



Design and Implementation of a V/F Controlled Three-Phase Induction Motor Drive Employing Voltage Source Inverter and SVPWM Technique

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Abstract-This paper presents a simple and efficient control strategy for both open-loop and closed-loop operation of a three-phase induction motor driven by a Voltage Source Inverter (VSI). The proposed system employs Space Vector Pulse Width Modulation (SVPWM) to generate high-quality switching signals for the inverter. A variable voltage and variable frequency (V/F) control technique is used to regulate the motor speed while reducing the starting current. A Proportional-Integral (PI) controller is incorporated in the closed-loop system, and its gain parameters are obtained using an embedded function for improved dynamic response. The proposed control method enhances the stability of the induction motor under varying operating conditions and provides smooth speed regulation with reduced torque ripple. Furthermore, the SVPWM-based inverter improves voltage utilization and minimizes harmonic distortion, resulting in better overall drive performance. A comprehensive simulation model is developed to evaluate the motor performance under different external load torque conditions. The simulation results demonstrate that the proposed system effectively tracks the reference speed and responds satisfactorily to changes in external torque, achieving reliable and efficient operation.

Keywords-Three-Phase Induction Motor, Voltage Source Inverter (VSI), Space Vector Pulse Width Modulation (SVPWM), V/F Control, PID Controller, Embedded Function, Speed Control.

I. INTRODUCTION

In recent times, three-phase induction motors have seen extensive utilization in industries owing to their plethora of appealing characteristics. These motors exhibit high reliability in harsh environmental conditions, possess self-starting capabilities, maintain nearly stable operation, and come with cheap costs and require maintenance [3]. PWM-VSI are widely employed as successfully drives for asynchronous motor, offering significant affordability and low THD [1]. It stands out caused by its big usage of the DC and minimal THD refer to previous methods [2], [6]. Recent research focuses on optimizing VSI parameters to enhance predictive accuracy [4], [9].

Various methods exist for controlling the beginning speed and current of three phase IM. While field-oriented control exists common for speed regulation, applications requiring a wide speed range often adopt capricious supply voltage with capricious frequency, as implemented in this study. Conventional proportional-integral (PI) controllers are employed to regulate motor speed by adjusting the frequency as well as amplitude inputs via

SVPWM Simulation chunk based on error signal between desired and actual speeds. A detailed Simulink implementation of SVPWM for three-phase inverter control is available in reference [7].

In comparing modulation strategies, SVPWM enjoys wide applicability due to its lower THD, flexibility in implementation, efficient voltage utilization, and high

efficacy [8],[12]. Control signals from SVPWM drive the many power switching methods in the three phase VSI, subsequently powering the three phase IM. Explore typically commence voltage & frequency control with an arrangement to achieve optimal starting characteristics. Consequently, implementing a protection system becomes imperative to prevent any potential damage to the IM. [10], [14]. the V/F arrangement initiates at zero and moderately ramps up to the ending arrangement. The progressive increase allows the beginning currents to ascend from zero until reaching the rated values.

A. Approach to Speed Regulation

The administrative aspects of IM (Induction motor) encompass 2 primary facets. Firstly, there's the primary to minimize the beginning current by employing fluctuating supply voltage. Secondly, there's pursuit of speed control, achievable through either closed loop or open loop systems,[13]. Numerous methods exist for regulating speed, with the most prominent ones being soft start mechanisms utilizing a storehouse of resistors and fluctuating frequency approach, within the scope of this paper. The specifications for the 3 phase squirrel cage model in Simulation MATLAB are as follows: 5.4 Hp (4 KW), 400V, 50Hz, and 1430 RPM [15]. The phase voltage is determined by serving as the input voltage supply for the controller. The rated torque can be calculated as follows:

$$\text{Torque } T = \frac{\text{power}}{\text{radian speed}}$$

The equation provided establishes the relationship between the synchronous speed n_s , Rotor speed n_r as follows: To initiate the machine from a standstill (zero speed), the slip value $S=1$ is inputted into the beginning

$$n_r = n_s(1 - s)$$

methods within the cluster of the motor. In this process mainly calculated torque and rotations of machine

B. Initiating and Controlling the Current During the Starting Phase

Control of the starting current involves a gradual increment in the source, ranging from initial voltage to high voltage. the motor speed is corresponding to frequency and reciprocal proportional to poles. This is achieved by employing a ramp signal with an amplitude of 1, the peak phase voltage. The resulting Voltage ensures a smooth increase in the supply voltage, which remains constant once the motor is in operation. The simulation signals are reiterate sequence.

