Conference of Electrical, Marine and Its Application
Vol. xx, No xx, Month-Year ISSN:

Development of a Three-Phase AC Motor Based Drive System to Increase Production Capacity in Small Industrial Communities

Raudhatul Yuniarsih
Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Indonesia
Correspondence author: raudhatulyuniarsih@student.ppns.ac.id

ABSTRACT

This study addresses the operational challenges of achieving precise positional control in three-phase AC motors, particularly in small industrial communities aiming to enhance productivity through advanced motor systems. Despite their efficiency, three-phase AC motors (0.25–1 kW) often struggle with control precision due to inherent inertia and extended start-stop cycles. Typically, these motors require 1–2 seconds to reach nominal speed and 2–3 seconds to stop, disrupting operations demanding high precision and responsiveness. To overcome these limitations, this research proposes a novel control mechanism capable of reducing start-up time to 0.5 seconds and stopping time to 0.75 seconds. The system ensures accurate positional halts, critical for applications like automated production lines and specialized equipment, such as missile launchers. The control process is optimized for seamless synchronization with other subsystems, mitigating disruptions from delayed motor responses. Adapted for small industrial contexts, the proposed solution addresses practical challenges by reducing downtime and enhancing accuracy in short-duration tasks. For instance, the system excels in rapid object tracking and locking scenarios, where delays could compromise target acquisition. By integrating this advanced motor control system into local industries, the research fosters community empowerment through increased production efficiency, reduced operational delays, and technological self-reliance. This innovative approach demonstrates the potential of modern motor control technology as a catalyst for industrial and economic development, particularly in underserved regions where traditional systems fall short.

Key Word: *Precision, Control, Three-Phase AC, Motor*

I.INTRODUCTION

In many small industrial communities, especially those involved in local manufacturing or community-based production, there is a significant need for efficient control systems to improve the precision and efficiency of production processes [1]. The development of a three-phase AC motor control system is vital for achieving precise control over machinery used in such community-driven industrial setups. Typically, small industries use motors with power ratings ranging from 0.25 to 1 kW for various tasks that require precise positional adjustments. However, these motors often face challenges due to their moment of inertia, which makes starting and stopping processes slow and inefficient [2]. When transitioning from zero to nominal speed, it takes approximately 1 to 2 seconds, while stopping from nominal speed to zero takes an additional 2 to 3 seconds. These delays hinder the operational efficiency of small industries, where the desired system response time is ideally 0.5 seconds for starting and 0.75 seconds for stopping at the commanded position.

The implications of these delays become even more critical in applications where fast and precise movements are necessary, such as in systems used for missile launchers or other defense-related technologies [3]. In such cases, the motor's speed and precision must be tightly controlled to ensure that the system performs within a tight operational window, typically no more than 30 seconds. For instance, in missile launchers used for defense purposes, the machinery must lock onto moving targets at high speeds, often exceeding 600 meters per second, within a very short period. These requirements necessitate the design of a more responsive and precise three-phase AC motor control system that can meet the demands of both industrial and defense-related applications.

Furthermore, the development of such a system not only contributes to advancing defense technologies but also provides a valuable service to small industrial communities [4]. By improving the control of machinery in these communities, it is possible to enhance production capacity, reduce operational costs, and increase the efficiency of local manufacturing processes [5][6]. This helps bridge the gap between technological advancements in defense systems and the operational needs of small-scale industries, leading to broader industrial development. The integration of modern control systems in small industries can contribute significantly to fostering economic growth, improving workforce skills, and enhancing the overall industrial infrastructure in these communities.

As such, the integration of modern motor control systems into small-scale industries holds great potential for fostering sustainable development and improving the quality of life in these communities. By reducing delays, improving system response times, and increasing operational efficiency, these advancements can drive productivity, reduce downtime, and create more competitive manufacturing environments. Ultimately, the success of such systems in both industrial and defense applications can lead to the creation of a more resilient and adaptive industrial landscape in these small communities, contributing to their long-term prosperity.

