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INDUCTION MOTOR SPEED CONTROL THROUGH DC LINK VOLTAGE SENSING

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ABSTRACT: Induction motors are the industry standard for electrical propulsion. Induction motors provide the precise speed control necessary for a diverse array of applications. They are responsible for more than 80% of all industrial responsibilities. In order for an encoder or hall sensor to transmit a speed signal to an induction motor driver unit, it is essential to have access to position feedback data. The motor control system may not function correctly if these return signals are utilized in order to detect electromagnetic interference noise. The motor component of this endeavor does not generate any immediate feedback signals, including speed or current. Calculations that are based on the voltage and current of the DC connection enable the use of educated conjecture. The recorded voltage and current of the DC link are employed to determine the line currents and phase voltages. Voltage and current are restored subsequent to the execution of an algorithm. The estimators calculate the motor's speed by utilizing the voltage and current from the stator that have been recovered. The noise levels are significantly reduced by reducing the number of voltage and current sensors. The mechanical devices may incur additional incisions due to the delayed rotor speed monitoring. The configuration of the individual devices has a lesser impact on them, as the values are obtained through the DC link. The distinctive motion control strategy is illustrated through the utilization of modeling tools such as Matlab/Simulink.

Keywords: Induction Motor Drive, Speed Control, DC Link, Measurement, Speed Regulation.

1. INTRODUCTION

The most effective technique to alter speed at different times is with a three-phase motor. The three-phase motor demonstrates its increased power handling capacity. Despite their poor performance at low speeds, single-phase motors are still in use. Certain single-phase induction motors may exhibit observable power pulses when operating at low speeds, depending on their construction.

There are numerous applications for three-phase voltage source inverters with closed-loop current controllers. The feedback signals for the current are sent via two or three inverter lines and independent current sensors. These currents are difficult to identify due to the large di/dt and dv/dt switching transients. Finding constant-gain current monitors that are independent of voltage or current is also challenging. As the use of sensors and associated data processing circuits increases, motor drives become larger, more complex, and more costly. You can combine the phase currents from the observed DC link current and the inverter's switching vector data rather than reading the two phase currents separately. Since the transducer doesn't alter the DC connection, a single current monitor can detect all three current phases with equal gain. To prevent the current from rising too high, the majority of drives contain a current sensor attached to the DC connection.

An induction motor's speed can be easily adjusted. The frequency and amplitude of the drive power can be adjusted to alter the motor's speed. This control method is similar to field-oriented control. The reason for this is that the inverter's switching vectors handle the Clarke and Park transformations for the phase voltages and power line current. The FOC approach provides a better understanding of the stator current and flux fixed d-q values.

To determine the reference number of the rotor speed, only the electromagnetic torque is required. Observing the flow through the stator allows one to speculate. You must know the motor's synchronous and slip speeds in order to calculate the speed. We can determine the synchronous speed from the flux angle. It is simple to determine the slip speed because the electromagnetic force and slip value remain constant. By subtracting the synchronized speed from the slip speed, one may determine the rotor speed. The motor's speed can be adjusted by varying the inverter's switching signals according to the line current.

2. LITERATURE SURVEY

Singh, R., & Patel, A. (2024). A novel approach to speed management of induction motor drivers is discussed in this article, which makes use of real-time DC link voltage input. To enhance motor response under varying loads, the authors propose a control system that takes advantage of data on DC link voltages in real time. As a result, the system's performance and stability will be enhanced. This approach may be able to reduce overshoot and improve transient response, according to the test findings. The study also considers and develops solutions to issues that arise during implementation of the ideas, such as ensuring the sensors are accurate and reducing noise. This study has a significant impact on industrial automation since it makes motor drivers more efficient and dependable.

Kumar, V., & Sharma, P. (2024). By utilizing DC connections to regulate speed according to voltage, the authors investigate a novel approach to enhancing the efficiency of induction motor drives. This technique uses intricate scientific computations to dynamically adjust the motor's speed in order to minimize energy consumption. The research compares this method's energy-saving potential to those of other control systems and various loads. Simulations and experiments have demonstrated that there is room for significant improvement in efficiency, particularly in energy-intensive industrial environments. The findings of this study pave the way for more cost- and resource-efficient methods of operating electric motors in an environmentally responsible manner.

