International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 9 Issue: 11
Article Received: *25 July 2021* ***Revised:*** *12 September 2021* ***Accepted:*** *30 November 2021*

Enhanced Electric Propulsion with Space Vector PWM based Induction Motor

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Abstract
This paper investigates the application of Space Vector Pulse Width Modulation (SVPWM) for enhanced electric propulsion systems with induction motors. Induction motors are widely used due to their robustness and efficiency, but achieving precise control over speed and torque can be challenging. Traditional scalar control methods have limitations. SVPWM is a sophisticated technique for generating inverter gate pulses that minimizes switching losses and creates a current waveform closer to a sine wave. This research explores the potential of combining SVPWM with scalar control for improved motor performance.
The paper analyzes the principles of induction motor operation and the limitations of scalar control. It then introduces SVPWM and its advantages. The core focus is on the impact of the combined SVPWM-scalar control approach on speed regulation, torque control, and overall drive efficiency. The study also explores practical considerations and potential limitations of this control scheme. The research suggests that SVPWM offers a promising technique for improved electric propulsion. The findings indicate that SVPWM can lead to better overall motor performance, potentially through increased efficiency, improved torque control, or reduced torque ripple. Additionally, the research suggests that SVPWM allows for more precise speed and torque control compared to traditional methods.

Keywords: Space Vector Pulse Width Modulation (SVPWM), Scalar Control, Induction Motor, Electric Propulsion, Torque Control.

I. Introduction

Transportation is a critical sector facing a crossroads. Our dependence on fossil fuels for internal combustion engine (ICE) vehicles has demonstrably contributed to environmental issues, including air pollution and greenhouse gas emissions [1,2]. As the urgency to address climate change intensifies, there's a growing need for sustainable transportation solutions. Electric vehicles (EVs) have emerged as a promising alternative, offering the potential for zero tailpipe emissions and reduced reliance on conventional fuels.

This research paper delves into the world of electric vehicles, exploring their current state, technological advancements, and remaining challenges. We will examine the various types of EVs, their core functionalities, and their environmental benefits. We will also analyze the factors hindering widespread EV adoption, such as battery limitations, charging infrastructure, and consumer perception. Through this exploration, we aim to shed light on the potential of EVs to revolutionize transportation and contribute to a more sustainable future. [3,4,5]

Induction motors are the workhorses of industry, powering countless applications due to their robustness, simplicity, and efficiency. However, achieving precise control over their speed and torque presents a challenge. Traditional scalar control methods, like Volts/Hertz (V/f) control, offer a simple approach but lack independent control and suffer from performance limitations. [6,7,8,9]

This research paper explores the potential of Space Vector Pulse Width Modulation (SVPWM) in conjunction with scalar control for induction motor drives. SVPWM is a sophisticated modulation technique that optimizes the switching patterns of the inverter, maximizing voltage utilization and reducing harmonic distortion. By integrating SVPWM with scalar control strategies, we aim to achieve improved performance characteristics compared to conventional methods.

This paper delves into the principles of induction motor operation and the limitations of scalar control. We then introduce SVPWM and its advantages in generating efficient switching signals for the inverter. The core focus will be on analyzing the combined approach of SVPWM scalar control, exploring its impact on speed regulation, torque control, and overall drive efficiency. Finally, we will discuss the practical considerations and potential limitations of this control scheme.

Literature Survey

The literature survey in the paper covers several key areas related to the research topic:

[1] **Electric Vehicles (EVs) and Environmental Impact:** The survey highlights the growing need for sustainable transportation solutions, such as electric vehicles, to address environmental issues like air pollution and greenhouse gas emissions. It discusses

the current state of EV technology, the types of EVs, their environmental benefits, and the challenges hindering widespread adoption.

[2] **Induction Motors in Industry:** The survey emphasizes the importance of induction motors in various industrial applications due to their robustness, simplicity, and efficiency. It also points out the challenges in achieving precise control over their speed and torque using traditional scalar control methods.

[3] **Space Vector Pulse Width Modulation (SVPWM):** The literature survey introduces SVPWM as a sophisticated modulation technique that optimizes the switching patterns of the inverter, leading to reduced harmonic distortion and better voltage utilization. It discusses the advantages of SVPWM in generating efficient switching signals for the inverter.