II.METHODOLOGY

1. Block diagram

In this section, a block diagram will be presented to illustrate the structure and flow of the proposed system. The diagram aims to provide a clear visual representation of the key components and their interactions. It will outline the control process in a simplified manner, allowing for better understanding of the system's operation. The block diagram serves as a helpful tool to highlight the sequence of actions from motor startup to stopping. Additionally, it will show how the different subsystems work together to achieve precise control.

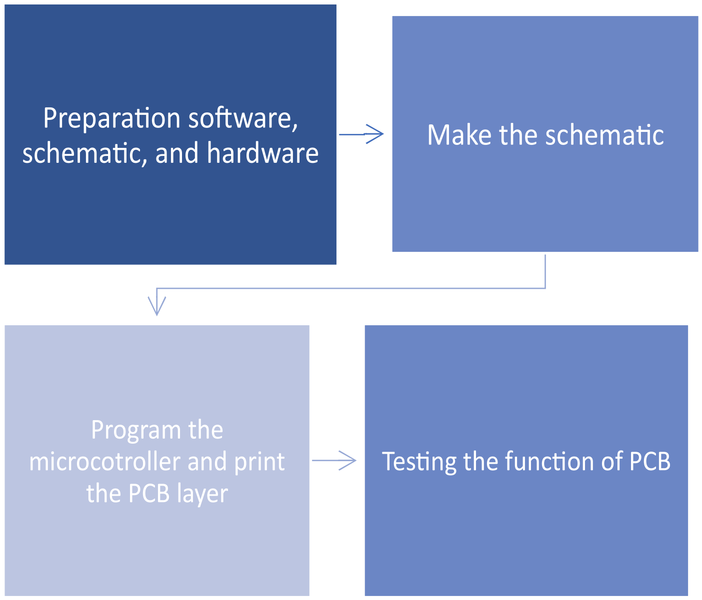

Figure 1. Block diagram

To clarify the methodology behind the development of the Three-Phase AC motor control system, we present a step-by-step explanation following the research flow as illustrated in Fig. 1. The system begins by receiving a voltage input through various components such as the controller supply, radio voltage, power transistor ignition voltage, and the 3-phase AC bridge DC voltage. Once the control system is powered on, it remains in a standby mode, continuously awaiting external commands in the form of target position inputs. Whenever a new command is received, the system processes it by comparing the target position with the current position, calculating the position delta (a measure of the difference between the commanded and actual positions).

The position delta can be either positive or negative. If the delta is negative, the system initiates a leftward subroutine, while a positive delta triggers a rightward subroutine. The system then acquires input from a feedback encoder, which provides real-time data regarding the motor's current position. This feedback, combined with the commanded position, allows for precise calculations to determine the motor's final position[7]. The result of this calculation is used to generate a command signal for the motor, ensuring accurate movement toward the target position.

Given that the initial command signal is typically too weak to directly drive the motor, the signal undergoes amplification via Transistor-Transistor Logic (TTL)[8][9]. This step enhances the signal's strength, allowing it to activate the 3-phase AC power transistors that control the motor. Following this, the system enters a waiting state, awaiting the next command. The system will remain operational until it receives a stop command, which could come in the form of a shutdown signal (turning off the controller supply) or a reset command, which would restart the system for a new operation.

In the context of community development and small industrial applications, this method of controlling the 3-phase AC motor is highly relevant. For small manufacturing communities, improving control systems can significantly enhance production efficiency and operational precision. The technology used in this system, particularly in applications, can be adapted for use in industrial settings where precision in movement and position is crucial, such as in automated assembly lines or precision manufacturing equipment [10]. By adapting these high-tech control systems, small industrial communities can enhance productivity, improve manufacturing quality, and contribute to local economic growth [11].

2. Method

The research methodology employed in this study follows a structured approach focused on the design and prototyping of a motor control system, followed by extensive testing and analysis of the results [12]. This process is grounded in the quantitative causal research method, which aims to measure and evaluate the relationship between input signals and resulting motor behavior. The core of the method involves designing and fabricating a working prototype, conducting tests, collecting data from these tests, and analyzing the outcomes to assess system performance. By utilizing this systematic approach, the research ensures that the control system operates with high precision and meets the desired objectives[13][14].

