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Application of SVPWM for V/F Control of a VSI-Propelled Three-Phase Induction Motor

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Abstract—This study proposes a straightforward and effective approach for open and closed-loop control of a three-phase induction motor fed by a three-phase voltage source inverter VSI. In order to regulate VSI, the space vector pulse width modulation (SVPWM) is implemented. The starting current and rotational speed of the three-phase induction motor are both controlled by a three-phase supply whose amplitude and frequency may be adjusted. Closed-loop feedback is achieved with the help of a proportional-integral (PI) controller, whose gain values are determined with the aid of Simulink tuner. To demonstrate the motor's behaviour when subjected to external rated torque, a comprehensive Simulink model is developed. The system was shown to respond as expected in simulations when external torque values were applied.

Keywords: SVPWM, Inverter, Induction Motor, and PID Control

I. INTRODUCTION

Three-phase induction motors are becoming increasingly used in modern businesses because of their numerous useful properties. They are inexpensive to operate and maintain, start up on their own, and can maintain a steady speed for long periods of time [1]. Induction motors' efficient drives, pulse width modulation voltage source inverters PWM-VSI, are widely employed. Total harmonic distortion in PWM-VSI is minimal and the frequency range is broad [2]. In comparison to conventional PWM methods, space vector pulse width modulation SVPWM makes better use of the dc-link and produces less distortion (THD) [3, 5]. Recent efforts to enhance the parameters of VSI [6,7] have also focused on improving the accuracy of their predictions. The starting current and rotational speed of a three-phase induction motor can be modulated in a number of different ways. The induction motor's speed is often regulated using a field-oriented controller. In contrast, our study makes use of the widely-adopted strategy of combining a variable supply voltage with a variable frequency for applications in which a broad range of speeds is of concern. The speed of a three-phase induction motor is controlled using a standard PI controller. The discrepancy between the target and actual motor speed is fed into the PI controller as an input. The Simulink block of the SVPWM receives its input (amplitude and frequency) from the PI controllers' output. Reference [8] provides an in-depth look at how space vector pulse width modulation SVPWM was implemented in Simulink to regulate the functioning of a three-phase inverter. When compared to other modulation techniques like PWM, SVPWM has widespread use due to its many benefits, including minimal THD, great flexibility in implementation, high use of the output voltages, and high efficiency [9],[10]. The three-phase induction motor is driven by the control signals generated by the SVPWM, which are then sent to the six power switches in the three-phase VSI. Scientists find that a V/F ratio of 220/50 produces a significant beginning current value. Consequently, a protective mechanism is required to safeguard the induction motor [11],[13]. This work employs a progressive rise in the V/F ratio from its initial value of 0 to its ultimate value of

220/50. As a result, beginning currents may be ramped up from zero to their rated value. There are four main parts to this study. The primary strategies for regulating velocity are presented in Section II. The regulation of the beginning current is discussed in Section III. In section IV, you'll find specifics on the Simulink model used to create this suggested system. Section V of the paper wraps up the results.

II. VEHICLE SPEED REGULATION TECHNIQUES

There are two basic focuses when discussing induction motor control. The first is to use a variable supply voltage to minimise the initial current draw. As a second use [14],[15], to regulate velocity in either an open-loop or closed-loop setup. The paper's scope includes a number of methods for regulating speed, including the widely-used soft start using a bank of resistors [16] and the variable frequency drives [17],[18]. The three-phase squirrel-cage presto Simulink MATLAB model contains the following technical parameters: 5.4Hp (4KW), 400V, 50Hz, and 1430RPM [19]. The controller's input voltage is set to be (4002)/3=326.6 V, which is the peak phase voltage. How to figure out the torque rating:

$$\left.\begin{aligned} T &= \frac{power}{radian\ speed\ (w)} \\ w = \frac{2\pi * n}{60} &= \frac{2\pi * 1430}{60} = 149.75 rad/sec \\ T &= \frac{4000}{149.75} = 26.71\ N.M \end{aligned}\right\} \quad (1)$$

Connection between synchronous and rotor velocities

$$nr = ns(1 - s) \quad (2)$$

Where nr is the rotor speed, ns is the synchronous speed, and s is the motor slip. The beginning conditions into block parameters of the induction machine include the slip value s=1, which causes the machine to begin at a speed of zero.

III. CURRENT STARTING CONTROL

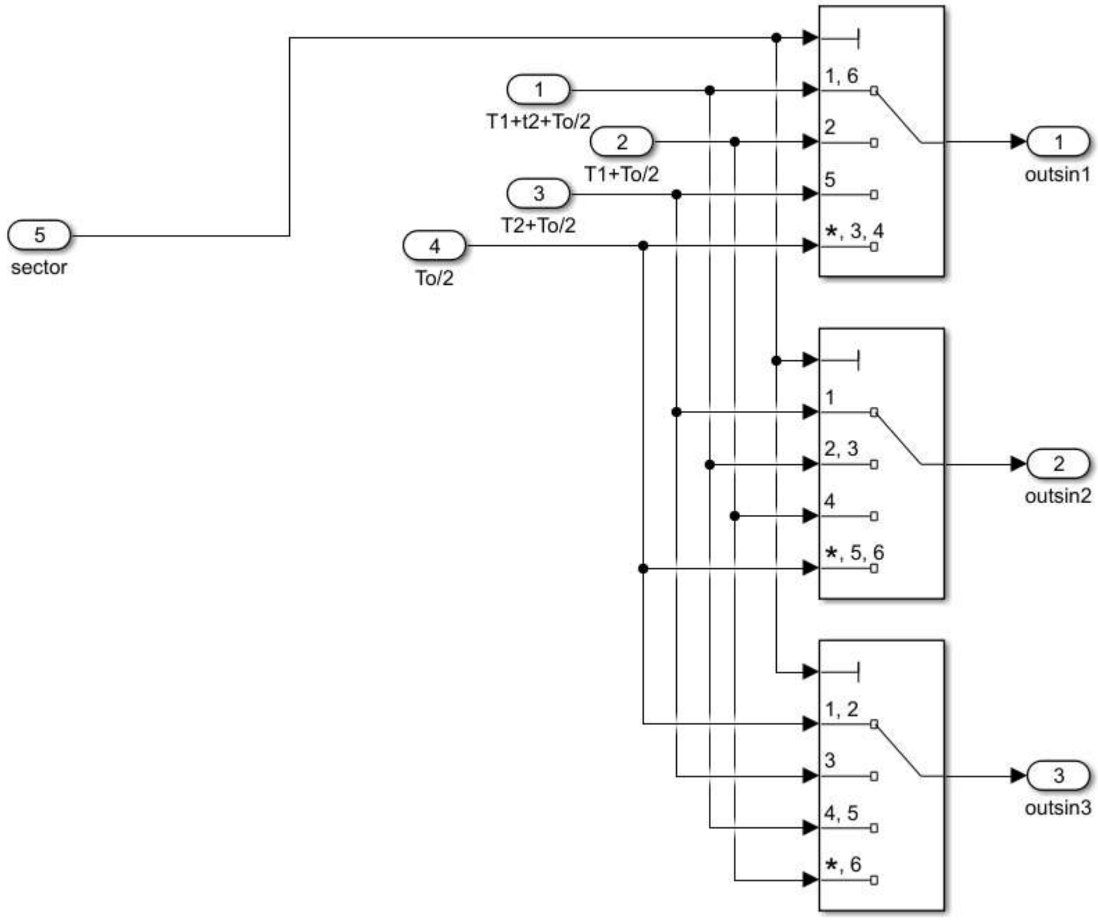
The initial current is limited by the supply voltage, which is ramped up from zero to the anticipated peak phase voltage of 326.6V. When the peak phase voltage is multiplied by a ramp signal with Amplitude = 1, the result is an output voltage that varies. As the motor spins, the supply voltage gradually rises to the set point, where it remains stable. For modelling purposes in Simulink, the ramp signal can be represented as a cyclical pattern. Induction motor speed is related to input supply frequency and inversely proportional to pole count.