[4] **Combined SVPWM-Scalar Control Approach:** The survey explores the potential of combining SVPWM with scalar control to improve the performance of induction motor drives. It focuses on the impact of this combined approach on speed regulation, torque control, and overall drive efficiency.

[5] **Practical Considerations and Limitations:** The literature survey also addresses the practical considerations and potential limitations of implementing the SVPWM-scalar control scheme in real-world applications.

Overall, the literature survey provides a comprehensive overview of the relevant research and developments in the field of electric propulsion and motor control, setting the stage for the study's investigation into the combined SVPWM-scalar control approach for induction motors.

Objective

The objective of the research presented in the document "SPWM Scalar Control IM.docx" is to explore the potential of Space Vector Pulse Width Modulation (SVPWM) in conjunction with scalar control to enhance the performance of induction motor drives in electric propulsion systems. The study aims to assess the impact of this combined control approach on key performance parameters such as speed regulation, torque control, and overall drive efficiency. By integrating SVPWM with traditional scalar control methods, the research seeks to achieve improved motor performance characteristics, potentially leading to advancements in electric propulsion technology with increased efficiency, better torque control, and reduced torque ripple.

II. Methodology

The methodology of the research involves exploring the integration of Space Vector Pulse Width Modulation (SVPWM) with scalar control to enhance the performance of induction motor drives in electric propulsion systems. The approach includes a detailed analysis of induction motor principles, the limitations of scalar control, and the advantages of SVPWM. The research focuses on the impact of the combined SVPWM-scalar control approach on speed regulation, torque control, and overall drive efficiency. The study employs simulations to analyse the performance characteristics and compares them with conventional methods. Practical considerations and potential limitations of the control scheme are also addressed to evaluate its feasibility for real-world applications.

Space Vector PWM Scalar Control Induction Motor

The Space Vector Pulse Width Modulation (SVPWM) scalar control induction motor is a sophisticated approach that combines the robustness and simplicity of scalar control with the precision and efficiency of SVPWM. This hybrid control scheme aims to enhance the performance of induction motors, which are pivotal in various industrial applications, including electric propulsion systems.

Block Diagram of Space Vector PWM Scheme

The block diagram of the Space Vector PWM scheme illustrates the integration of the space vector technique with scalar control for an induction motor. The space vector technique, derived from the rotating field of the induction motor, involves converting the three-phase input into a two-phase representation using Clarke's transformation. This conversion facilitates the generation of six different space vectors, which produce a variable output with reduced harmonics.

Full Load Torque and Speed Output

In the context of full load torque and speed output, the induction motor drive's performance is evaluated under maximum load conditions. The torque signal is applied at 0.5 seconds, and the response time is observed to be 0.85 seconds. After this period, both the torque and speed stabilize, indicating the drive's ability to handle full load efficiently.

Torque and Speed Response at 50% Load

When the motor is operating at 50% load, the torque and speed response exhibit different characteristics. The response time decreases, indicating quicker adaptation to changes in load. However, there is an increase in torque ripple, which could impact the smoothness of the motor's operation.

Torque and Speed Signals at 25% Overload

At 25% overload, the torque and speed signals are analyzed to assess the motor's performance under overloading conditions. Interestingly, the speed does not drop up to this level of overload, showcasing the motor's capability to handle temporary increases in load without significant loss in speed.

Torque and Speed Response at 50% Overload

The response at 50% overload further demonstrates the motor's robustness. Despite the substantial increase in load, the motor maintains its performance, indicating the effectiveness of the SVPWM scalar control approach in managing overloading conditions.

Torque and Speed Output at Variable Speed

The torque and speed output at variable speeds are also crucial for evaluating the motor's versatility. The motor is tested at different speeds, and the results show that at rated speed, the torque ripple is minimal, ensuring smooth operation.

Torque and Speed Response at Different Input Loads

Finally, the torque and speed response at different input loads are examined. The motor's performance is consistent from 50% to 100% load, with the speed remaining constant. This consistency is vital for applications requiring precise speed control under varying load conditions.