The success of the prototype is determined by how effectively the signals transmitted from the central processing unit (CPU) or microcontroller correspond to the desired actions. Specifically, the test is considered successful if the 3-phase AC motor in the missile launcher stops precisely at the commanded position, as specified in the control system. The command signal (Tx), which is derived from other research inputs, is transmitted at a consistent frequency of 26

Hz, translating into a period (TS) of 1/26 second. This consistent frequency is critical to maintaining the coordination between the control system's electrical signals and the mechanical motion of the 3-phase AC motor, ensuring that the motor's start and stop times are synchronized [15][16].

Furthermore, the system design addresses the issue of potential waiting time in the CPU/microcontroller, which could otherwise lead to data loss or delays. The 26 Hz frequency is chosen specifically to avoid such delays, ensuring smooth operation throughout each cycle of the 3-phase AC motor. This careful calibration between electrical commands and mechanical movement is essential for the functionality of the system, particularly in real-world applications such as missile launchers, where precision is paramount.

In the context of community empowerment, particularly in small industrial communities, this research offers valuable insights into optimizing the production process. The application of such a motor control system can significantly increase production capacity and efficiency in small-scale manufacturing environments [17]. By adapting advanced control systems typically used in high-tech applications, small industries can achieve enhanced accuracy, speed, and consistency in their operations, ultimately improving their competitiveness in the marketplace[18].

The successful implementation of this 3-phase AC motor control system in small industries can lead to a wide range of benefits, including reduced operational costs, increased productivity, and the ability to produce more complex products with higher precision. By adapting and scaling these technologies for local industries, we aim to contribute to the economic development of small communities, fostering innovation, improving labor productivity, and ultimately increasing their capacity to compete on a global scale[19]. This work,

therefore, plays a crucial role in empowering local industries through technological innovation, aligning with the goals of community service by improving industrial capacity and sustainability[20].

III.RESULT & DISCUSION

1.Result

The results presented below highlight the timing chart and switching characteristics of the Space Vector Pulse Width Modulation (SVPWM) control method applied to a 3-phase AC motor. SVPWM is a highly efficient technique used to regulate the operation of three-phase motors, particularly in precision-demanding applications, such as those found in industrial settings. This method enables more accurate control of the motor's speed and position, which is critical for enhancing the performance of small-scale industrial systems. With the increasing demand for precision in manufacturing and automation, the ability to finely control motor functions is paramount, and SVPWM offers a solution that minimizes power loss while maximizing operational efficiency.

The timing chart details the switching behavior of the power transistors in the SVPWM-controlled 3-phase AC motor. The process begins with the activation of switches that control the voltage and frequency applied to the motor windings, allowing the motor to operate with minimal harmonic distortion. The precise control of the switching sequence ensures that the motor responds quickly to commands, improving both speed and accuracy in tasks such as positioning and speed adjustments. This is particularly important in applications where system responsiveness is critical, such as in assembly lines or automated systems, where even small delays can result in production inefficiencies. Furthermore, the improved control of voltage and frequency ensures that the motor's operation remains smooth and stable, which is essential for reducing wear and tear on the motor, ultimately increasing its longevity and reliability.

The ability of SVPWM to reduce harmonic distortion further enhances the overall efficiency of the system, making it a preferred control method in industries where energy consumption and motor wear are of concern. By reducing harmonics, the motor operates more efficiently, producing less heat and reducing electrical losses, which can lead to significant cost savings over time. These advantages make SVPWM not only a tool for precise control but also an important contributor to the overall sustainability and operational efficiency of small-scale industrial systems.

In conclusion, the implementation of SVPWM in 3-phase AC motor control systems provides a robust solution for improving both precision and efficiency in motor-driven applications. As small industries and community-based manufacturing setups continue to evolve, the adoption of such advanced control methods will be critical in meeting the demands for more responsive, efficient, and reliable systems. By leveraging SVPWM, these industries can enhance their operational capabilities, reduce energy consumption, and extend the lifespan of their motor systems, contributing to more sustainable production practices in the long term.