II. PROPOSED SYSTEM

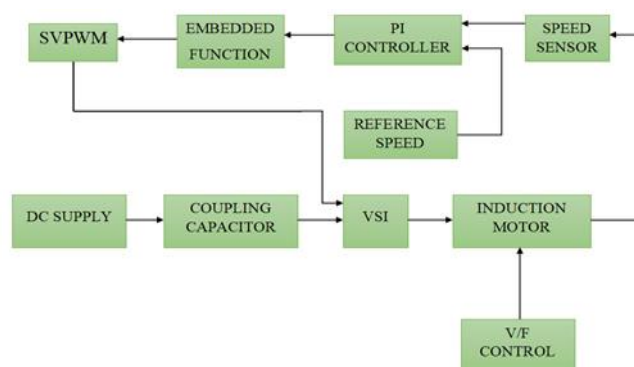


Fig.1. Proposed Method Block Diagram

A. The operation involves several key steps & processes. Here is an overview of how the system works

The DC supply is connected to the Coupling Capacitor which gives supply to the VSI. The Induction motor takes the Supply from VSI. The V/f control ensures the ratio of voltage to frequency remains constant, optimizing motor Performance and also controlling the starting current of the motor. The actual speed set point is inputted to the System. The PI(Speed) controller adjusts the output to minimize faultsto actual speed and reference speed. This is given to the Embedded function. After proper functioning the output is given to SVPWM. SVPWM generates the switching signals for the VSI (connected to the speed controller).

B. SIMULATION DIAGRAM OF THE PROPOSED SYSTEM

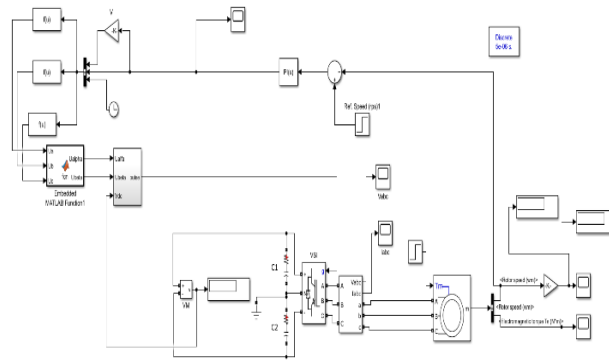


Fig.2.Closed Loop

The Simulink model illustrating the implementation of SVPWM in its entirety is depicted in Fig.3. the sectors as shown in below fig.4 it has N, T2, T these three sectors are splitting each sector have 6 sectors and pulses like Tcm1 Tcm2, Tcm3, the three sectors each sector lengthening 1/6 part of the circle. Fig.3 illustrates the simulation calculations to sectors by using atlab.

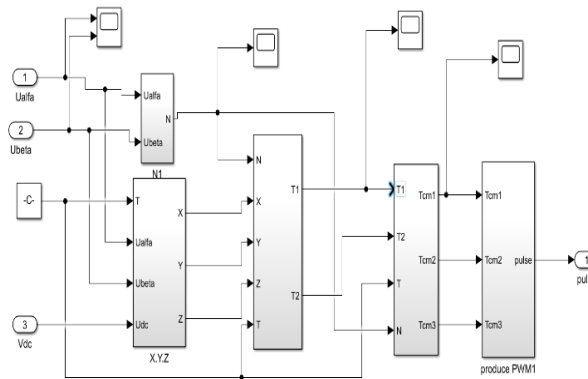


Fig .3. Simulation for SVPWM

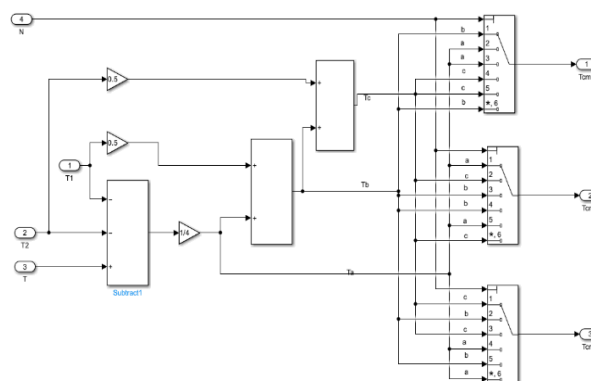


Fig .4. Sector Spanning

III. SIMULINK RESULT(OPEN LOOP)

This open loop Simulink giving the dc supply to the charged capacitors and it enhances the voltage the it converts dc to ac by using VSI and given to induction motor. the actual speed and torque is obtained. Bu using repeating sequence calculate the gain values and given to the embedded function by using these:

$$\begin{aligned} & (u(1)*\sin(u(2))) \\ & (u(1)*\sin(u(2)-(2*\pi/3))) \\ & (u(1)*\sin(u(2)+(2*\pi/3))) \end{aligned}$$