$$ns = 120 f / p \quad (3)$$

Where f is the frequency and p are the number of pole pairs.

IV. Proposed System Modelled in Simulink

SVPWM breaks down the cycle into six segments for examination. Within the larger cycle, each sector accounts for sixty degrees. In Fig. 1 we see the proper sector finding Simulink model. 1a. In Fig. we see the three-phase control signals. 1b. The 2 kHz saw-tooth carrier frequency is used to modify these signals. Figure displays the generated pulses. 1c. The gating inputs of the power transistors in the three-phase VSI are linked to these pulses. As can be seen in Fig. 1, the whole Simulink model for implementing SVPWM is presented. 1d.



(a) Sector Number (sec)

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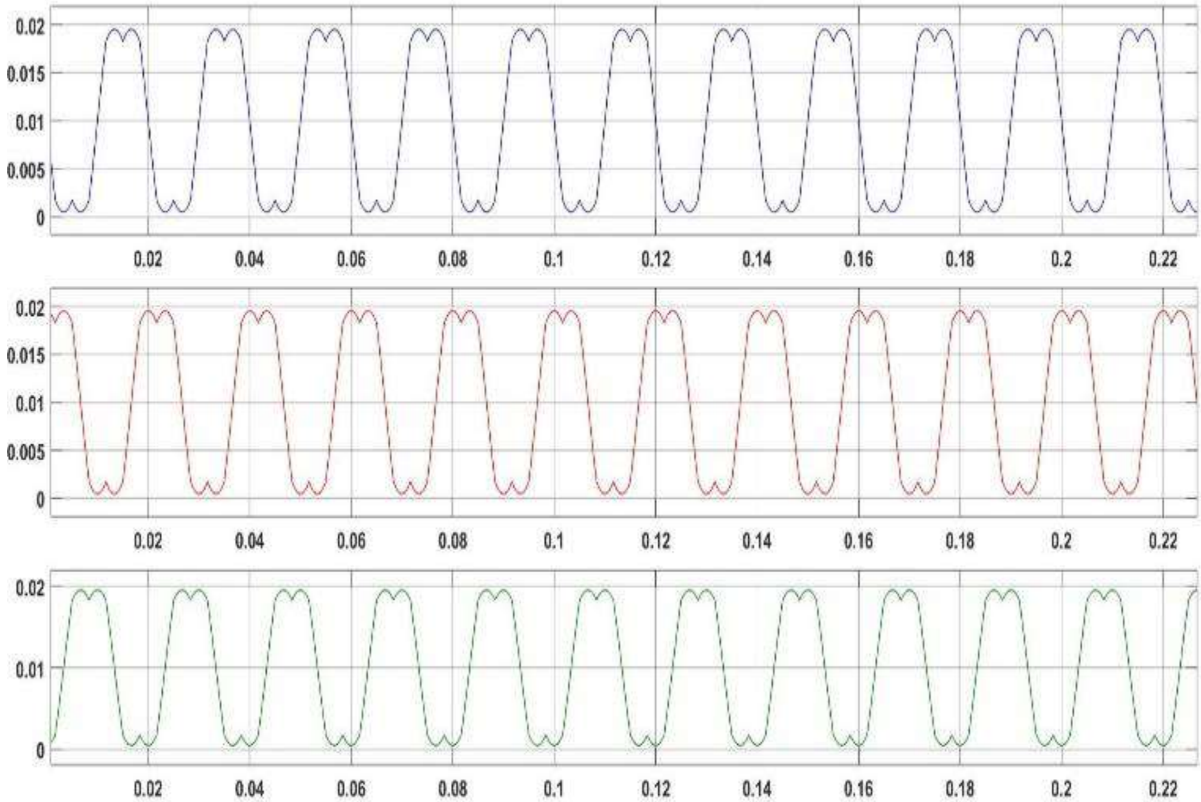