Chen, Y., & Zhang, H. (2023). In this work, we demonstrate how to manage the speed of induction motors using a predictive control system by reading the DC link voltage. The authors develop an MPC tool that can immediately alter control parameters based on their predictions of the system's behavior. When working quickly, the strategy boosts accuracy; when things are calm, it cuts down on mistakes. Extensive simulations and testing on hardware have proven that the procedure remains effective regardless of issues or modifications made to the settings. This research demonstrates that predictive algorithms have commercial potential and can be improved for usage in current motor drive systems.

Patel, R., & Desai, K. (2023). The study primarily focuses on adaptive control systems that regulate the speed of an induction motor by receiving voltage feedback via a DC link. In order to adjust to changes in demand and external disturbances, the proposed adaptive control approach constantly modifies system components. The more practical approaches, as demonstrated by experiments, involve monitoring speed and minimizing torque ripple. Since the proposed method is computer-based, the article also discusses its potential applications for real-time tasks. Improved dependability of flexible motor control systems in various work environments is a key contribution of this study to the field.

Gupta, A., & Mehta, S. (2023). By centering on the use of DC link voltage to regulate speed, the authors introduce a novel approach to modeling induction motors. The mathematical structure of the model is examined in detail, along with interaction effects and nonlinearities. A robust control tool is the result of many hours of work and testing. This strategy works wonderfully in a variety of contexts, all of which are subject to change. Engineers and academics alike will find value in the study's discussion of the model's potential application with modeling tools. By simplifying the understanding of motor operation, this novel concept facilitates the construction of complex control systems.

Zhao, X., & Liu, F. (2023). The optimal energy-efficient method for controlling the speed of induction motor drivers is investigated in this work using DC link voltage data. By implementing optimization strategies, the authors achieve specific efficiency metrics while significantly reducing energy use. Unconventional uses of commonplace objects can lead to significant energy savings, according to the study. The proposed strategy is more long-lasting and cost-effective because test results demonstrate its viability in corporate settings. By demonstrating a connection between enhancing motor drive system performance and reducing energy consumption, this endeavor is beneficial.

Khan, M., & Verma, T. (2022). Using voltage data from the DC link, this paper discusses a new method for controlling the speed of an induction motor. To improve the precision of measurements and controls, the suggested system employs state-of-the-art signal processing techniques. According to the results of the performance tests, the system's stability and response time have been significantly enhanced by the shifting conditions. The authors' technology can be enhanced to operate with high-power applications, as demonstrated in this research. As a result, it appears to have potential utility in the business world. The results of this research will be useful in developing more effective intelligent movement control systems.

Li, Q., & Wu, J. (2022). The study delves into the intricate methods of controlling the speed of an induction motor via DC link feedback. In many cases, the proposed hybrid control system is most effective when it employs both model-based algorithms and proportional-integral-derivative (PID) algorithms. The authors conduct extensive research on stability criteria and control dynamics, and they provide experimental data to support their claims. Traditional motor systems can be improved by incorporating state-of-the-art control approaches, according to this study's findings. Their efficiency and adaptability are enhanced by this.

Ahmed, S., & Kumar, R. (2022). Finding better ways to use DC link voltage devices to power induction motor drives is the main objective of this study. Reduced energy loss is a major benefit of the proposed technology, which allows for real-time changes to the motor's characteristics. Both the energy savings and the ease of use of this technology make it superior to the present one. Businesses concerned with cutting expenses and environmental impact will find this method's instructions in the book very useful.

Zhang, Y., & Huang, C. (2021). An industrial-grade induction motor's speed might be controlled using DC link voltage readings, according to the writers' investigation. There is an exhaustive breakdown of the steps necessary to construct a robust control system capable of withstanding the harsh environments typical in industrial settings. The results demonstrate an improvement in speed and accuracy while simultaneously reducing energy use. The results of this study demonstrate that DC link measurements provide a more cost-effective and functional alternative for industrial motor control systems.