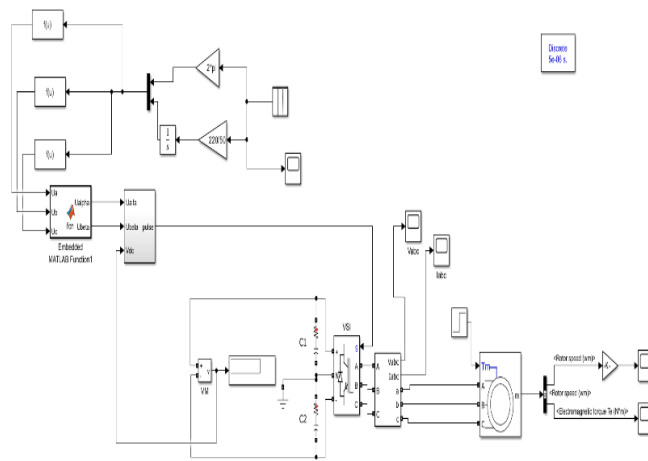


Fig.5. Open Loop Simulink

After functioning SVPWM generate the pulses. This process continuously occur when the desired output is obtained as shown in Fig.6. the open loop Simulink the outputs are given as shown in below Fig 6, 7, 8 and analyse the response of the motor.

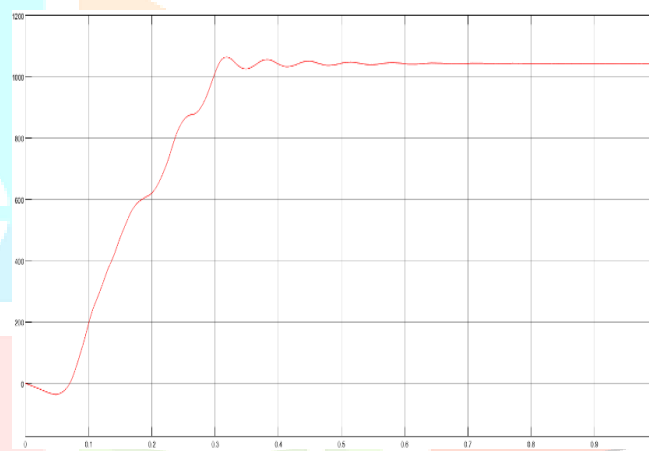


Fig.6.Speed (rpm)

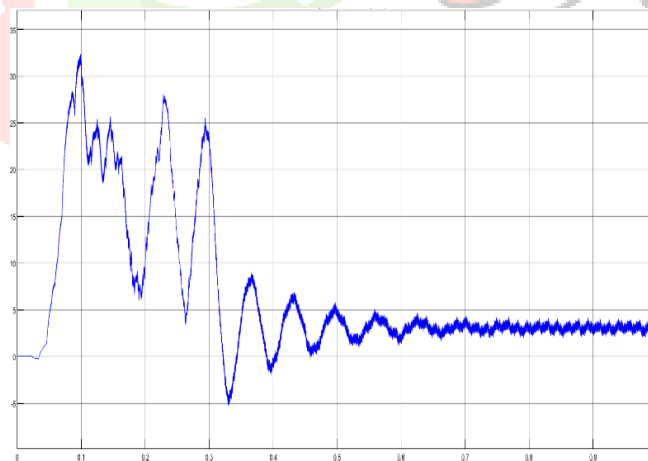


Fig.7.Torque(N-m)

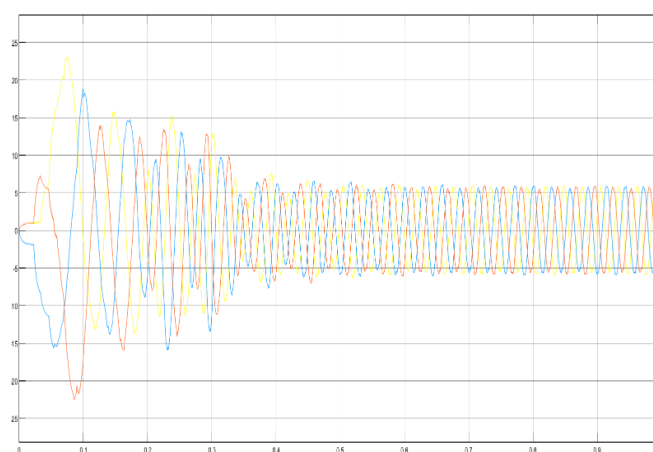


Fig.8.Currents (I_{abc})