(b) Three phase-controlled signals for SVPWM

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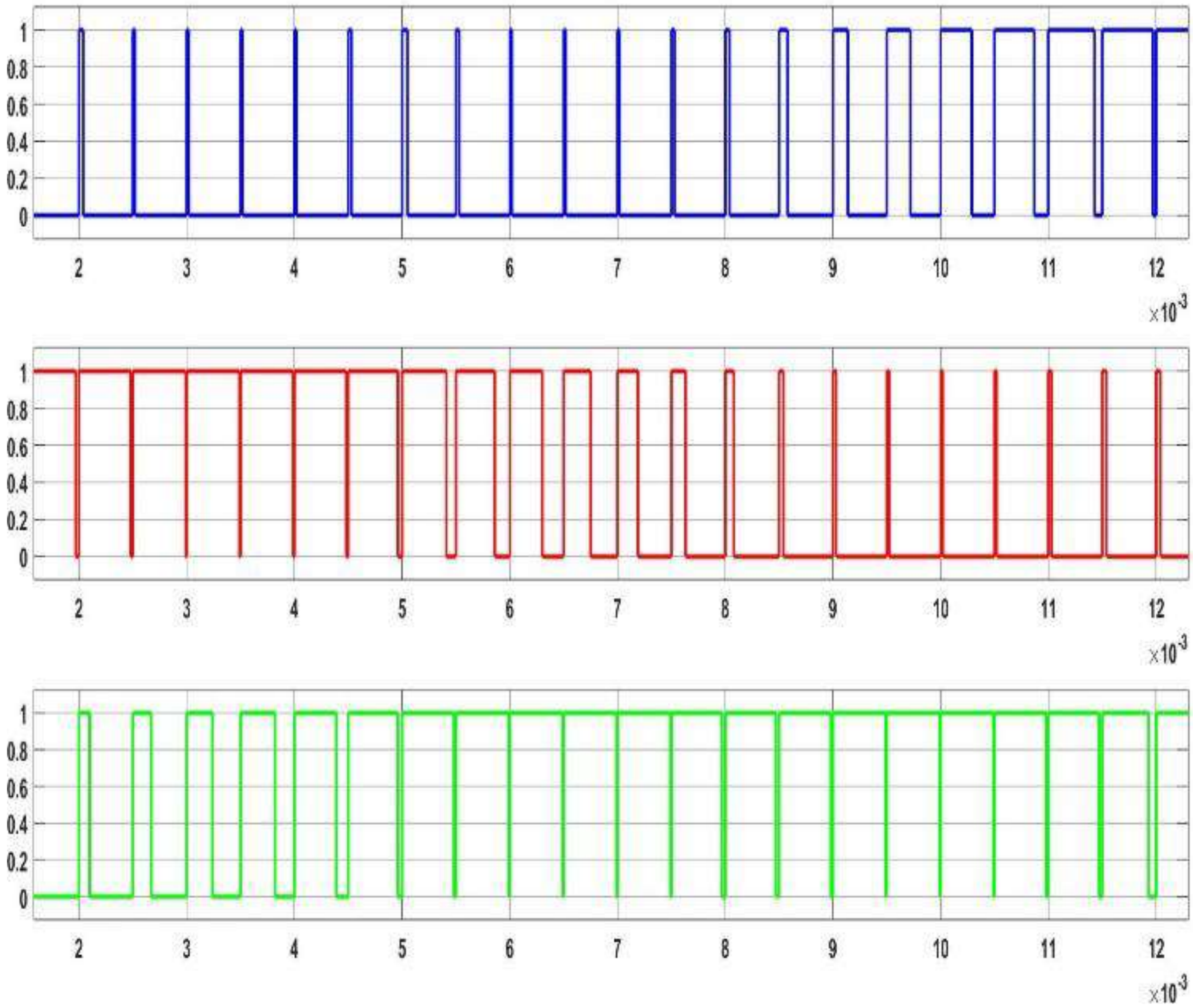
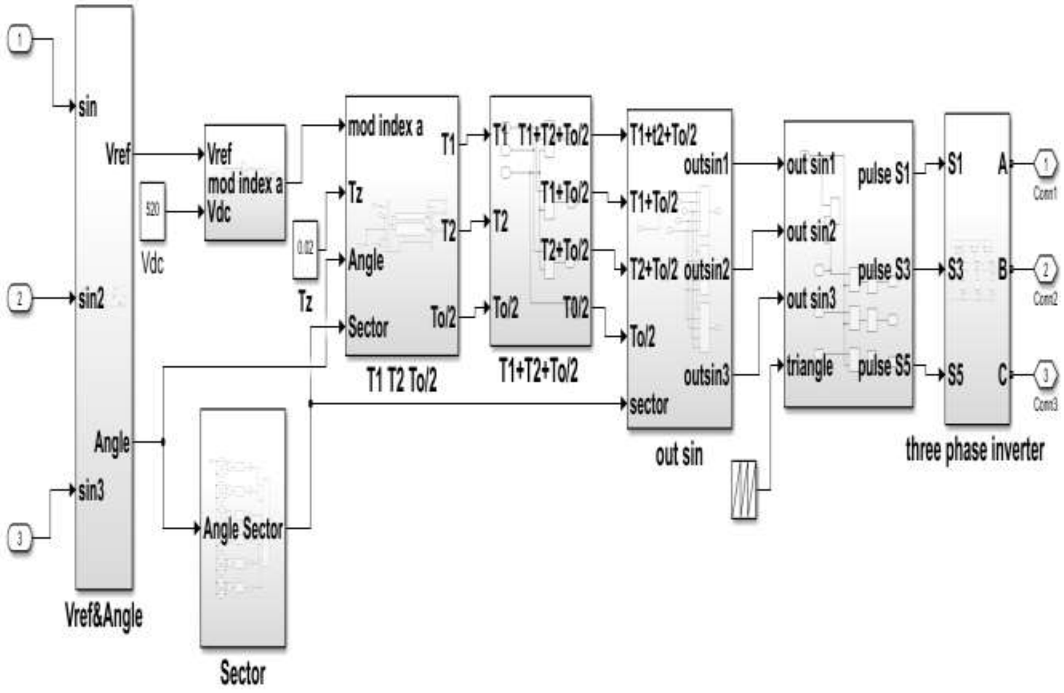


