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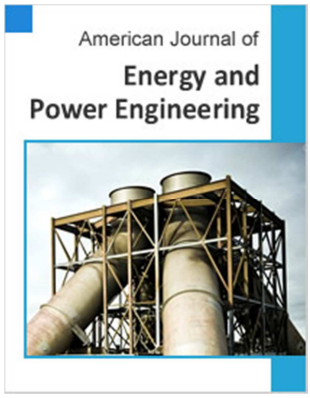

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High Performance of v/f Method Based on PID Controller with Space Vector Modulation to Modified Permanent Magnet Synchronous Machine

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Abstract
This paper deals with the problem of v/f control of permanent magnet synchronous machine which is the open loop v/f method is inherently unstable. In order to overcome the v/f problems, the pi control is used to optimize the rotor speed and to achieve close loop for system as results to enhance the PMSM system. In addition, the space vector modulation is used to eliminate the pwm problems and to modified the efficiency of system. The simulation results of system with PID controller and SVM demonstrate that the system is more effective with high performance.

1. Introduction

The v/f control is also called V/HZ control or scalar control and it is simple with relatively easy but expensive to implement. In the last decade, the use of permanent magnet synchronous motors PMSM in motion control application has significantly increased because of their features like high efficiency and high power density [1]. In order to enhance the performance of power system stability, the field orient control is used to adaptive speed and to modified the whole system [2], [3].

Once of method of power system used sensorless control o estimate the rotor speed by using the electromotive force [4] and kalman filter [5, 6]. In addition, v/f method can be used on behalf of field orient control [7-10] because of its simplicity and consequently the is more stable.

The researchers in [8-10] achieved stability to control v/f method with pmsm without dumper winding and the DC link is used to optimize the algorithm which decrease the main power to permanent magnet synchronous motor. Various techniques were reported for enhanced of V/F method based on machine [11] [12] [13] but it caused increase the cost and reduce the reliability

In this proposed method, the v/f control can be enhanced by using the space vector modulation with pid control to counteracted the weakness of open loop system that is used in v/f method as results to improve the efficiency of the whole system.

2. Theoretical Background

Permanent Magnet Synchronous Machine

The mathematical model of the pmsm is used for analyzing the change in the dynamic behavior of the motor. The change in the dynamic behavior of the motor affects the motor parameters such as speed, torque, resistance, flux and etc. So, the dynamic model is needed for analyzing the behavior changes of the induction motor. The dynamic model of the induction motor is derived by transforming the three phase quantities into two phase direct and quadrature axes quantities. The mathematical equation of stationary reference of the motor is given as following.

$$V_{ds} = i_{ds}(R_s + L_s p) + i_{dr}.L_m p \quad (1)$$

$$V_{qs} = i_{qs}(R_s + L_s p) + i_{qr}.L_m p \quad (2)$$

$$V_{dr} = i_{ds}.L_m p + \omega_r.L_m.i_{qs} + i_{ds}(R_r + L_r p) + i_{qr}.\omega_r.L_m \quad (3)$$

$$V_{qr} = i_{qs}.L_m p - \omega_r.L_m.i_{ds} + i_{qr}(R_r + L_r p) - i_{qr}.\omega_r.L_r \quad (4)$$

Then, the motor flux is expressed in terms of current and inductance. The expression of d-q axes flux linkages of rotor and stator windings are described as follows.

$$\psi_{ds} = \psi_{dr} = i_{dr}.L_r + i_{ds}.L_s \text{ and}$$

$$\psi_{qs} = \psi_{qr} = i_{qr}.L_r + i_{qs}.L_s \quad (5)$$

Where, V_{ds}, V_{qs}, V_{dr} and V_{qr} are the d-q axes voltages of stator and rotor respectively. Then, i_{ds}, i_{qs}, i_{dr} and i_{qr} are the d-q axes currents of stator and rotor respectively. The resistance and inductance of the stator and rotor winding are denoted as R_s, R_r, L_r and L_m respectively. The stator and the rotor flux of the motor are described as ψ_{ds}, ψ_{dr}, ψ_{qs} and ψ_{qr} respectively.