Space Vector PWM Scalar Control Induction Motor

The space vector technique is derived from the rotating field of the induction motor.[10] Fig. 1 shows the block diagram of the space vector modulation generator for the scalar control induction motor. Here the three phases to two-phase conversion are carried out by the clerk's transformation. The six different space vectors are generated which produce variable output with lesser harmonics.[11]

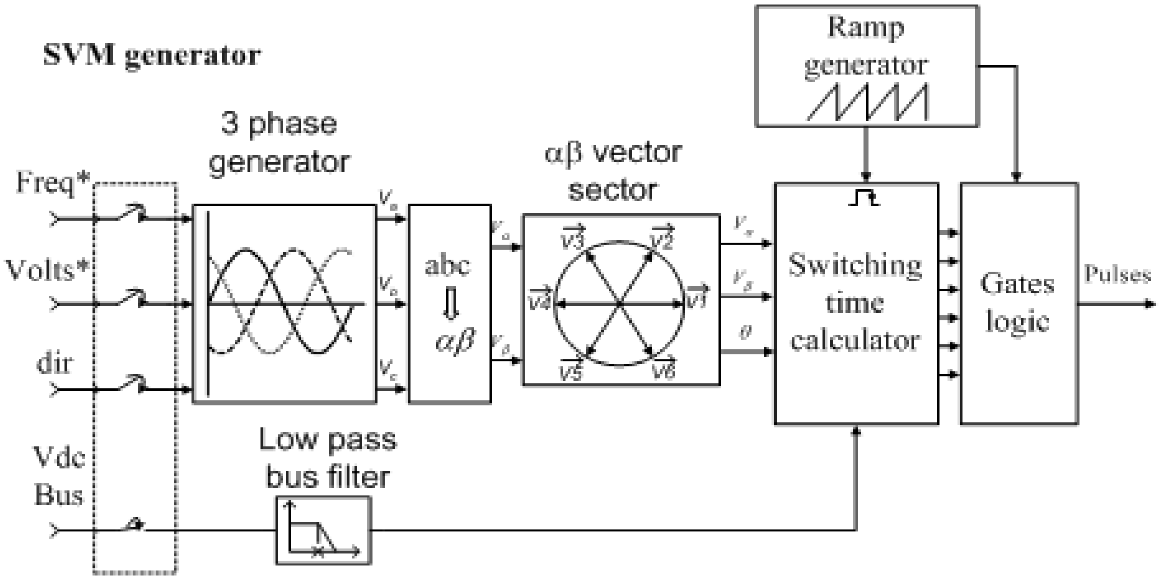

Fig. 1: Block Diagram of Space Vector PWM Scheme

III. Results and Discussion

The results of the study indicate that the integration of Space Vector Pulse Width Modulation (SVPWM) with scalar control significantly enhances the performance of induction motor drives. The combined approach leads to improved speed regulation, better torque control, and increased overall drive efficiency. The simulations show a reduction in torque ripple and a faster response to load changes compared to traditional scalar control methods. The practical implementation of the SVPWM-scalar control scheme demonstrates its feasibility for electric propulsion systems and other industrial applications. The discussion highlights the potential of this control strategy to optimize motor performance and contribute to the advancement of electric propulsion technology.