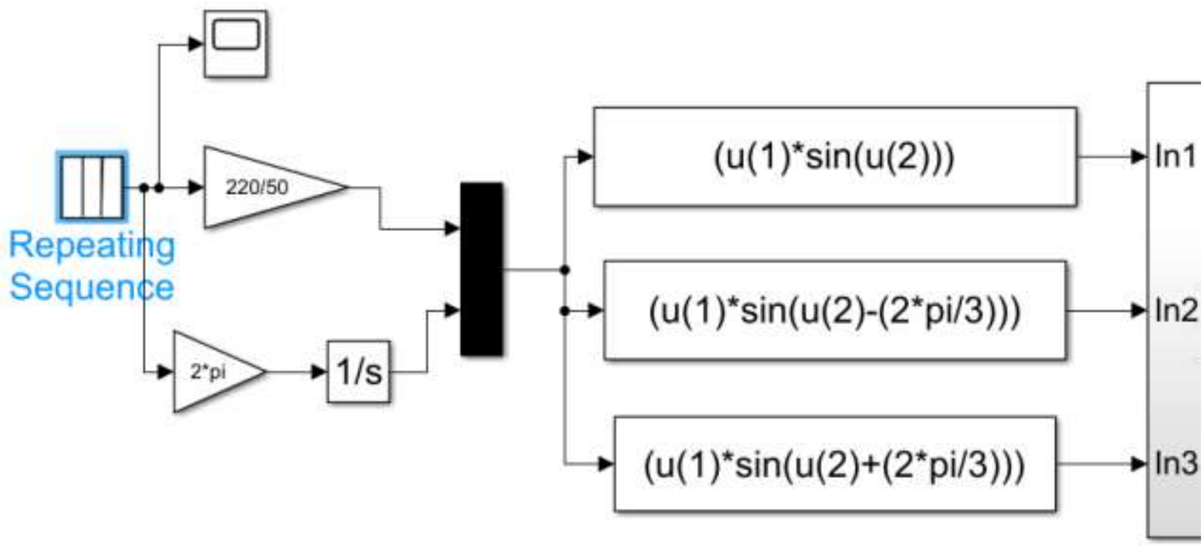
Time (sec)
(c) Pulses to the three-phase inverter switches



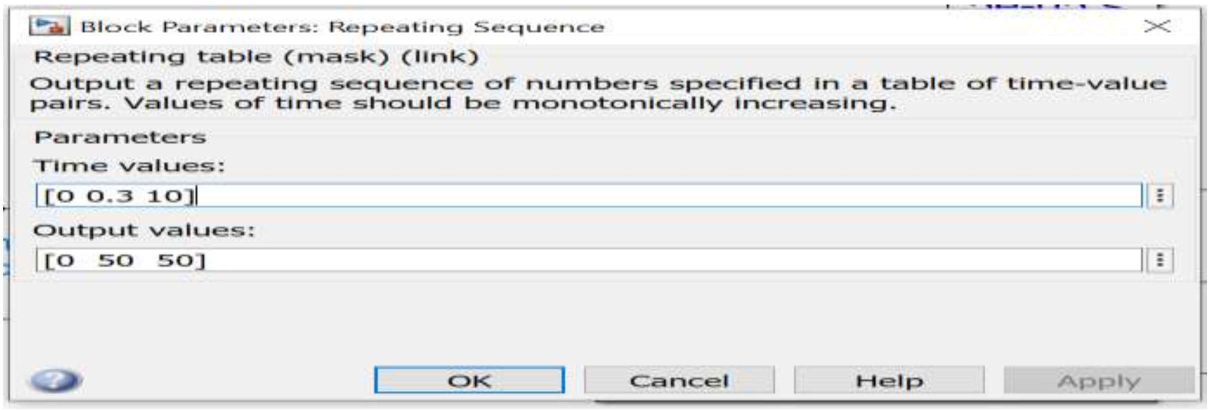
(d) Simulink model for SVPWM

Fig. 1. Implementing SVPWM in Simulink.

To control both the starting current and the speed of the motor V/f control is modelled in Fig. 2 and the three-phase supply is shown in Fig. 3.



(a)



(b)

Fig. 2. Controlled voltage supply for the Simulink model.

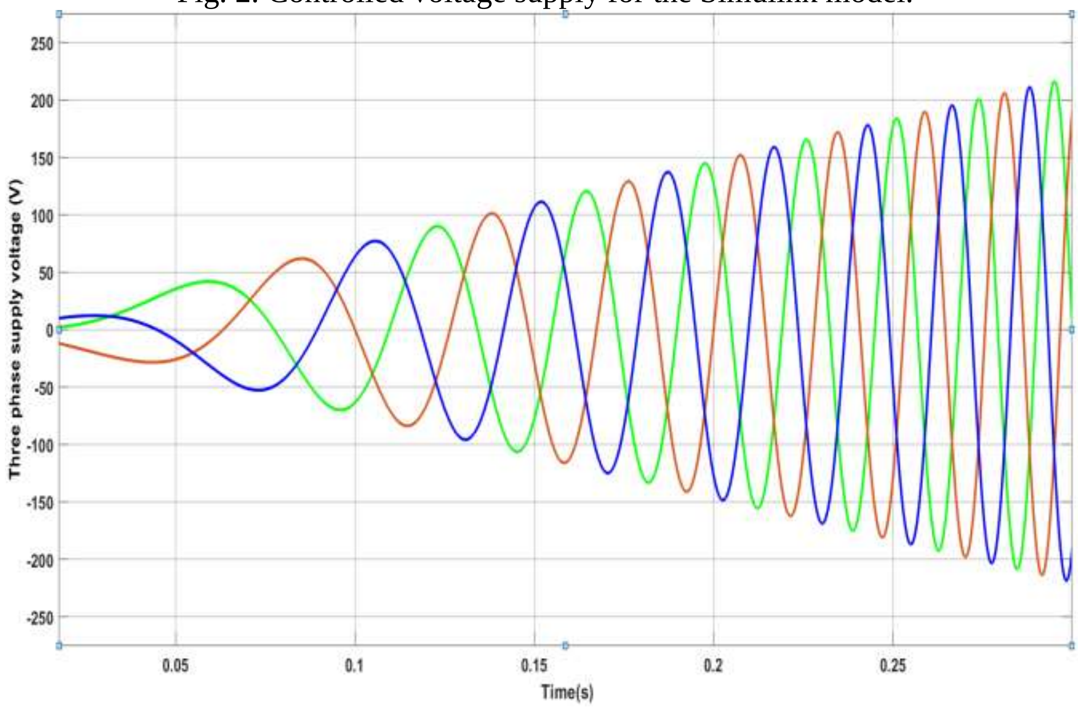


Fig. 3. Three-phase power using a volt/farad (V/f) regulator.