The electromagnetic torque of the motor is obtained from the inductance and the d-q axis current. The d-q axis current of the motor is obtained from the flux linkages that occurred in the stator and rotor of the motor. The expression of the electromagnetic torque that is produced by the motor is given as follows.

$$T_e = \frac{3}{2}.P.L_m.L_r.(i_{qs}.i_{dr} - i_{ds}.i_{qr}) \quad (6)$$

$$\theta_e = \tan^{-1}\left(\frac{\psi_{qs}}{\psi_{ds}}\right)$$

Where, T_e is the electromagnetic torque which is produced by the induction motor,P is the number of poles, and θ_e is the angle between flux linkages in the stator and rotor windings.

The equivalent circuit corresponding to these equations is illustrates in Figure 1.

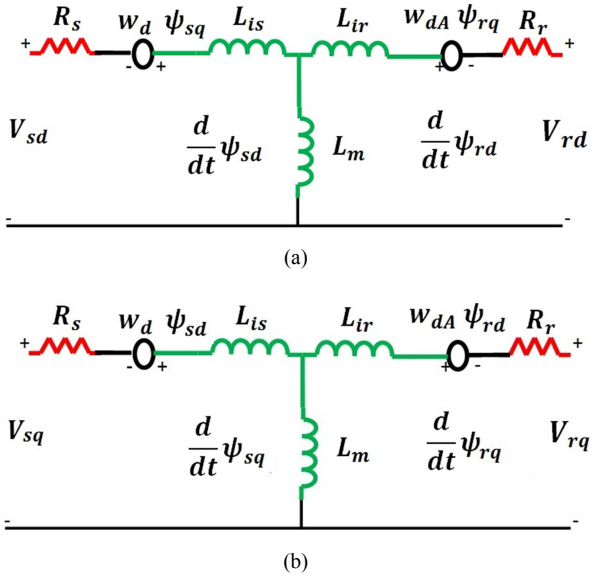

Figure 1. *The equivalent circuit of PMSM (a) in d-erame (b) in q- frame.*

Space Vector Modulation (SVM)

Space vector modulation is an algorithm for the control of pulse width modulation (PWM). It is used for the production of alternating current (AC) waveforms. There are different variations of SVM that result in different quality and computational requirements. SV PWM refers to a special method of determining the switching sequence of the upper three power transistors of a three-phase VSI. It has been shown to produce less harmonic distortion in the output voltages or currents in the windings of the motor load. The SV PWM has been playing pivotal and practical role in power conversion. It is using space vector concept to compute the duty cycle of the switches which is essential implementation of digital control theory of PWM modulators. All Space Vector Modulation (SVM) techniques use a set of vectors that are defined as instantaneous space-vectors of the voltage and currents at the input and output of the converter. These vectors are produced by the different switching states that the converter is able of generating. The diagram of space vector is shown in Figure 2.

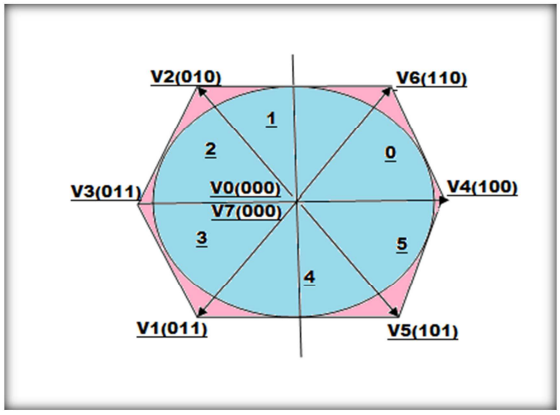

Figure 2. *Space vector diagram.*

The Basic Idea of v/f Control

The fundamental idea of v/f control can be demonstrated by assume that the stator flux linkage is constant and the resistive term is negligible. The v/f control method is also called open loop control. this method is simple and low cost to control where reduce dynamic performance is acceptable. The v/f control is heavily dependent on the selected parameters on the controllers.