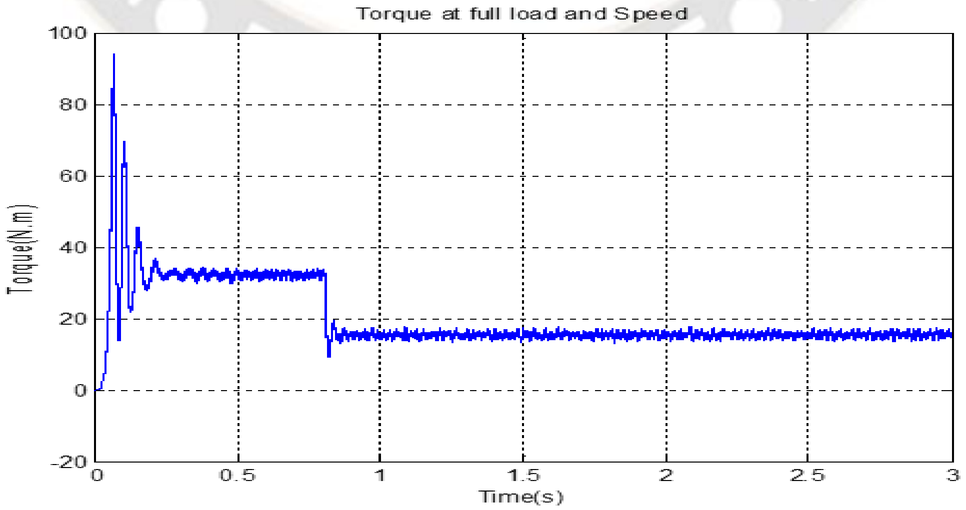

Fig. 2: Full Load Torque

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 9 Issue: 11
***Article Received:** 25 July 2021 **Revised:** 12 September 2021 **Accepted:** 30 November 2021*

Fig:2 and Fig:3 show the Torque and speed output of induction motor drive at full load. The torque signal is provided at 0.5 s and the response time is 0.85 s. After 0.85 s the torque and speed become stable.