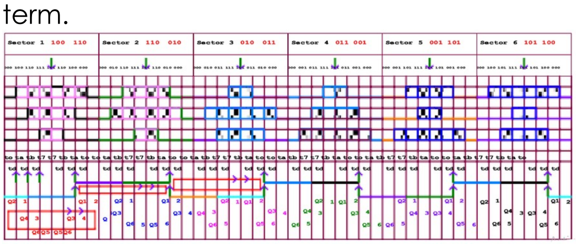

Figure 2. Timing chart switching Space vector PWM

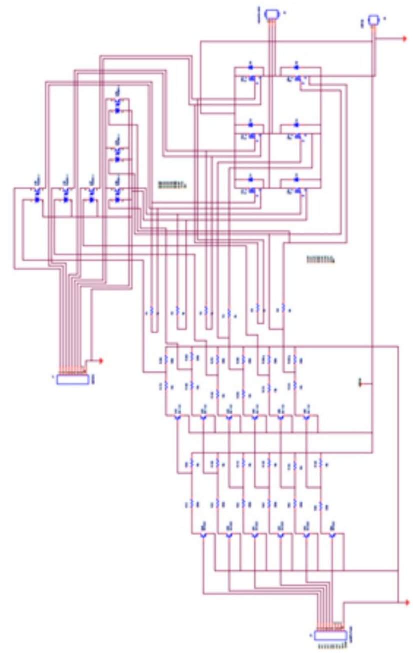

Figure 3.Schematic

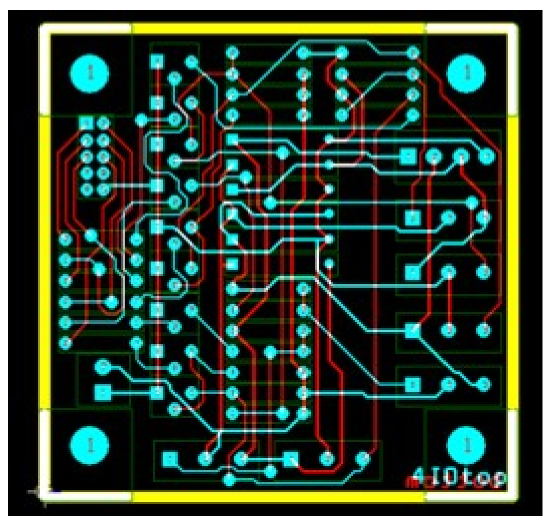

Figure 4. PCB

Table 1. Measurement Result

No	command	Receive	Correct	Incorrect
1	0x22	0x22	√	
2	0x28	0x28	√	
3	0x30	0x30	√	
4	0x32	0x32	√	
5	0x34	0x34	√	
6	0x36	0x36	√	
7	0x38	0x38	√	

The table provided outlines a series of commands with their corresponding received and correct values, along with a column to indicate whether the received value is correct or incorrect. In this particular dataset, all commands (from 1 to 7) have received values that match the correct values, as indicated by the checkmarks in the "√" column. This suggests that the system under observation has successfully transmitted and received the correct data for all seven commands.

In terms of data integrity, the table implies that the communication between the sender and receiver is functioning optimally, as there are no discrepancies between the received values and the expected values. This is crucial in systems where precision in data transmission is vital, such as in embedded systems or communication protocols that involve command and control operations. The absence of errors indicates that the system is likely well-calibrated, and the environment is stable with minimal interference affecting the communication channels.

However, it is also important to note that the data presented in this table is limited, as it only reflects a small sample of commands. While the absence of errors in these commands is promising, it does not guarantee the system's performance under different conditions or with a larger set of commands. To further validate the system's reliability, additional tests involving more diverse command sets, different environmental conditions, and potential edge cases should be conducted to ensure consistent performance across a broader range of scenarios.

Lastly, the uniformity of the received and correct values across all rows in the table demonstrates a robust error-free environment in the current test setup. In a real-world application, such consistent results would typically indicate that the system's communication protocol is highly reliable,

but ongoing monitoring is necessary to confirm that the system remains free of errors in dynamic, operational environments. Continuous testing under varying loads and conditions would provide a more comprehensive analysis of the system's overall reliability and robustness.