3. Problem Formulation and Proposed Methodology

The pmsm drives are widely used in high performance industrial applications. In high performance systems, the speed of the machine is affected by load disturbance, parameter variations, and model uncertainties. In order to maintain the constant speed, the compensation of factors that affects the motor speed is indispensable and it is one of the important and challenging tasks. Traditionally, the speed of pmsmis often controlled by fixed gain closed loop feedback control mechanism. In fixed gain controller, the controller gains are very sensitive to the speed affecting factors. So, it is unable to perfectly control the speed of the IM. This problem can be solved by different kinds of techniques such as sliding mode control (SMC), variable structure control (VSC), self tuning techniques, adaptive controller and more. Also, the above existing controller depends on the accurate mathematical model of the system. However, there is a difficulty in developing the mathematical model of the system because the system model can't be adapted for the unknown load and parameter variations. So, the accuracy of the model and the speed of the system are affected. The vector control method has found wide acceptance in the industry. However, this control technique requires complexity to coordinate transformation, inner current control loop, and to achieve system parameters. To overcome this problem, in the paper, the scalar control based on space vector modulation (SVM) with PID controller is used. The detail of the proposed method will be described in the following section.

4. Proposed Method

In this proposed method the actual speed is used as close loop and compared with reference speed. The error between the reference speed and actual speed are applied to two PIDcontrollers. output of these PID controllersare called the reference voltages. These two voltages with clock are converted to $V_\alpha and\ V_\beta$by using clark transformation. These $V_\alpha and\ V_\beta$ are applied to SVM to generate signal which applied to inverter to operate the machine.

5. Simulation Results

The simulation of this proposed method is built in by Matlab based on toolbox of Simulink.

To demonstrates the effectiveness of this proposed method, some results of Simulink are presented. The actual speed is closely follows the reference speed as shown in figure 3.

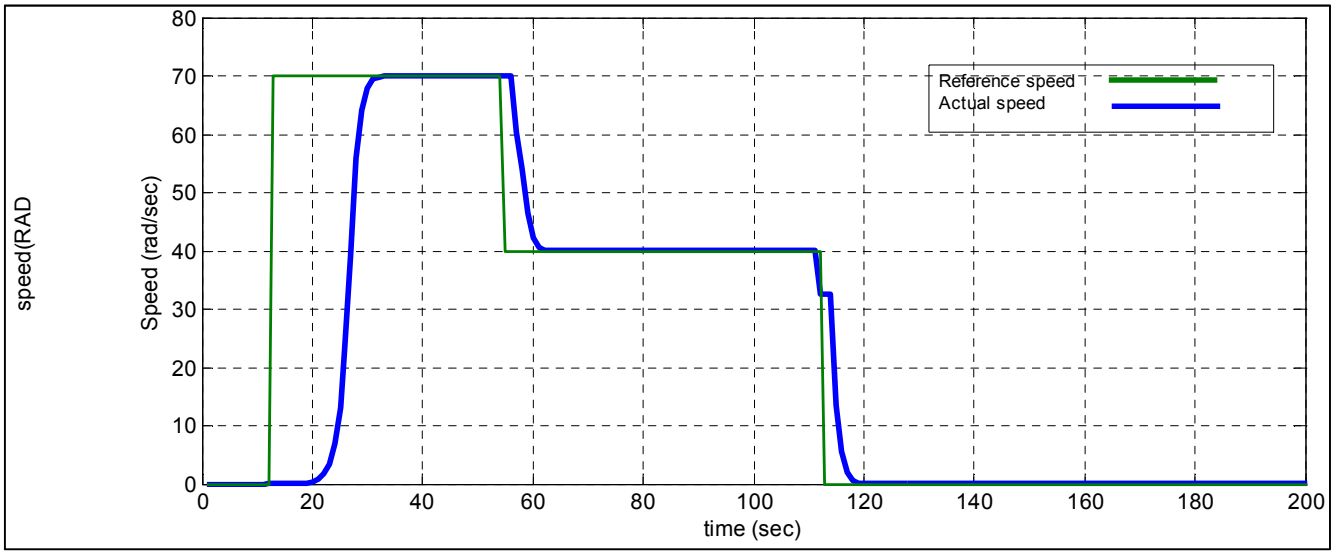

Figure 3. *The referernce speed with actual speed.*

From figure 4, it can be noted that the the load torque when change rapidely, the change of speed is trevial which demonestrate that the system control is more effectiveness and counteracted the deteriorate of system weakness.