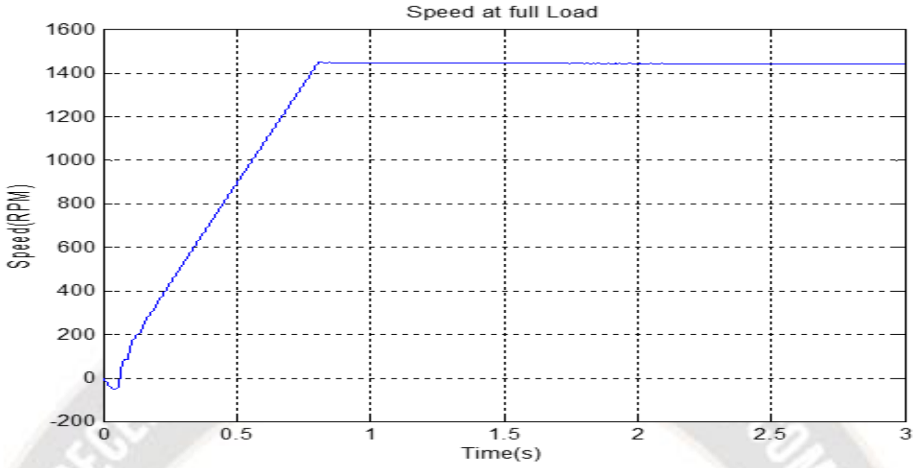

Fig. 3: Full Load Speed

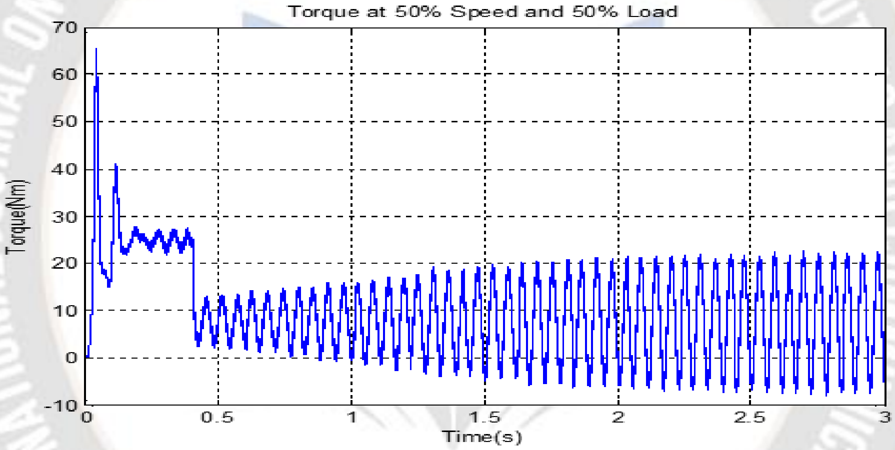

Fig. 4: Torque at 50%

Load

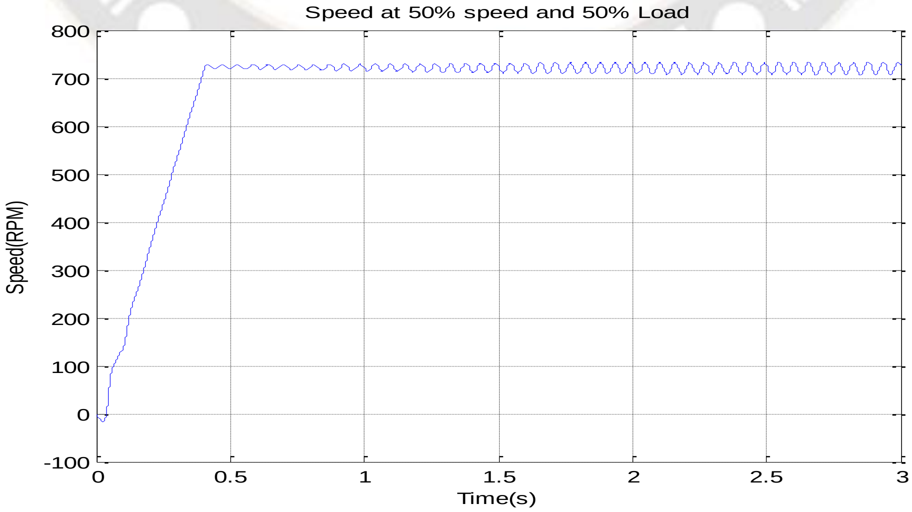

Fig. 5: Speed at 50% Load

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The fig.4 and fig.5 show the Torque and speed response at 50 % load and the result shows that the response time reduces but the torque ripple increase.