This model is used as a V/f supply to the SVPWM part. A three-phase inverter is cascaded with SVPWM and used as a drive circuit to the three-phase induction motor as shown in Fig. 4 and the resulting control signals are shown in Fig. 5 for the open-loop control.

In order to power the SVPWM component, this model is employed. As can be seen in Fig. 1, the driving circuit for the three-phase induction motor consists of a cascaded three-phase inverter with a sinusoidal voltage pulse width modulator. Figure 4 depicts the output control signals from Equation 4. Open-loop control yields a value of 5, so that's what we'll use.

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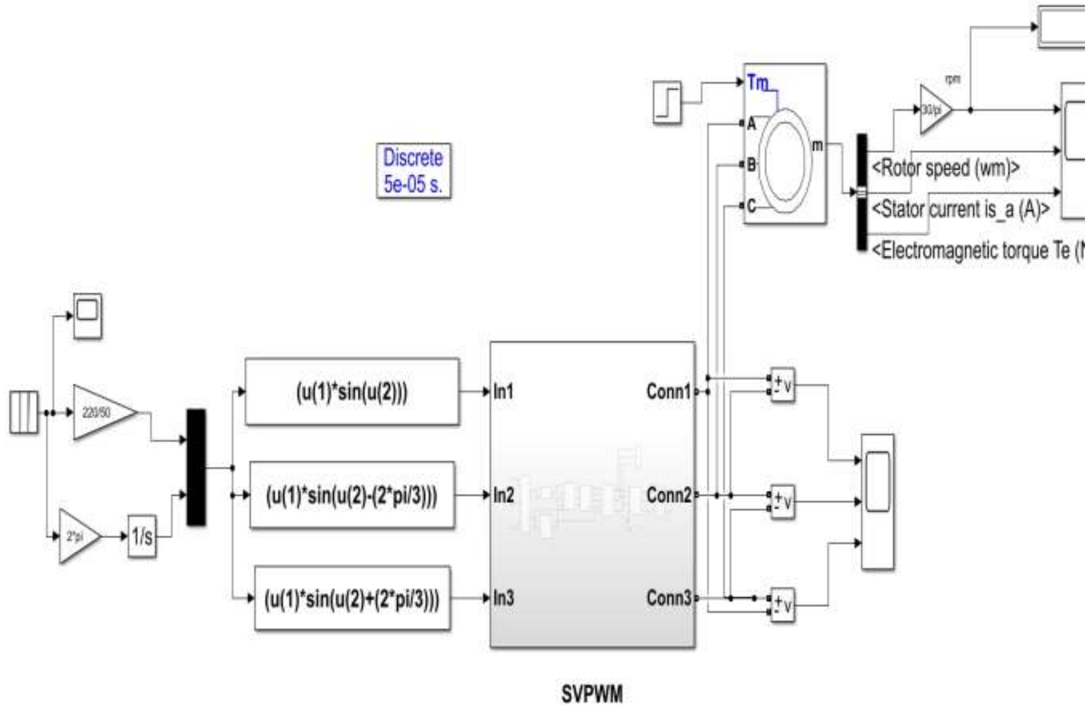

Fig. 4. Create a model of the system in Simulink (open loop).

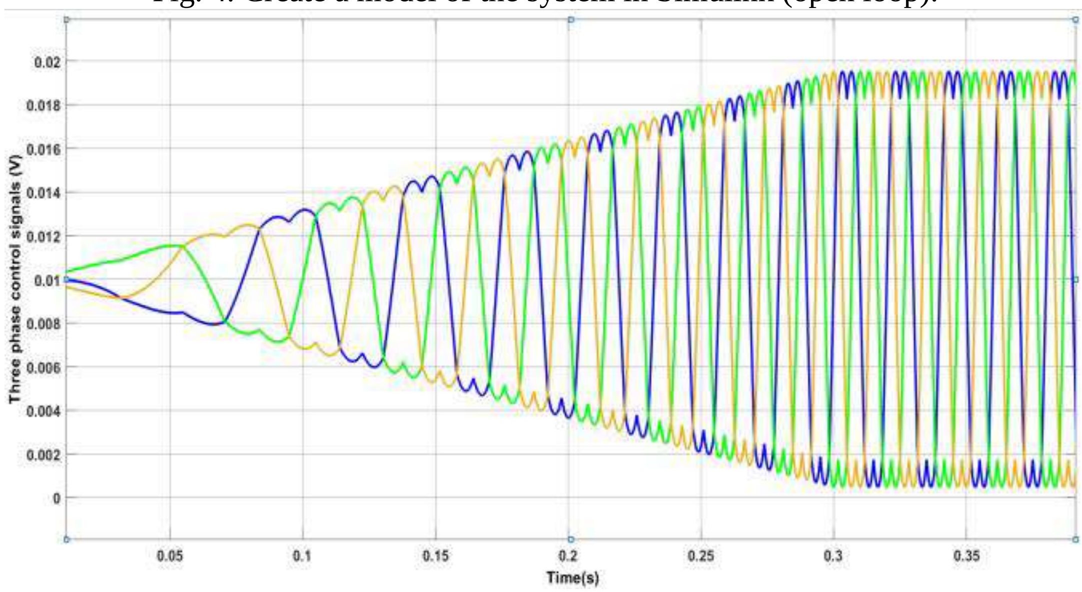

Fig. 5. Triadic control signals.

The open-loop model shown in Fig. 4 is used to find the response of the three-phase induction motor when subjected to an external torque of 28Nm at simulation time at 0.6s. Fig. 6 shows that the speed decreased to 1300 rpm and stayed at this value compared with 1500rpm at no load. The stator current increased to about 20A and the electromagnetic torque reaches around 30Nm to compensate for the load torque.