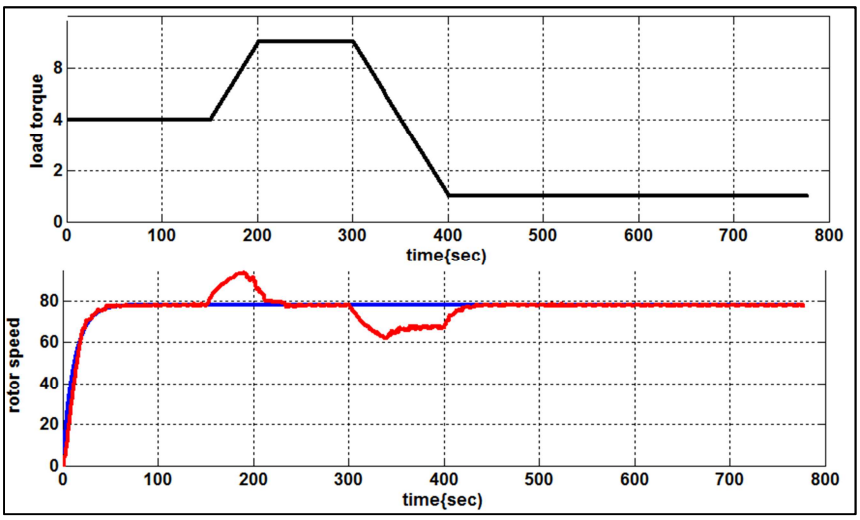

Figure 4. *The relation between load torquew with speed.*

Figure 5 shows that the output of space vector modulation which is more symetrical and synchronous that enhances the switching of transisters of inverter IGBT. The emhance of switching of inverter minimize the losses of whole system.

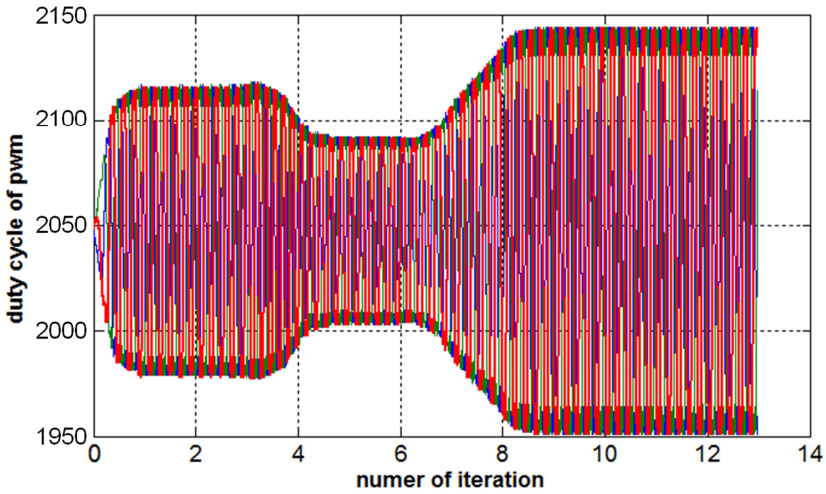

Figure 5. *Shows the output of SVM.*

The simulink of v/f control with pid controller is shown in figure 6 which consist of two pid controllers. In addition, the six out put signals of space vector modulation are applied to two level inverter. Furthurmore, the two level inverter consist of six trtansistors type IGBT.