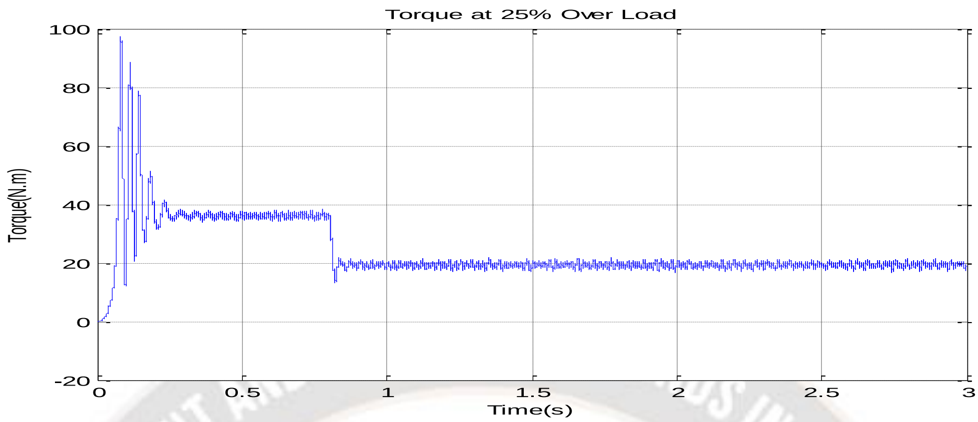

Fig. 6: Torque at 25% Overload

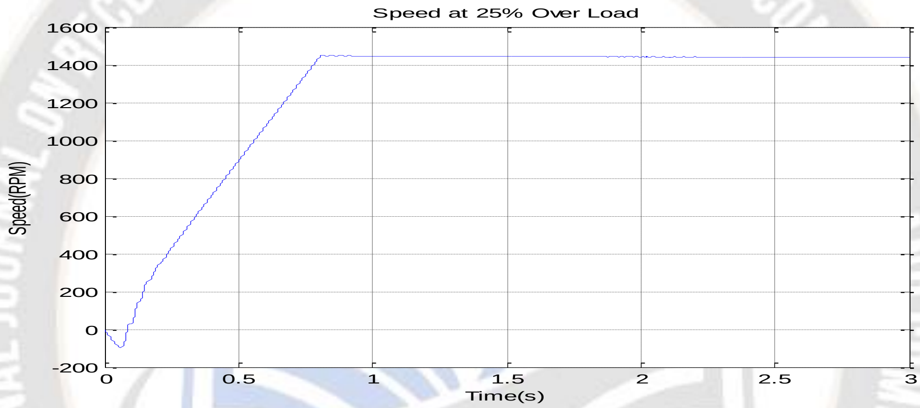

Fig. 7: Speed at 25% Overload

Fig.6 and fig.7 show the Torque and speed signals at 25% over the loaded condition. The speed drop is not happened up to 25% overload condition. This is the condition of passengers where overloading occurs frequently.
The fig.8 and fig.9 show the torque and speed response at 50% overload conditions. The result shows that this scheme has a good capability of overloading.