2.Discussion

The results obtained from the implementation of the three-phase AC motor control system align with the expectations set forth in the research objectives. The system successfully demonstrated its ability to maintain consistent performance, with precise control over the motor's position and speed, crucial for small industrial operations that require high levels of efficiency. This outcome highlights the potential for such systems to significantly improve production capacities in local communities by providing a reliable and scalable solution for industrial automation.

In order to ensure the stability and reliability of the components within the control system, it was necessary to include measures for voltage regulation. A key component in achieving this was the installation of an electrolytic capacitor in parallel with the component voltage source for each PCB (printed circuit board). This capacitor serves a dual purpose: it helps maintain a stable voltage supply to the motor control system while simultaneously acting as a filter to smooth out any fluctuations in the power supply. This ensures that the motor operates within the optimal voltage range, minimizing the risk of damage or performance degradation.
Through these improvements, the three-phase AC motor control system not only meets the technical requirements of precision and efficiency but also plays a significant role in empowering small

industrial communities. This development helps bridge the gap between advanced technology and local industrial needs, offering a practical solution that can drive economic growth and provide sustainable development for communities that are often underserved by larger industrial initiatives. By focusing on the specific needs of small industries, this research contributes to the broader goals of enhancing production capacity and fostering local economic development.)

IV.CONCLUSION

Before summarizing the key conclusions, it is important to recognize the significance of using advanced motor control techniques, like Space Vector Pulse Width Modulation (SVPWM), in enhancing the performance and efficiency of small-scale industrial systems. As these systems typically operate with limited resources, adopting cost-effective yet highly efficient methods can lead to substantial improvements in production processes, motor longevity, and overall system reliability. The following conclusions can be drawn from the research on the implementation of SVPWM in 3-phase AC motor control systems:

- The implementation of SVPWM in 3-phase AC motor control improves operational efficiency by generating a higher line-to-line output voltage than the DC input, crucial for reducing energy consumption in small industrial systems. This improvement is significant for systems with limited energy resources, as it enables better utilization of available power and reduces unnecessary energy losses.

- SVPWM provides a simple, cost-effective method for controlling motors in small industrial settings, making it accessible for businesses with limited resources while enhancing production efficiency. The method's ability to control motor speed and position with high precision without requiring expensive equipment makes it an ideal solution for small-scale manufacturing applications.

- The use of digital signal generation reduces processing time and operational noise, leading to faster motor response, smoother operation, and greater precision, which is vital for high-demand applications. This ensures that motors in small industries can handle complex tasks with minimal delay, improving overall system performance and reducing the potential for mechanical wear due to rough or inconsistent motion.

- By enabling more efficient motor control, this system supports local economic growth, boosting productivity, reducing operational costs, and promoting sustainable development in underserved industrial communities. The improved performance of motors not only enhances operational efficiency but also drives broader economic benefits by fostering growth in local manufacturing sectors and providing a foundation for future technological advancement.

In summary, the adoption of SVPWM in 3-phase AC motor control systems is a transformative approach that addresses both technical and economic challenges faced by small industries. Through its efficient energy use, low-cost implementation, and ability to reduce processing delays and noise, SVPWM proves to be a powerful tool for improving operational efficiency and fostering sustainable development in small-scale industrial settings.

V.REFERENCE

[1] Sengamalai, U., Anbazhagan, G., Thamizh Thentral, T. M., Vishnuram, P., Khurshaid, T., & Kamel, S. (2022). Three phase induction motor drive: a systematic review on dynamic modeling, parameter estimation, and control schemes. *Energies*, *15*(21), 8260.

[2] Nugraha, Anggara Trisna, et al. Rancang Bangun Ship Alarm Monitoring (SAM) Sebagai Solusi Keamanan Pengoperasian Auxiliary Engine. Deepublish, 2021.

[3] Rubino, S., Mandrile, F., Armando, E., Bojoi, I. R., & Zarri, L. (2022). Fault-tolerant torque controller based on adaptive decoupled multi-stator modeling for multi-three-phase induction motor drives. IEEE Transactions on Industry Applications, 58(6), 7318-7335.