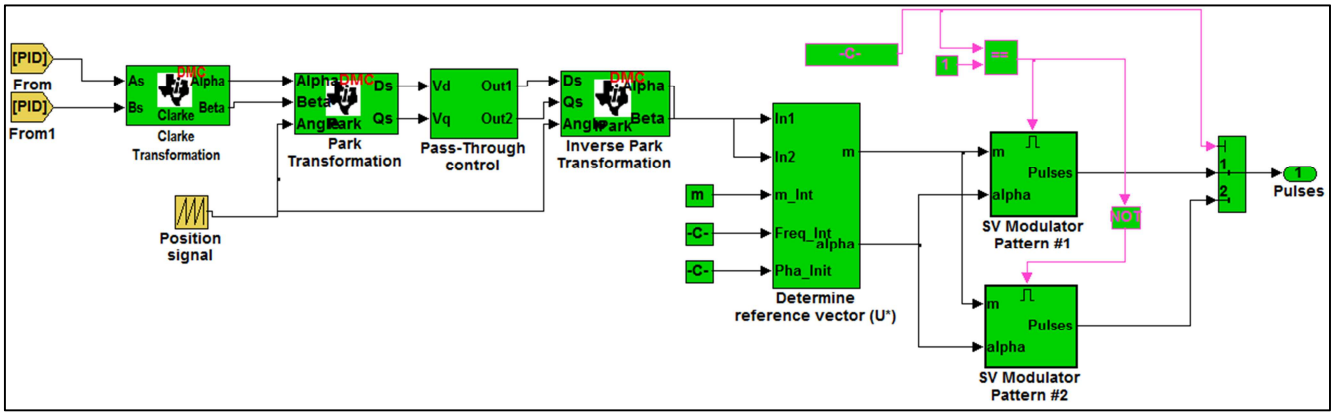

Figure 6. *Simulink of proposed method based on pid controllers.*

From figure 7, it can be sen that the number of iteration with duty sycle of space vector modulation which is more smooth and arrangement.

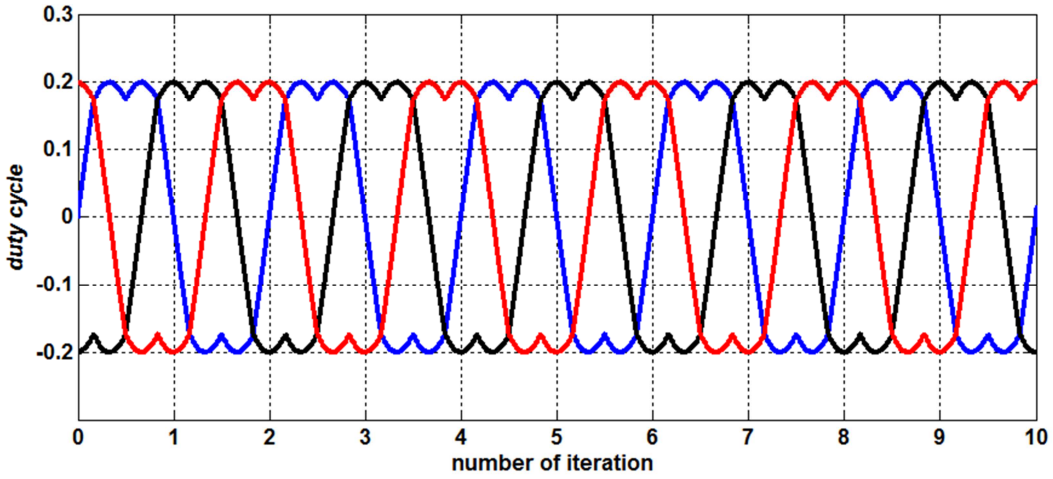

Figure 7. *The number of iteration of SVM.*

The ouput of two pid controllers are shown in figure 8. It appears that the difference between two signals is ninty degree. In addition, the relationship between the alfa beta voltage are shown in figure 9 which is free of ripple.