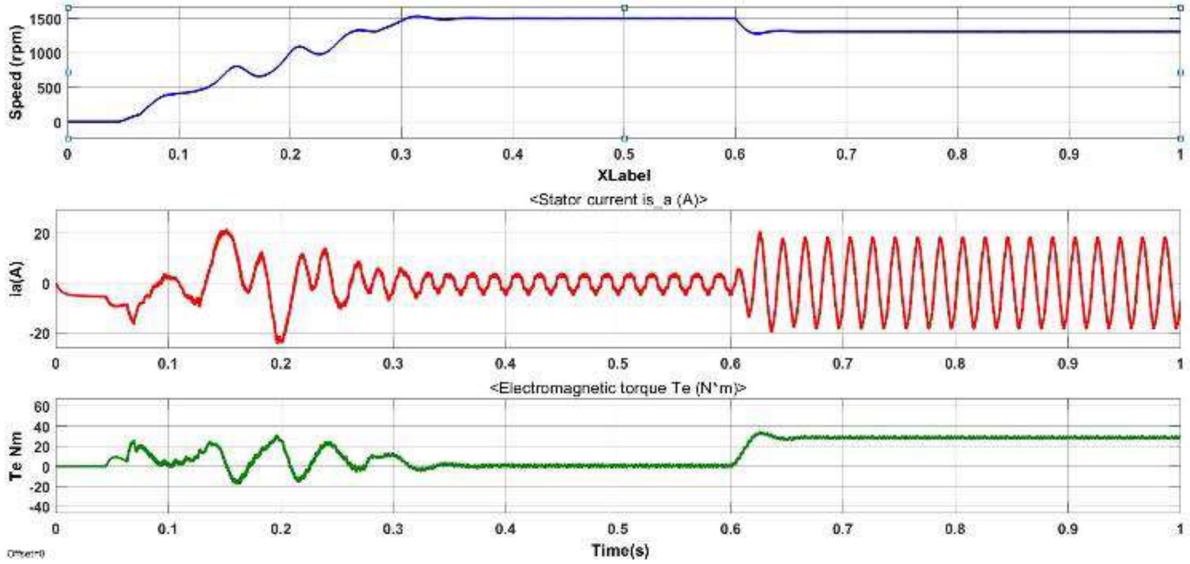

Fig. 6. What happens when you open the feedback loop in an induction motor.

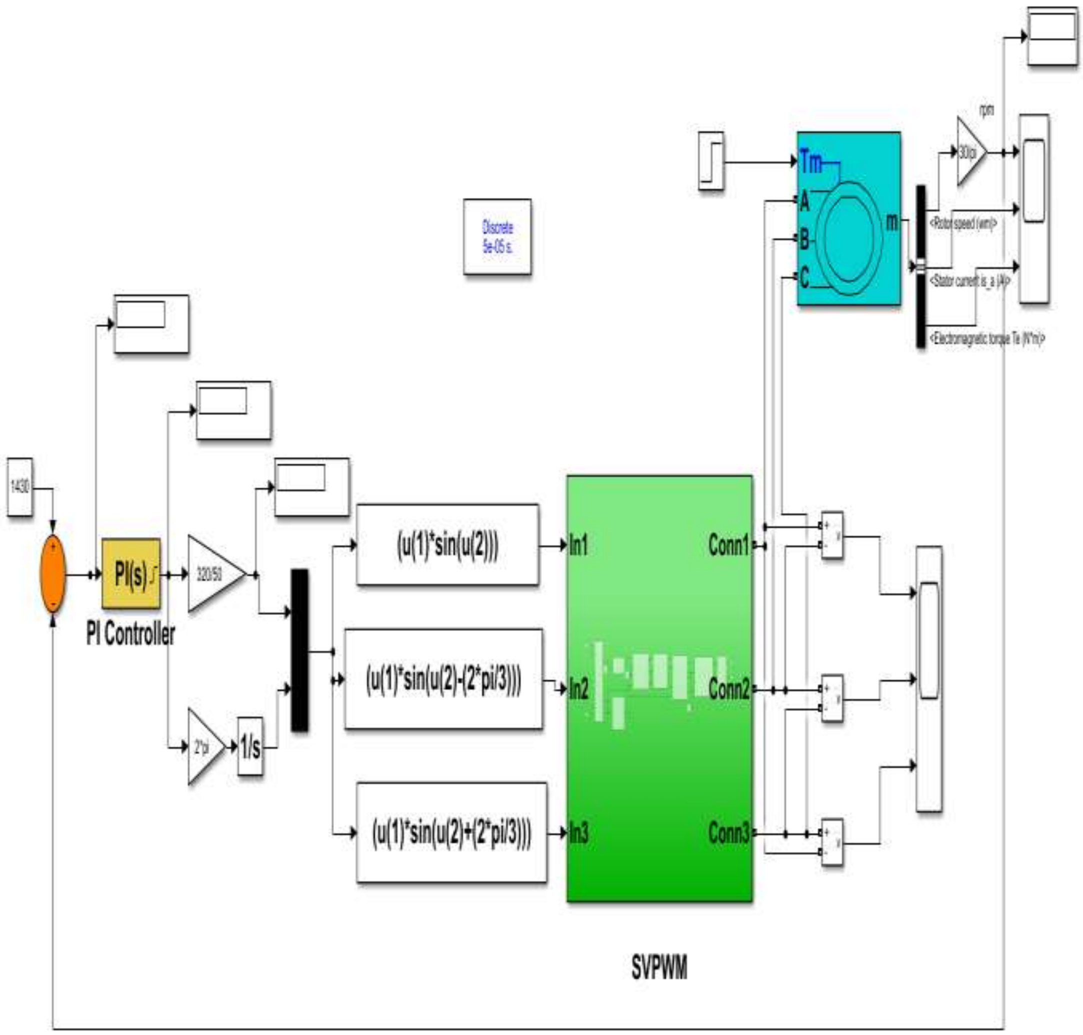

Fig. 7. Create a model of the system in Simulink (closed-loop).

In order for the induction motor to return to the reference speed after the external torque is loaded on the shaft of the motor, a closed-loop system is initiated in Fig. 7. A feedback rotor

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speed is compared with a reference speed of 1430 rpm and the difference is supplied to proportional and integral PI controller. The output of the controller is supplied to the V/f three-phase supply to compensate for the error. This process is repeated until the actual speed approximately matches the reference value. The values of the proportional and the integral are used as P=0.0001, I=0.1, and D=0. These values were found using Automatic tuning of the gain after linearization via Simulink environment [20]. The closed-loop response is shown in Fig. 8.