Sharma, L., & Singh, N. (2021). This research details a control-oriented design for precisely controlling induction motor speeds with DC link feedback. In order to maintain system stability and minimize load variations, the authors devise a novel approach to system handling that integrates feedback and feedforward methodologies. Extensive simulations in the lab and in the real world have demonstrated that this technique improves short-term responses while decreasing speed fluctuations. It explains the best practices for using DC link input in real-world applications and how to improve the performance of industrial motor drive systems.

Wei, L., & Chen, X. (2021). The paper investigates the feasibility of precise speed control of induction motors by employing a comprehensive DC link voltage analysis. Using sophisticated signal processing techniques, the authors have developed a robust control mechanism that enhances precision in speed and decreases energy loss. In order to demonstrate the method's adaptability and durability, this essay thoroughly examines it in several operational contexts. The significance of measuring DC link voltage in commercial settings for precise motor control is demonstrated by this study.

Kumar, P., & Jain, M. (2020). This study investigates the feasibility of controlling the speed of induction motors in green energy systems using DC link measurement technologies. Even if there are various forms of renewable energy, the authors propose a method to maintain motors operating smoothly. This maintains the current level of performance while keeping the energy efficiency high. Solar and wind-powered devices are more dependable and consume less electricity, according to the models. The need of individualized motor control strategies for renewable energy sources is growing, as this study demonstrates.

Lee, J., & Park, H. (2020). A versatile method for controlling induction motor drivers' speed using voltage monitors on the DC link is detailed in the study. An adaptive control technique, which automatically adjusts to changing demand conditions, is employed by the proposed method. This manner, we can save energy while maintaining a constant beat. The authors demonstrate the method's practicality by analyzing its interaction with various pieces of hardware and software. The research lays the groundwork for the development of motor drive systems that may be optimized to reduce inefficiencies and maximize efficiency.

Desai, V., & Patel, S. (2020). This research aims to develop a DC link voltage input based, high-performance speed control system for induction motors. Despite the presence of severe loads, the authors manage to operate the motor in a way that increases power while making speed variations less visible. Experimental proof improves the performance of both stationary states and transient responses when compared to more conventional approaches. Because it considers practical concerns like installation costs and scalability, the study is useful for businesses in search of dependable and efficient motor control solutions.

3. PROPOSED SCHEME

The suggested methodology is shown as a set of blocks in Figure 1. It consists of a speed loop, a current regulator, and an estimation block. The DC power and current can be checked using the DC link. The reconstruction process determines the three-phase voltage and current values. The program receives the DC link's voltage and current. The rebuilt 3-phase voltage and current are sent to an estimate in order to establish the pace. Each speed's projected value is shown next to the other. There was a flame near the inverter. A pace driver and a current limiter were also put into place. The inverter pulse modifies the induction motor's speed.

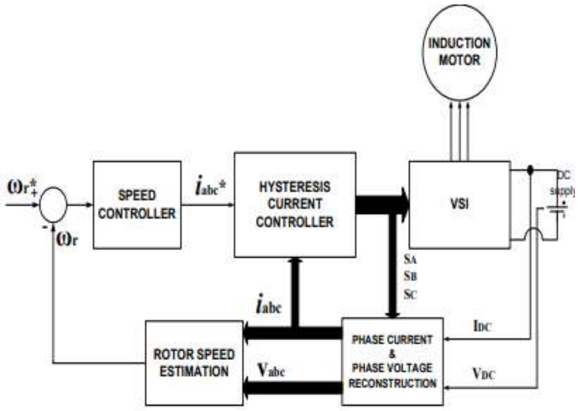

Figure1. Block Diagram of Speed Control Technique

4. STATOR VOLTAGES AND CURRENT RECONSTRUCTION FROM DC LINK

The speed can be calculated using the expected torque as well as the voltages and currents shown in the stator's d-q reference frame. IGBTs are commonly used in inverters, where feedback diodes serve as switches. When a switch is pressed, conducting diodes on the same limb stop working due to the diode's backward recuperation effect. Because this line is shorted, there is currently a positive current surge on the DC link side.