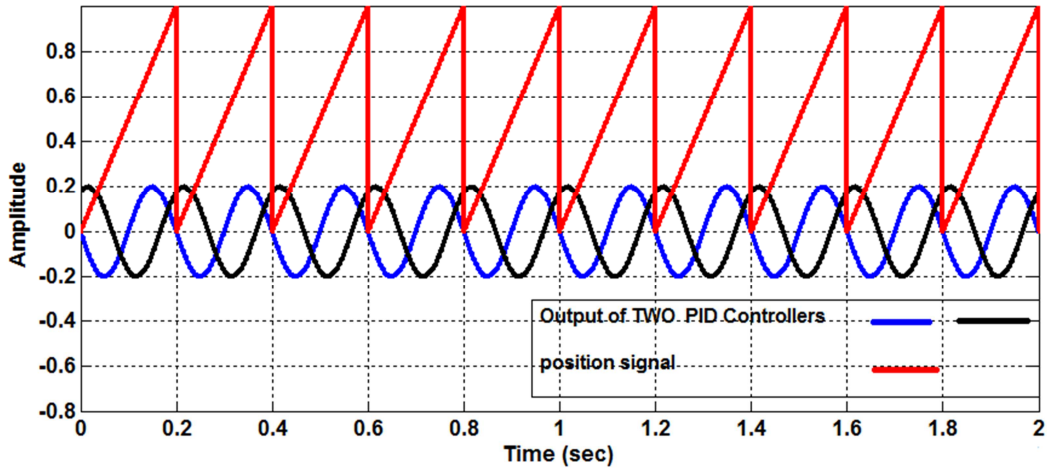

Figure 8. *Out of pid controller.*

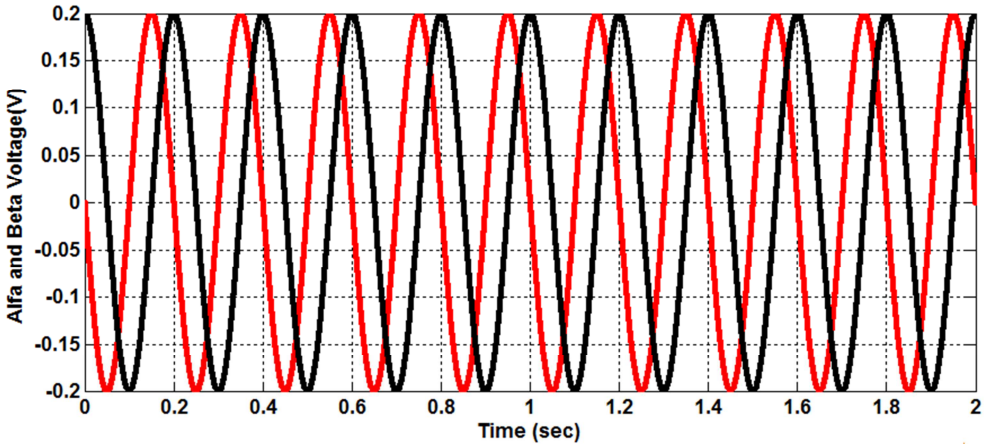

Figure 9. *Alfa and beta voltage.*

Finally, the relation between direct and quadrated voltage are shown in figure 10 which is converted based on park transformation.

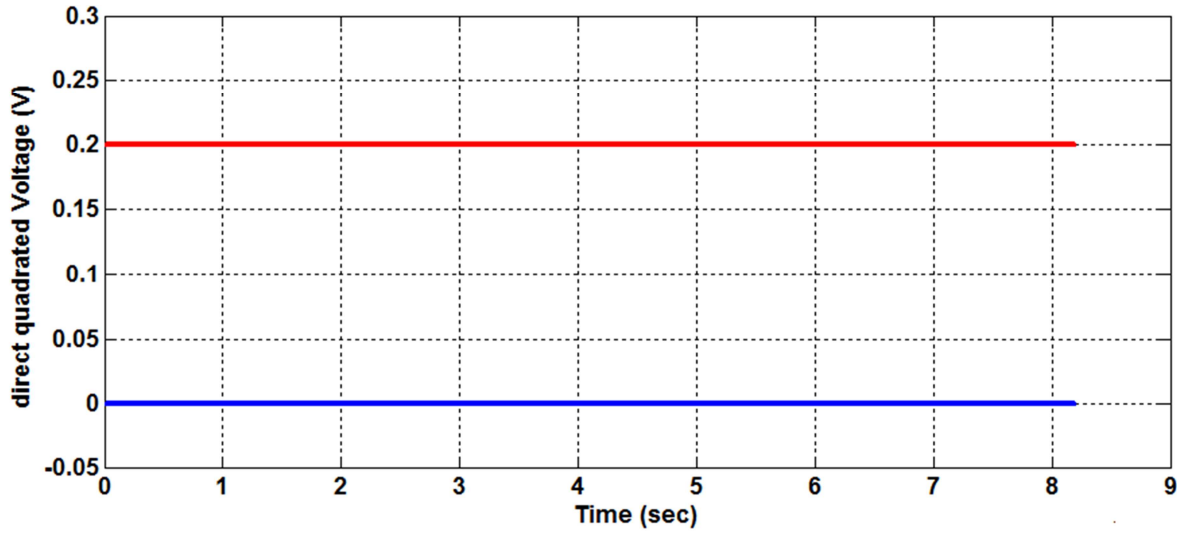

Figure 10. *D-q voltages.*

6. Conclusion

In this paper, it can be noted that several approaches have been formulated for resolving the v/f method. The simulation results of this proposed method proved that the open loop system problems of v/f method are solved based on pid controler with space vectro modulation to enhance the whole system and to eliminate the switching problem of IGBT as results to modified the system. Finally, this simulink can be validated by using the trexas instruments D-SPACE interfacing with matlab.

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