IV. SIMULINK RESULT(CLOSED LOOP)

Fig 2 illustrate the Simulink model for the closed loop system. The closed and open loop both are similar in this system giving the dc supply to coupling capacitor and it enhances the voltage and by using inverter convert dc to ac and giving to induction motor, it gives the actual speed and torque. Reference speed is given to PI controller and it compares the both actual speed and reference and gives the desired to the embedded function gives to SVPWM it the pulses by using VSI.as shown the Fig9, 10, 11 are the closed loop response analyses speed, torque and currents. In this method proportional and integral values are used $P=0.02$ and $I=1.1$ and $D=0$.

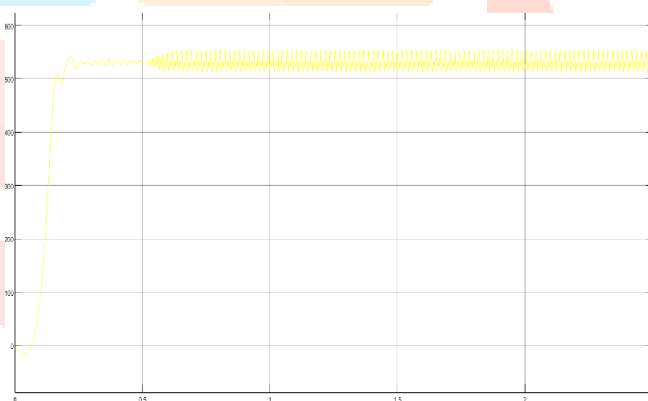


Fig.9.Speed(rpm)

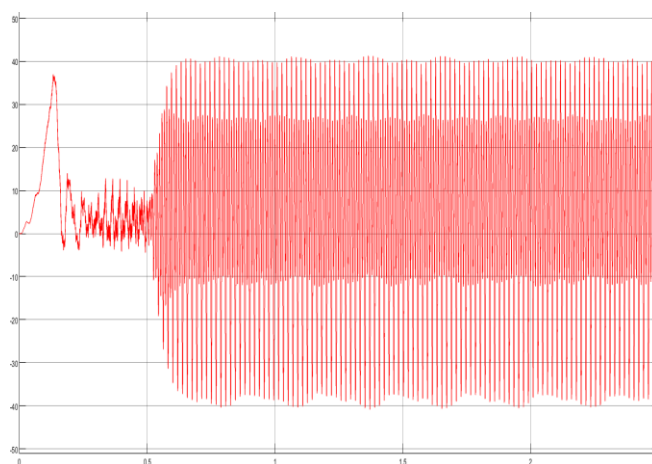


Fig.10.Torque(N-m)

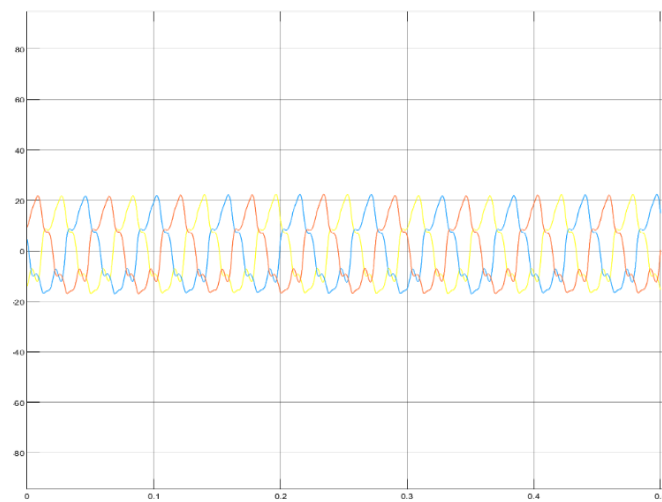


Fig.11.Currents (I_{abc})

V. CONCLUSION

The proposed MATLAB/Simulink model has been successfully developed to control the starting current and speed of a three-phase induction motor. The drive system utilizes a Voltage Source Inverter (VSI) with Space Vector Pulse Width Modulation (SVPWM) to achieve efficient motor operation. Compared with conventional techniques, the proposed method provides improved speed control while maintaining a lower Total Harmonic Distortion (THD). The SVPWM technique enhances the quality of the inverter output voltage, resulting in smoother motor performance and better power utilization. Furthermore, the developed control strategy ensures reliable operation under different operating conditions, and the simulation results confirm its effectiveness over existing methods.

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