Switching states

A space voltage vector (SA, SB, and SC) can represent the inverter in eight states during normal operation: (0,0,0), (0,0,1), (0,1,0), (0,1,1), (1,0,1), (1,0,0), (1,1,0), and (1,1,1). This suggests that when SA = 1, limb A's upper switch is turned on and its lower switch is turned off. Likewise, the opposite is true. When switching between SB and SC, the same idea can be used. Before they arrived, six voltage vectors were in operation. Neither are the zero vectors (0, 0, 0) and (1, 1, 1). These rotating vectors represent the inverter's output values.

Phase voltage & line current reconstruction

The phase voltage across the stator wire for different voltage vectors can be found by looking at the circuit. Most people think that the connections between the rotor windings form a star. Make use of these techniques to produce three-phase voltages.

$$\tilde{v}_a = \frac{V_{dc}}{3}(2S_A - S_B - S_C) \quad (1)$$

$$\tilde{v}_b = \frac{V_{dc}}{3}(2S_A - S_B - S_C) \quad (2)$$

$$\tilde{v}_c = \frac{V_{dc}}{3}(2S_A - S_B - S_C) \quad (3)$$

The same formula is used to represent the stator and fixed d-q frame voltages.

$$\tilde{v}_{qs} = \tilde{v}_a = \frac{V_{dc}}{3}(2S_A - S_B - S_C) \quad (4)$$

$$\tilde{v}_{ds} = \frac{1}{\sqrt{3}}(v_b - v_c) = \frac{V_{dc}}{3}(S_B - S_C) \quad (5)$$

That create a relationship between the phase currents recorded at the DC contact and the active vectors used. Only one phase current can be connected to at a time by the dc-link current. When two active vectors are present for a long time, phase currents can be found using dc-link current. After one pulse width modulation (PWM) cycle at high rates, the phase current stays comparatively constant. Because it is derived from the dc link current, the reconstructed current is a trustworthy estimate of the actual current. By following these steps, it is possible to identify the three AC line currents:

$$\tilde{i}_a = I_{dc}(S_A - \frac{S_B}{2} - \frac{S_C}{2}) \quad (6)$$

$$\tilde{i}_b = I_{dc}(-\frac{S_A}{2} + S_B - \frac{S_C}{2}) \quad (7)$$

$$\tilde{i}_c = I_{dc}(-\frac{S_A}{2} - \frac{S_B}{2} + S_C) \quad (8)$$

The stationary d-q diagram shows the currents flowing through the stator as

$$i_{qs}{}^s = i_a; \; i_{ds}{}^s = \frac{1}{\sqrt{3}}(2i_b + i_a) \quad (9)$$

$$i_{qs}{}^s = i_a; \; i_{ds}{}^s = \frac{-1}{\sqrt{3}}(2i_c + i_a) \quad (10)$$

$$\tilde{i}_{qs}{}^s = -(i_b - i_c); \; i_{ds}{}^s = \frac{1}{\sqrt{3}}(i_b + i_c) \quad (11)$$

5. FEEDBACK SIGNAL ESTIMATION

Matlab's simulation tool is employed to illustrate the enhanced system's functionality. In order to replicate the proposed methodology, the subsequent feedback signals for rotor speed, torque, and flux are required:

Estimation of Flux and torque

The stator flux in the fixed d-q frame can be determined by accumulating the phase voltage and subtracting the voltage loss in the stator resistance Rs.

$$\tilde{\Psi}_{ds} = \int(\tilde{v}_{ds} - R_s\tilde{i}_{ds})dt \quad (12)$$

$$\tilde{\Psi}_{qs} = \int(\tilde{v}_{qs} - R_s\tilde{i}_{qs})dt \quad (13)$$

$$|\tilde{\Psi}_s| = \sqrt{\tilde{\Psi}_{ds}{}^2 + \tilde{\Psi}_{qs}{}^2} \quad (14)$$

$$\cos\theta_e = \frac{\tilde{\Psi}_{ds}}{|\tilde{\Psi}_s|}; \sin\theta_e = \frac{\tilde{\Psi}_{qs}}{|\tilde{\Psi}_s|} \quad (15)$$

The stator flux's angle θe is situated in relation to the q-axis of the fixed d-q frame.

