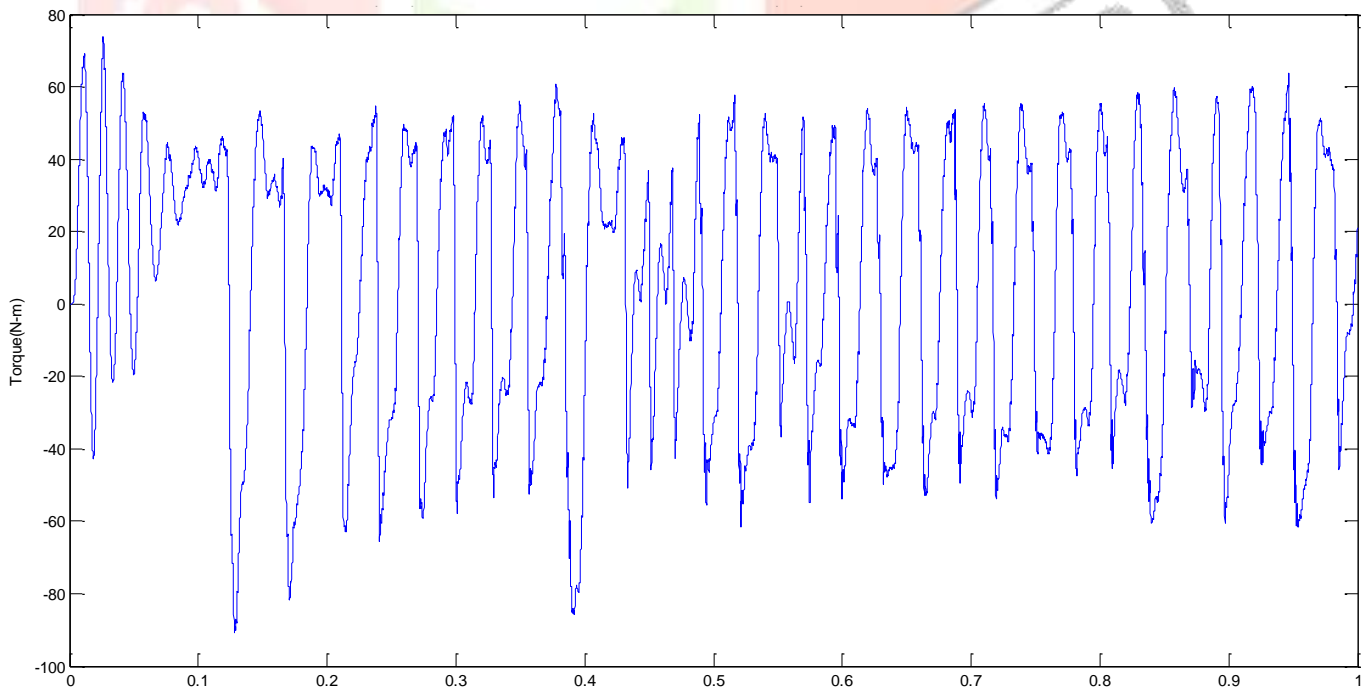


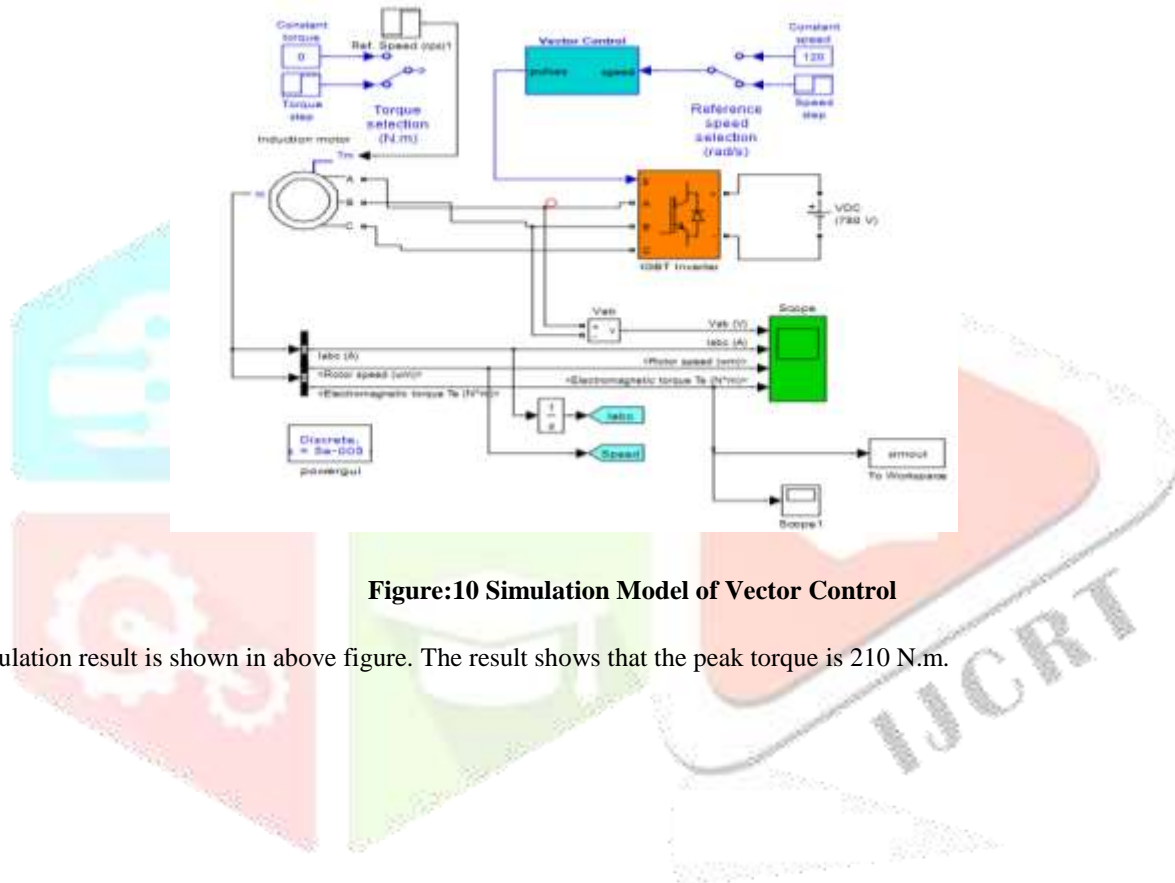
Figure9:Torque-Speed Characteristics of SVPWM

## 2.4 VECTOR CONTROL

There are number of speed control technique for induction motor among them scalar control technique is easy to implement as well as it gives good response in steady state condition but the dynamic response is poor. Due to inherent coupling effect the dynamic response is not good. The another speed control technique is vector control technique. As the name suggest the magnitude and phase angle both can be controlled in this scheme.

In vector control scheme, the dynamic model of induction motor is consider which gives good performance in steady state as well as transient condition. The dynamic model is made by converting three phase quantity to two phase quantity called as d-q axis.

In vector control scheme the induction motor is controlled like dc motor wherever the torque and flux parts are decoupled.



**Figure:10 Simulation Model of Vector Control**

The simulation result is shown in above figure. The result shows that the peak torque is 210 N.m.