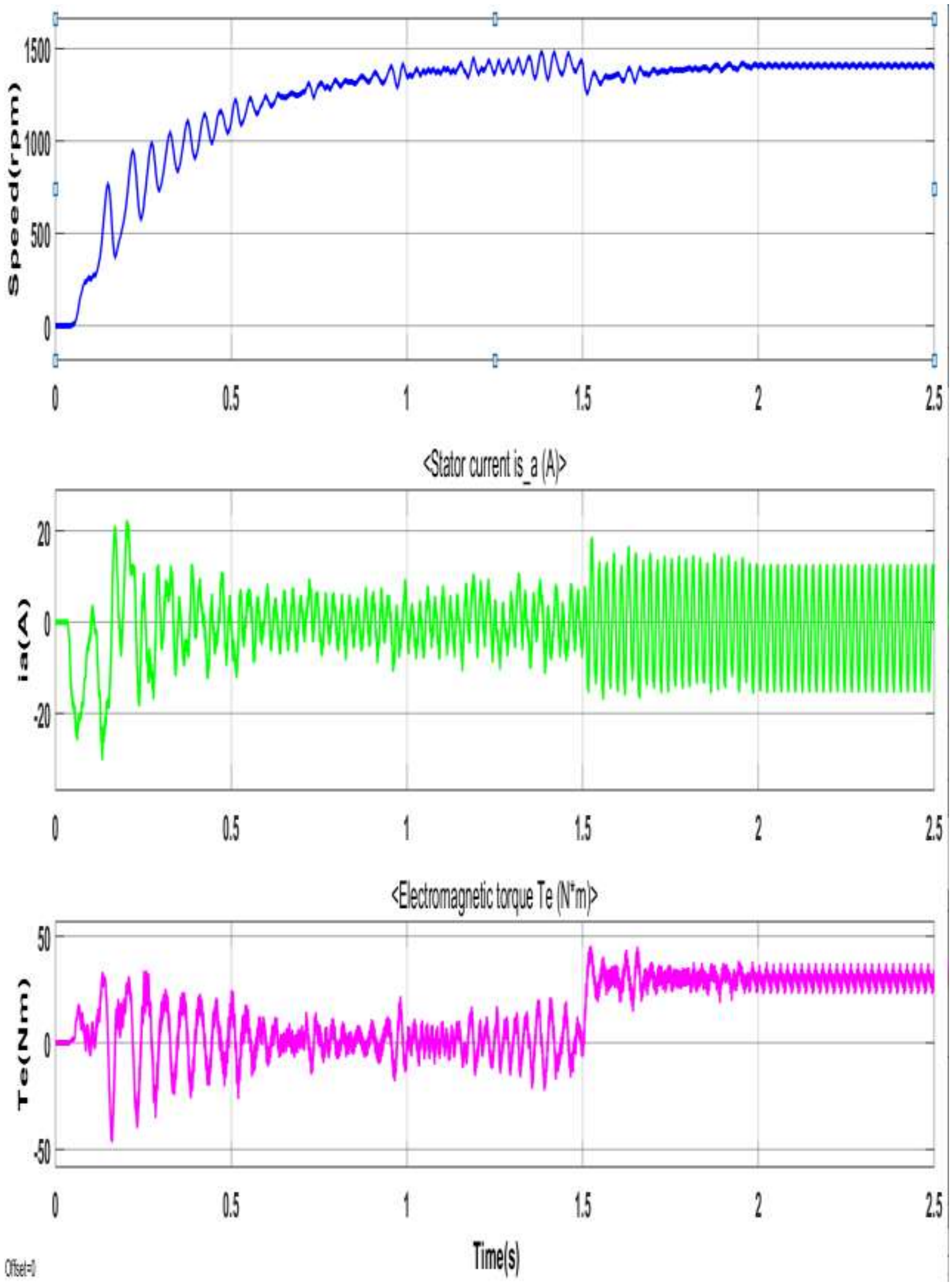
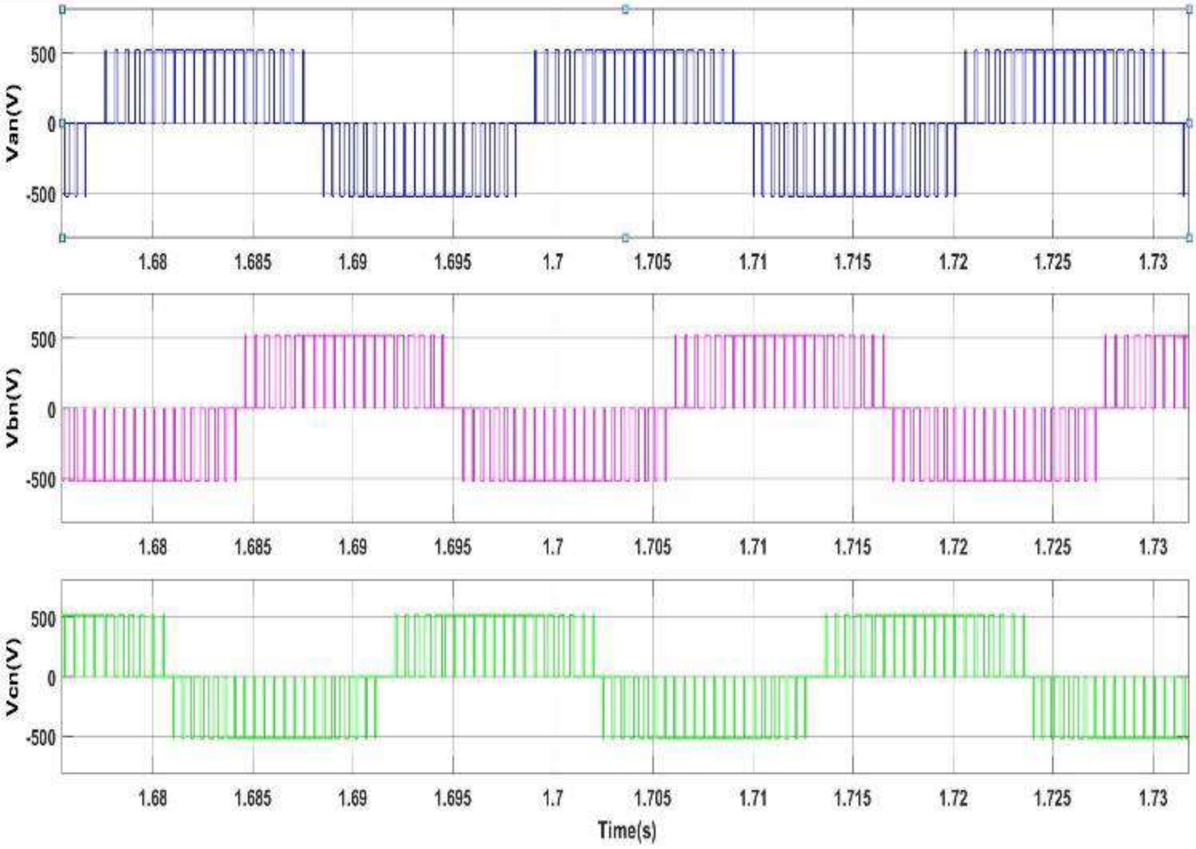