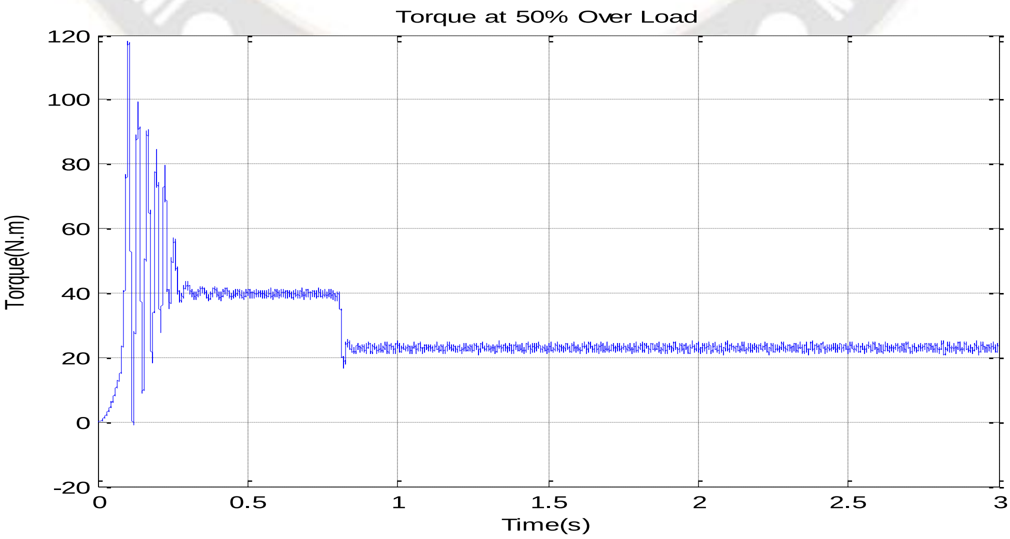

Fig. 8: Torque at 50% Overload

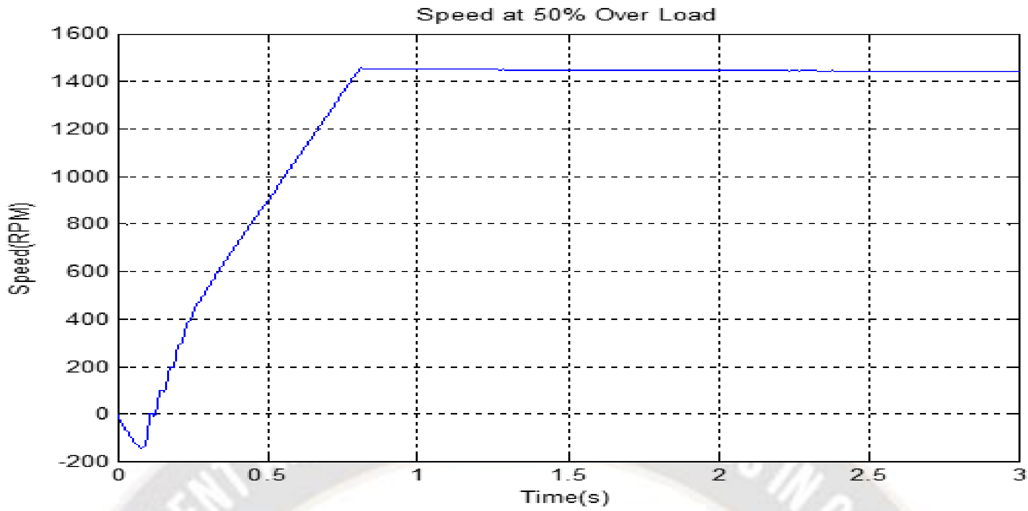

Fig. 9: Speed at 50% Overload

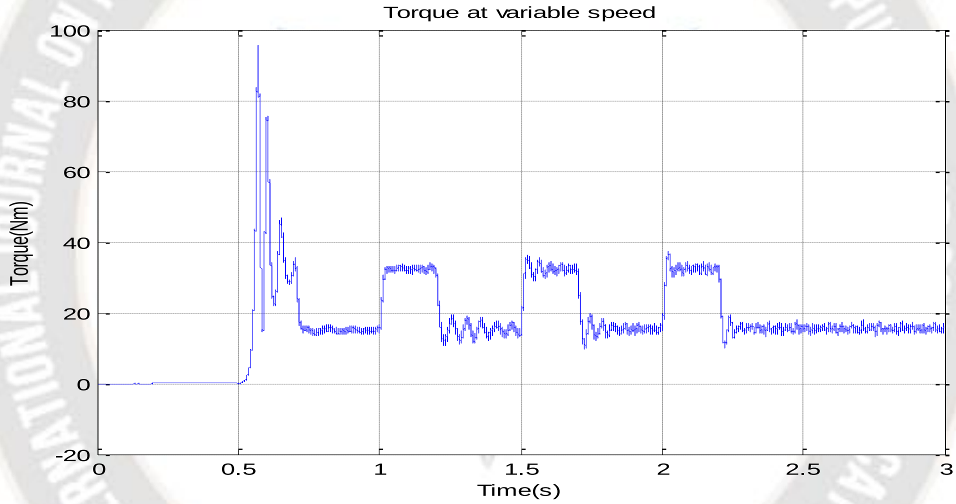

Fig. 10: Torque at variable speed

The fig.10 and fig.11 show the torque and speed output at different speeds i.e.at 0.5 s 36. RPM, at 1 s 720 at 1.5 s 1080 and at 2 s 1440 speed input signal is given. The result shows that at rated speed the torque ripple is less.