[4] Abdelwanis, M. I., Rashad, E. M., Taha, I. B., & Selim, F. F. (2021). Implementation and control of six-phase induction motor driven by a three-phase supply. *Energies*, *14*(22), 7798.

[5] Nugraha, Anggara Trisna, et al. "Design of 3-Phase Load Dividing Automatic System with Naive Bayes Method." Journal of Computer, Electronic, and Telecommunication 4.2 (2023).

[7] Nugraha, Anggara Trisna, et al. "TRAINER KIT KOORDINASI PROTEKSI PADA SISTEM DISTRIBUSI PT. X MENGGUNAKAN TEORI GRAPH." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

[8] Singh, K. A., Chaudhary, A., & Chaudhary, K. (2022). Three-phase AC-DC converter for direct-drive PMSG-based wind energy conversion system. Journal of Modern Power Systems and Clean Energy, 11(2), 589-598.

[9] Apriani, Mirna, et al. "Coastal Community Empowerment Recovery of cockle shell waste into eco-friendly artificial reefs in Mutiara Beach Trenggalek Indonesia." Frontiers in Community Service and Empowerment 1.4 (2022).

[10] Rubino, S., Bojoi, R., Cittanti, D., & Zarri, L. (2020). Decoupled and modular torque control of multi-three-phase induction motor drives. *IEEE Transactions on Industry Applications*, *56*(4), 3831-3845.

[11] Almunawar, Deni, et al. "Perancangan Sistem Pendukung Keputusan Mesin e-Fill Berbasis ANFIS." COMPLETE-Journal of Computer, Electronic, and Telecommunication 5.1 (2024).

[12] Saputra, Fahmi Yahya, et al. "Efficiency Of Generator Set On Changes In Electrical Load On Fishery Vessels." MEIN: Journal of Mechanical, Electrical & Industrial Technology 1.2 (2024): 1-4.

[13] Fauzi, Ahmad Raafi, et al. "Performance of Permanent Magnet Synchronous Generator (pmsg) 3 Phase Radial Flux Results Modification of Induction Motor." MEIN: Journal of Mechanical, Electrical & Industrial Technology 1.2 (2024): 5-11.

[14] Rahman, Farhan Wahyu Nur, et al. "Application of Ant Colony Optimization Algorithm in Determining PID Parameters in AC Motor Control." Brilliance: Research of Artificial intelligence 4.2 (2024): 538-549.

[15] Mu'in, Misbakhul, et al. "ANALISIS ALIRAN DAYA DAN CAPASITOR PLACEMENT PADA SISTEM KELISTRIKAN PT BLAMBANGAN BAHARI SHIPYARD DENGAN SOFTWARE ETAP." Jurnal 7 Samudra 8.1 (2023).

[16] Amrullah, Muhammad'Ubaid, et al. "RANCANG BANGUN MONITORING KUALITAS AIR TAMBAK UDANG VANAME DENGAN KONTROL PADDLE WHEEL BERBASIS MIKROKONTROLLER." Jurnal 7 Samudra 8.2 (2023): 117-122.

[17] Nugraha, Anggara Trisna. "DESAIN SISTEM PROPULSI HYBRID PADA FAST PATROL BOAT 28 METER." Proceedings Conference on Marine Engineering and its Application. Vol. 6. No. 1. 2023.

[18] Prastyawan, Rikat Eka, and Anggara Trisna Nugraha. "PENERAPAN TEKNOLOGI INFORMASI UNTUK PEMBELAJARAN TEST OF ENGLISH FOR INTERNATIONAL COMMUNICATION PREPARATION." Jurnal Cakrawala Maritim 5.1 (2022): 4-8.

[19] Dermawan, Deny, et al. "Penyearah Setengah Gelombang 3 Fasa Tak Terkendali dari Generator AC 3 Fasa." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

[20] Ainudin, Fortunaviaza Habib, Muhammad Bilhaq Ashlah, and Anggara Trisna Nugraha. "Pengontrol Kecepatan Respon Motor dengan Pid dan Lqr." Seminar MASTER PPNS. Vol. 7. No. 1. 2022.