Fig. 8. Closing the feedback loop in a three-phase induction motor.


500
0
-500
Van(V)
1.68
1.685
1.69
1.695
1.7
1.705
1.71
1.715
1.72
1.725
1.73
Vbn(V)
Vcn(V)
Time(s)

(a)

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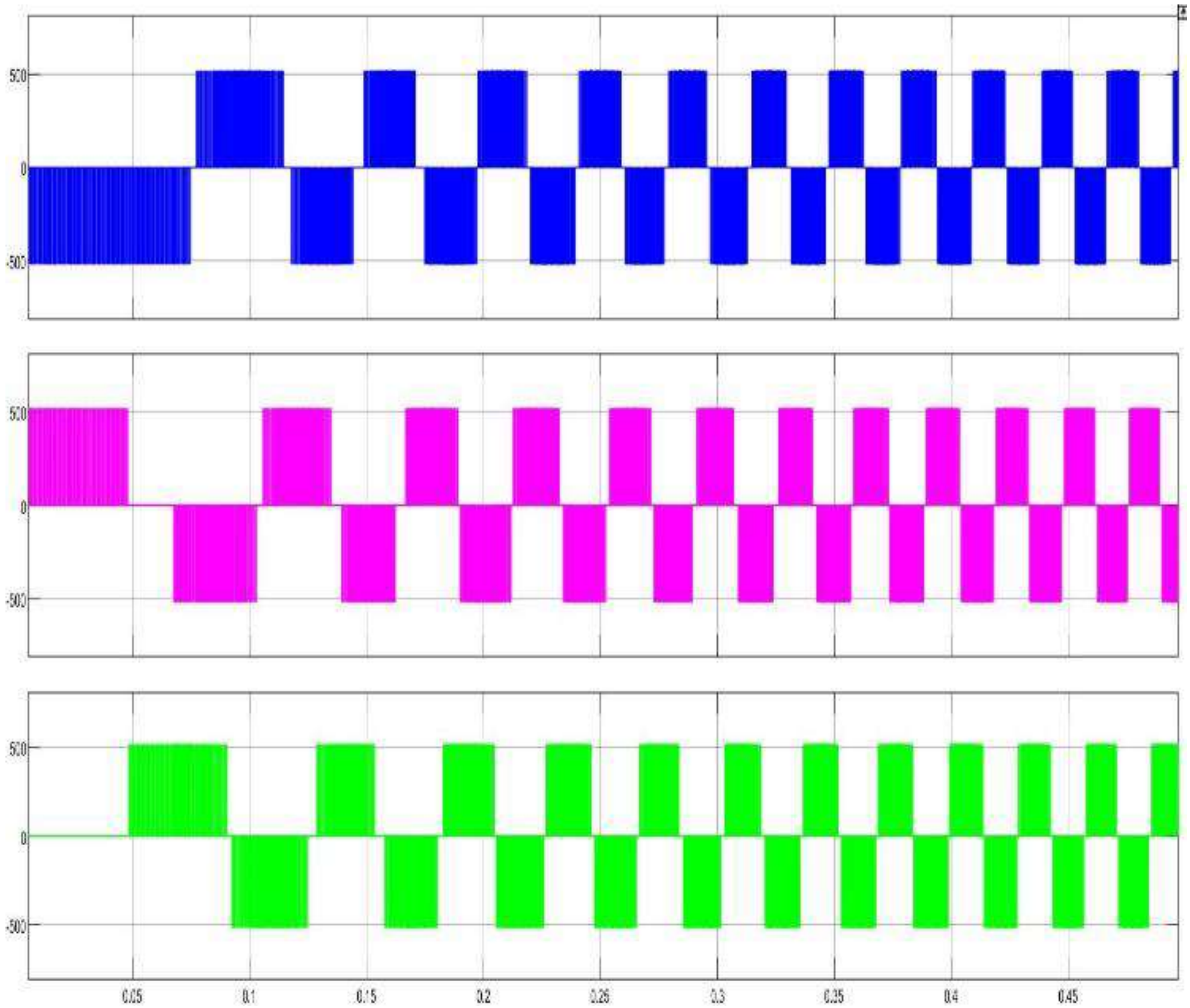

Time (sec)
(b)
Fig. 9. The output voltage of a three-phase inverter.

Figure 9a depicts the average output voltage of the three-phase inverter over a brief period of operation as a result of V/F regulation, whereas Fig. After a lengthy period of time, 9b demonstrates stable state. It's important to note that the inverter output frequency varies from zero at rest to around 50Hz at the induction motor's rated speed.

V. SUMMARY

Simulink models a three-phase supply with varying amplitude and frequency to regulate the induction motor's starting current and rotational speed. By using this method, the beginning current may be increased gradually, rather of being set at a large amount as is the case with conventional soft starting techniques. The motor is driven by a three-phase inverter. Space vector pulse width modulation is used to regulate the inverter because of its low total harmonic distortion (THD). The motor is tested under open-loop control, the response demonstrates a soft beginning current, and the motor gradually approaches its rated current. all of the fundamental building systems stated are modelled in Simulink MATLAB. In open loop control, when the motor is exposed to external rated torque, the speed drops within the prescribed range.

To compensate for external rated torque, a PI controller can help the motor return to its original speed under closed-loop control.

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