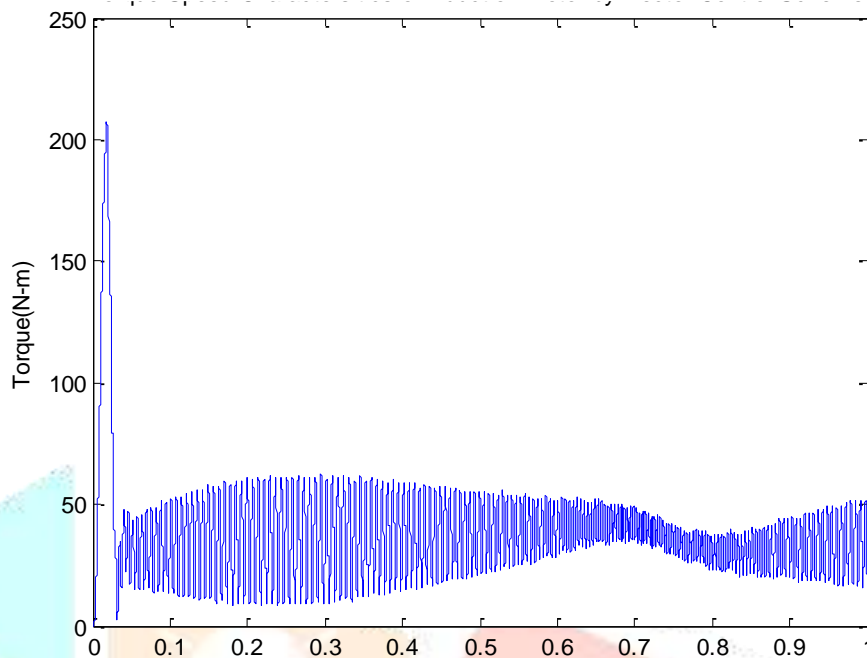


Figure11: Torque-Speed Characteristics of Vector Control

2.5 DIRECT TORQUE CONTROL(DTC)

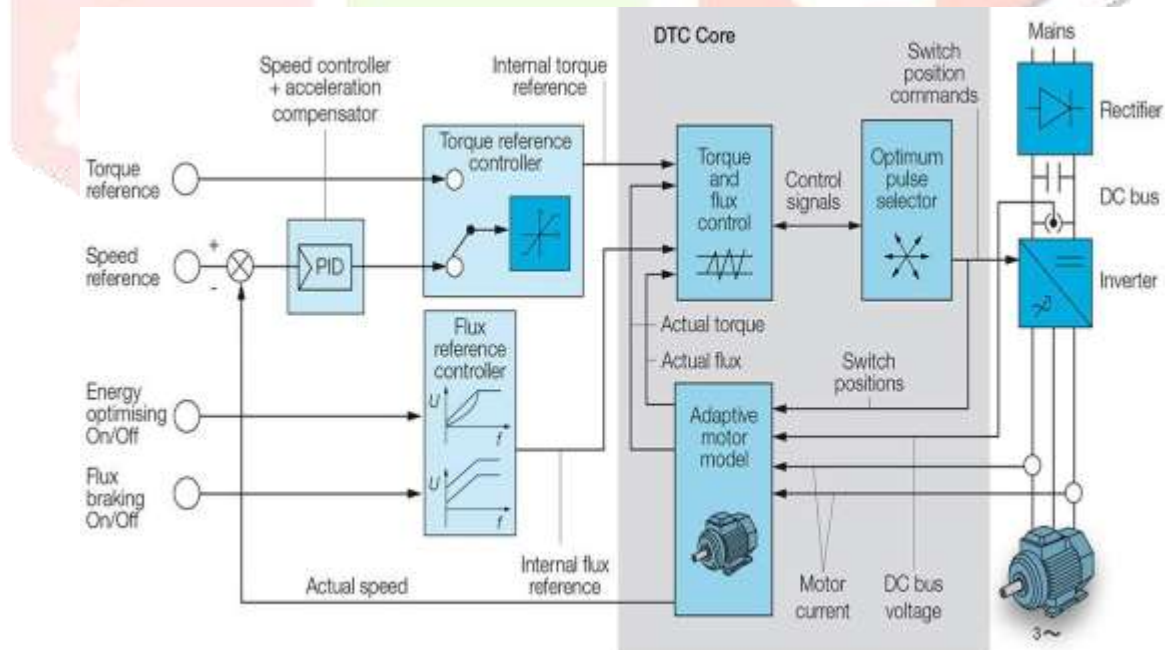
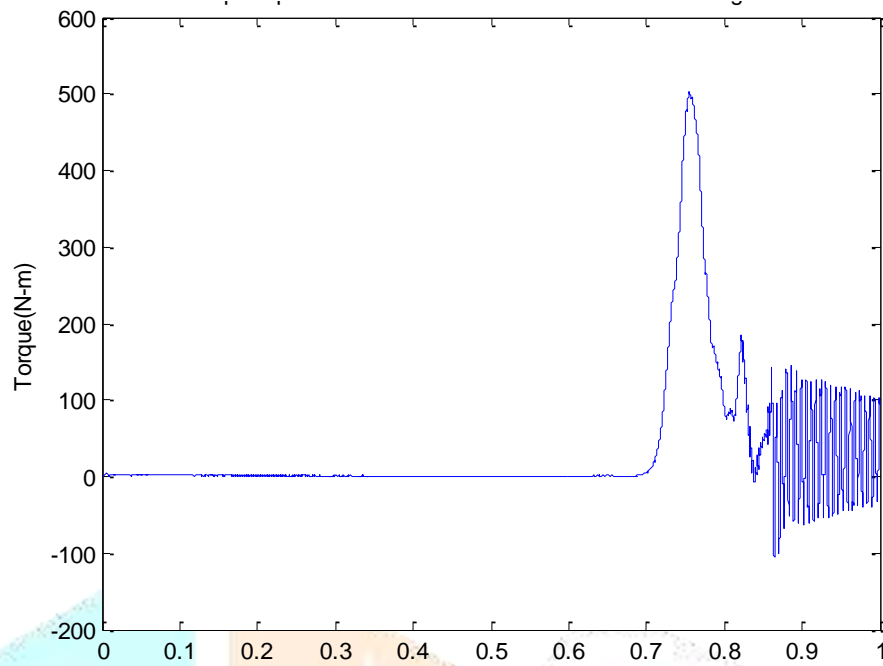