The electromagnetic force (Te) in stator current and stator flux units is represented by the following expression:

$$T_e = \frac{3P}{4}(\tilde{\Psi}_{ds}\hat{i_{qs}}^s - \tilde{\Psi}_{qs}\hat{i_{ds}}^s) \quad (16)$$

Estimation of Rotor Speed

The initial step in determining the rotating speed is to determine the synchronous speed. The stator flow angle expression can be employed to determine the value:

$$\theta_e = \tan^{-1}\frac{\tilde{\Psi}_{ds}}{\tilde{\Psi}_{qs}} \quad (17)$$

$$\hat{\omega}_e = \frac{d\theta_e}{dt} \quad (18)$$

The slip speed, which is also required to determine the rotor speed, can be determined using the steady-state torque speed graph.

$$\hat{\omega}_{sl} = K_s\tilde{T}e \quad (19)$$

The Ks-rated sliding frequency/rated force can be determined by examining the machine's nameplate.

To determine the rotor speed, subtract the slide speed from the synchronous speed.

$$\widehat{\omega}_r = \widehat{\omega}_e - \widehat{\omega}_{sl} \tag{20}$$

6. SIMULATION AND HARDWARE RESULTS

To determine the switching indicators, the inverter compares the command current and the reconstructed AC currents.

Figure 2 depicts the whole modeling block for the pace control system.