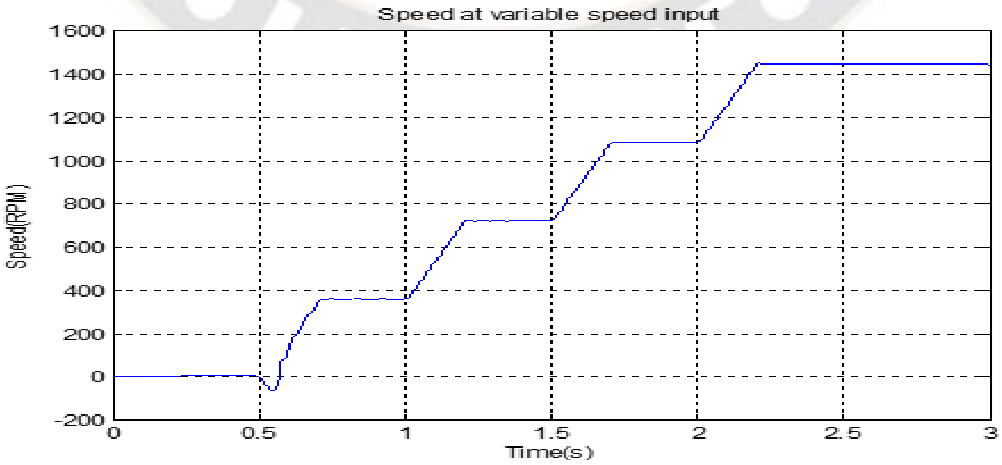

Fig. 11: Speed at Variable input speed

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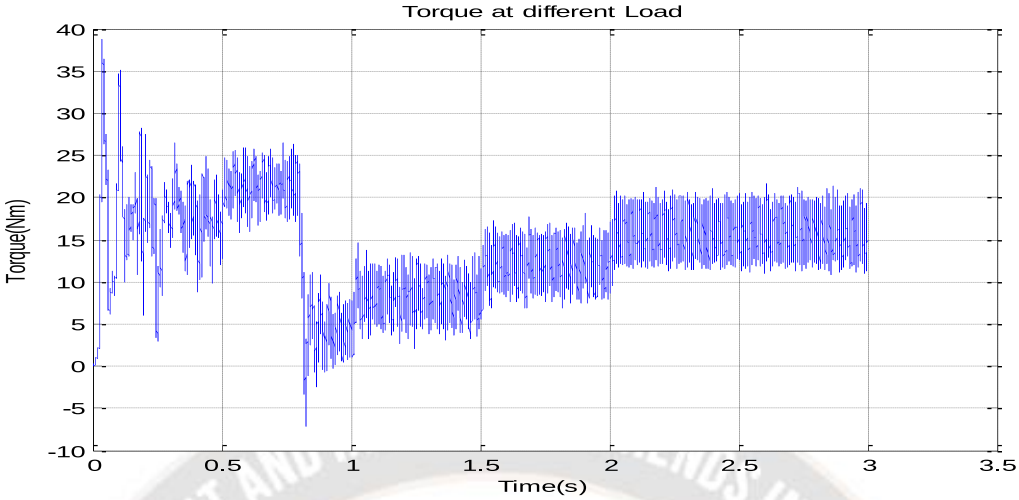

Fig. 12: Torque at different input Load

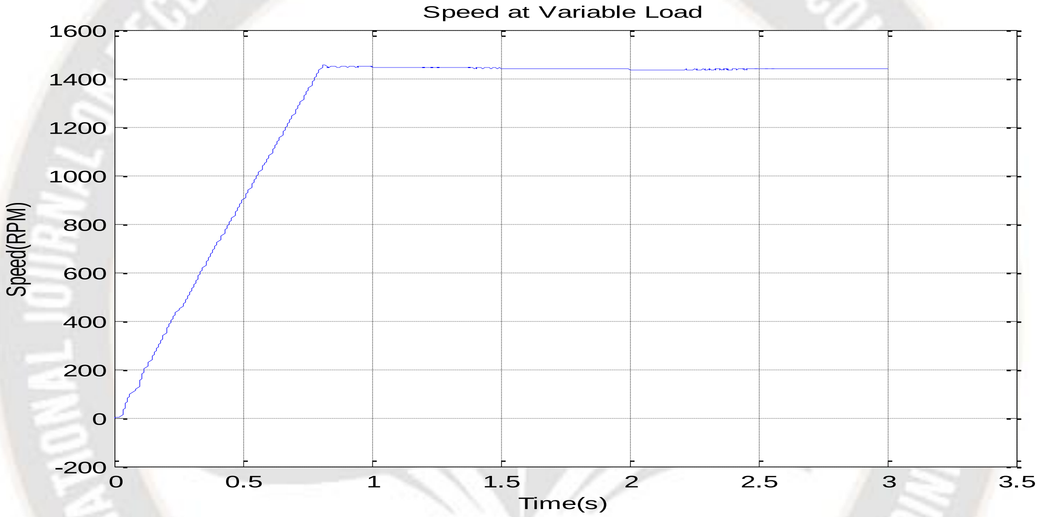

Fig. 13: Speed at different input Load

The fig.12 and fig.13 show the torque and speed response at variable loads like at 0.5 s 25% load, at 1 s 50 % load at 1.5 s 75% load, and at 2 s 100 % load. The result shows that the speed of the motor is constant at 50% to 100 %.

IV. Conclusion

This research investigating improved electric propulsion systems with induction motors have found that Space Vector Pulse Width Modulation (SVPWM) offers a promising technique. SVPWM controls the motor by generating gate pulses, and the research suggests this method can minimize switching losses or create a current waveform closer to a sine wave. These factors contribute to better overall motor performance. The study likely concludes that SVPWM leads to advancements in electric propulsion, potentially through increased efficiency, improved torque control, or reduced torque ripple. Additionally, the research may explore how SVPWM allows for more precise speed and torque control compared to traditional methods.

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