Figure12 :Model of DTC

Direct torque control is the advance control technique where the torque of the motor is controlled directly without any hall sensor which is there in vector control scheme. The main disadvantage of vector control scheme is that it require costly hall effect sensor which make the scheme complicated while in direct torque no any hall effect sensor is required.

The DTC model is shown in above figure. It consist of two separate loop, one for torque control and another for speed control. So, in direct torque control the torque and speed can be controlled undependably.

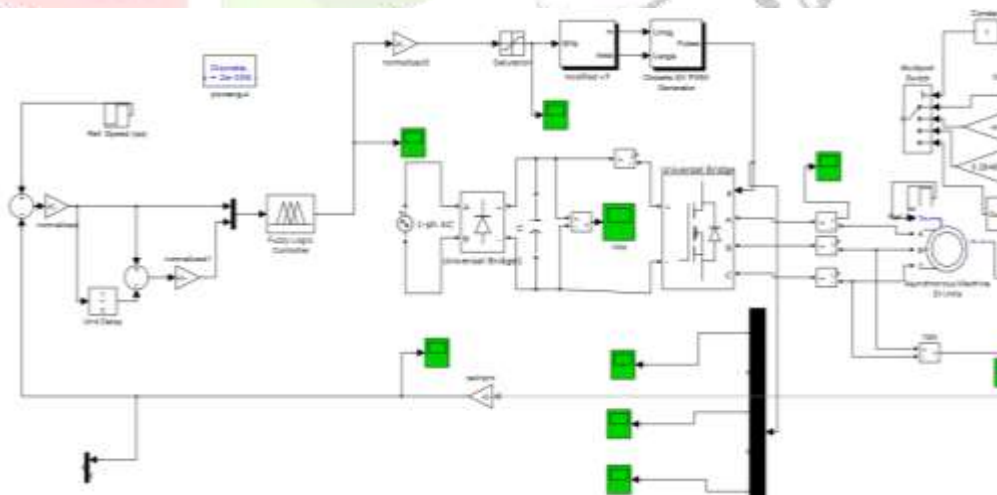


The simulation result of SVPWM DTC control induction motor is shown in below figure. The result shows that the peak torque is 500 N.m.

**Figure13: Torque-Speed Characteristics of DTC**

**2.6 FUZZY LOGIC CONTROL(FLC)**

Now a days artificial intelligence (AI) based speed control is very accurate method as this scheme is human thinking process. Fuzzy Logic based control(FLC) is one type of artificial intelligence (AI) control where the logic is based on human thought process. Fuzzy Logic based control(FLC) is perfect control method as it is consider nonlinearity and dynamic condition. The main advantages of Fuzzy Logic based control(FLC) is that it does not required any perfect mathematical model.



**Figure:14 Simulation Model of FLC**

The simulation result of v/f control by Fuzzy Logic control induction motor is shown in below figure. The result shows that the peak torque is 600 N.m.