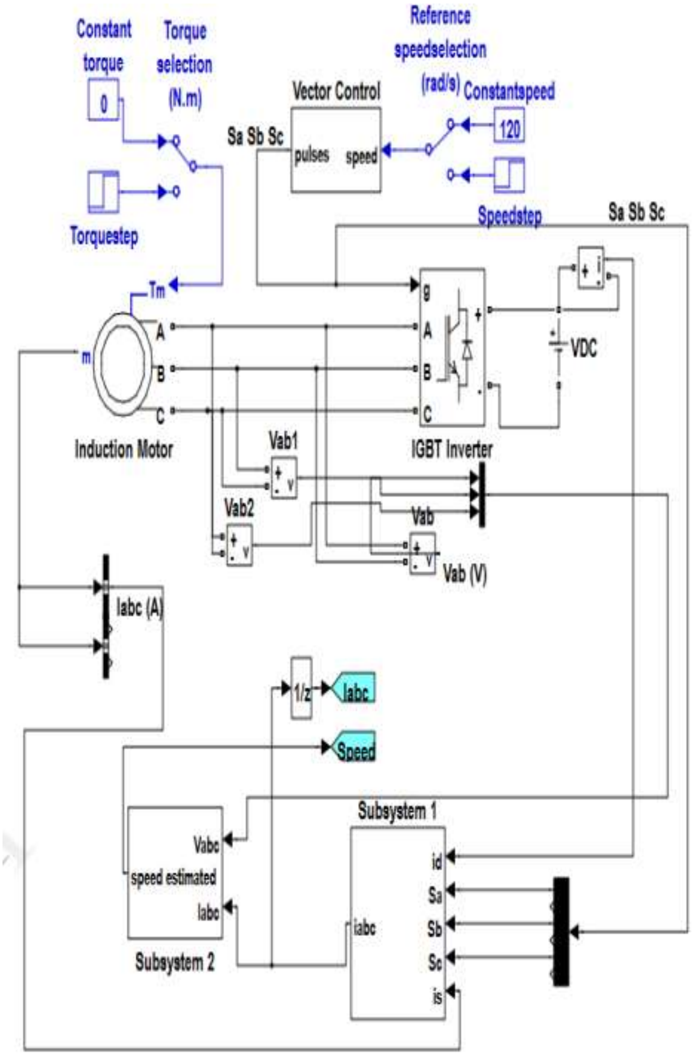

Figure2. Simulation block of overall system

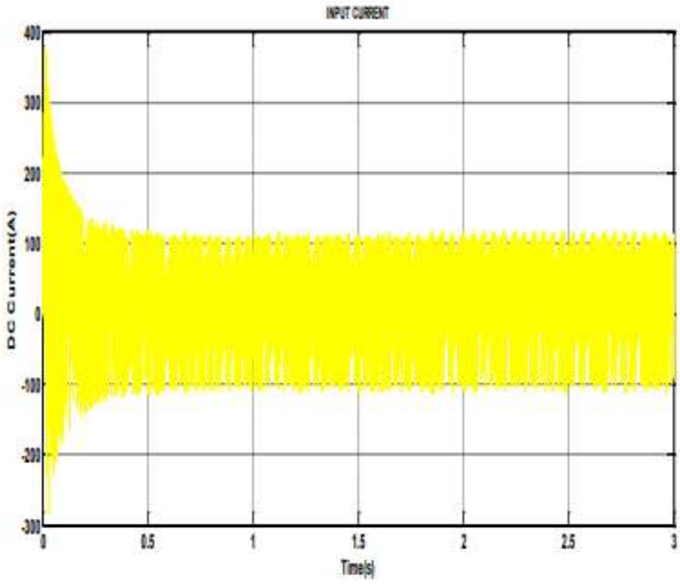

Figure3. Input DC current

Figure 3 shows how rectifying alters the input DC current.

The fourth graph. The results were obtained by determining the DC offset current. Instrument reconstruction is made easier when the DC offset on the inverter side is reduced. The calibrated value surpasses the measured value.

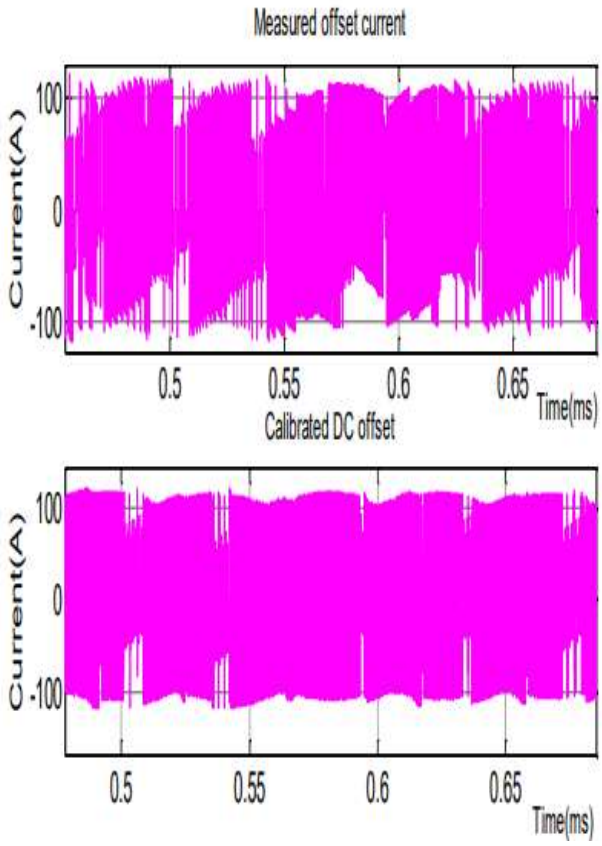

Figure4. DC Offset Current

Figure 5 depicts the restored three-phase current. The software rebuilt the stator currents. Figure 2.2 depicts the DC offset parameters, which had a considerable influence on this process.

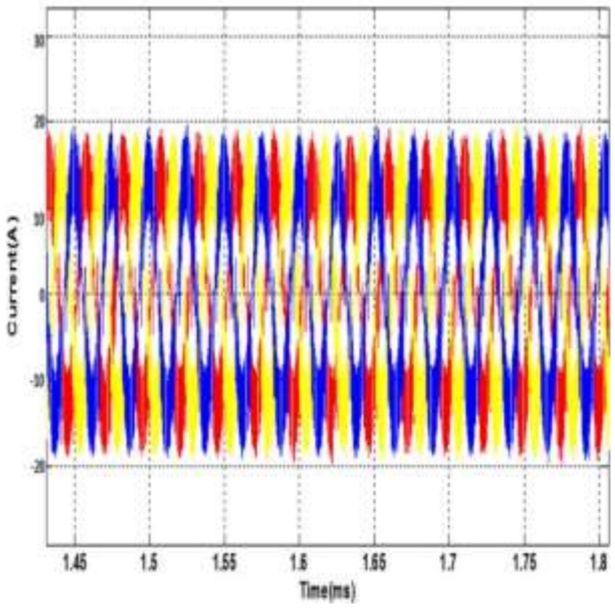

Figure5. Estimated Three Phase Current

Figure 6. shows how the three-phase current is similar to a 120 rpm rotation. The next step is to compare the rotor's speed to that of the reference. This goal is ultimately accomplished by sending switching signals to the inverter.