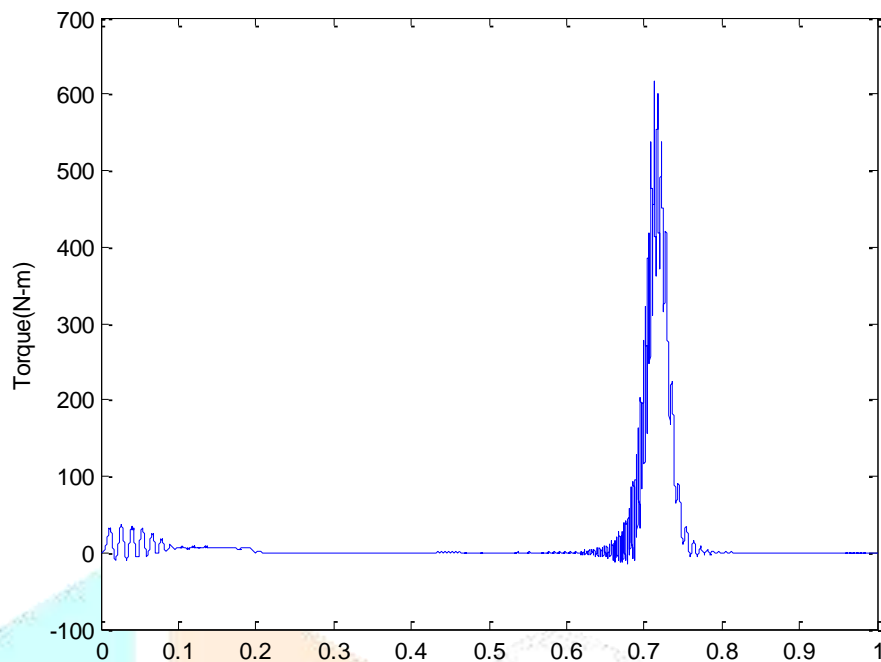


Figure15: Torque-Speed Characteristics of FLC

## II. COMPARISON DIFFERENT SPEED CONTROL METHODS OF AN INDUCTION MOTOR

Table 2 Comparison between different types of speed control techniques

Sr. Number	Technique	Maximum Torque(N.m)
1	V/f by PWM	1100
2	V/f by SVPWM	138
3	SVPWM based Close loop control with PI	70
4	Vector Control	210
5	DTC	500
6	V/f control by Fuzzy Logic	600

The Table 2 shows the comparison between different types of speed control techniques of an induction motor drive.

The degraded performance for a sampling time Scalar control with variable voltage variable frequency (PWM) is easy to implement, however the inherent coupling result (that is each the flux and therefore the force are functions of voltage or current and frequency) offers sluggish response and therefore the system is susceptible to instability due to a high order system result. When the electrical converter operates within the sinusoidal mode of SVPWM, the DC link voltage of the electrical converter isn't absolutely used. an appropriate over modulation theme is needed to beat this drawback. So, it's helpful in up DC link voltage utilization, reducing commutation losses ,THD and optimization of shift patterns also. But, once the amount of the electrical converter will increase, the implementation of area vector modulation becomes cumbersome thanks to the problem in crucial the situation of reference vector, calculation of on-times and enormous range of switching states.

At present, the PI controller is most generally adopted in industrial application because of its straightforward structure, simple to design and low value. The closed-loop methodology offers a a lot of precise answer to dominant the speed than the open-loop methodology. Further, the closed-loop technique controls the force too, that isn'texhausted open-loop management methodology. The closed-loop methodology contains an error management loop, as a result of the slip is proportional to the force.

Fast response of vector control build it higher than different technique of speed control of induction motor, By victimization this technique we tend to attend most response in minimum time .By result analysis amendment in load torque speed attend reference speed in minimum time, by comprise with scalar managementtechnique this technique is quick correct and management variable speed of induction motor. We are able to management speed by varied parameters of motor, load torsion, load limit price. Its sharp and correct operate of flux and speed management. By redefining the most force and acceleration limit parameters the increase time might even be changed simply.

Superior force response is simply one feature of DTC. The technology offers more client edges, together with no want for motor speed or position feedback in ninety fifth of applications. Thus, installation of pricey encoders or alternative feedback devices is avoided. It conjointly having benefits like correct force and speed management all the way down to low speeds, yet as full startup force all the way down to zero speed, glorious force dimensionality, high static and dynamic speed accuracy.

Fuzzy logic provides an exact level of artificial intelligence (AI) to the controllers since they fight to imitate the human thought method. This facility isn't offered within the standard controllers.

## CONCLUSION

It can be concluded that every control schemes have advantages and disadvantages. Scalar control technique called as V/f control is a low cost method, simple and immunity to errors of feedback signals. Scalar control methods consist of disadvantages like sluggish response and the system instability due to high order system effect. The results of simulation shows that PI controller based SVPWM gives good dynamic performance compared to the open loop V/f. The SVPWM is better compared to SPWM, but SVPWM technique is difficult to implement. DTC gives sharp and accurate function of flux and speed. Conventional V/f with fuzzy logic based V/f can be compared and result shows that the peak torque can be reduces and motor give smooth response. At last it can be concluded that the artificial intelligence based fuzzy logic control gives better performances in both transient and steady states condition compared to conventional PI controller.

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