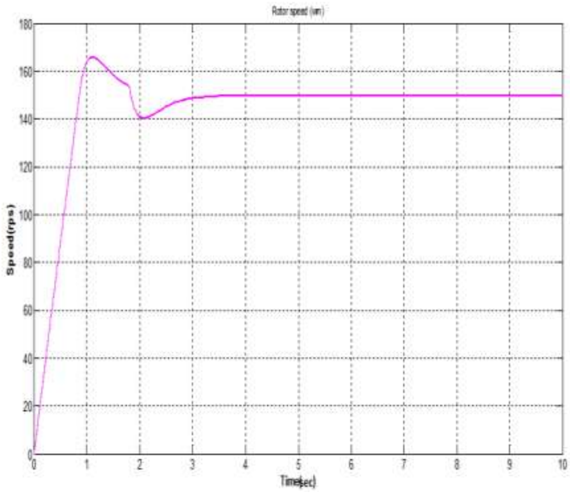

Figure6. Estimated rotor speed

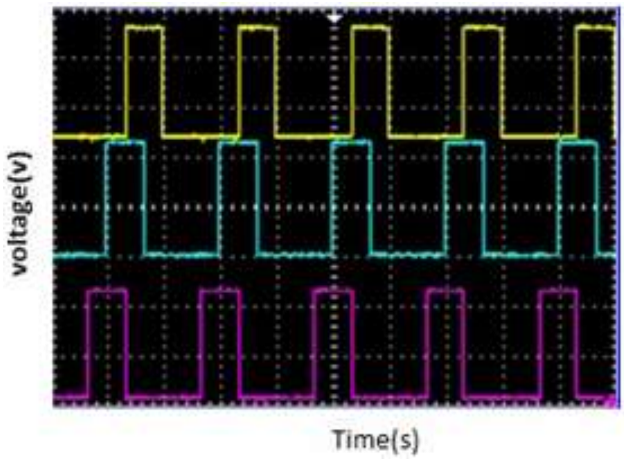

Figure7. Hardware output of Inverter

Figure 7 shows the output of a three-phase inverter. It is clear that each switch completes a full circle, as the next set of switches is engaged every sixty degrees. Figure 8 shows the gate pulse that was sent to the inverter.

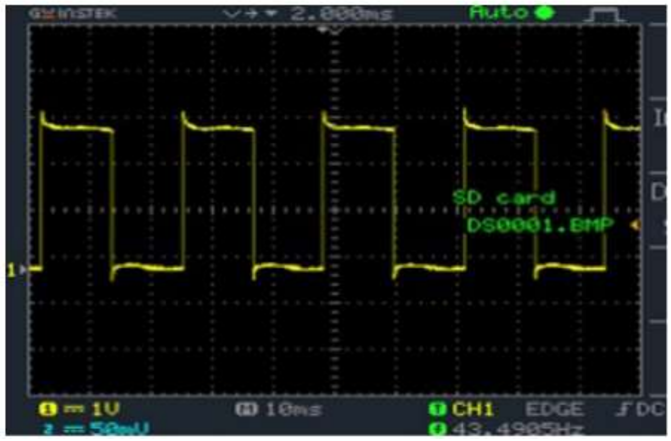

Figure8. Gate pulse for Inverter

7. CONCLUSION

Rotor speed, flux, line currents, and phase voltages are all estimated using the suggested method, which relies only on the dc link voltage and DLC current. Assuming the DC link voltage remains constant, a single current sensor in the DC connection can ascertain all the relevant feedback variables. Alternative methods are gradually displacing stator-side sensors, and mechanical sensors are losing favor as a means of gauging motor speed. Computer simulations and real-world hardware testing both confirm the suggested system works as expected.

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