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Integration of VFD and PLC for Motor Speed Optimization

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Abstract: *This work explores the implementation of three-phase motor speed control using a Variable Frequency Drive (VFD) in conjunction with a Programmable Logic Controller (PLC) and a Human-Machine Interface (HMI) to enhance energy efficiency, precision, and operational adaptability in industrial environments. The VFD modulates the supply frequency to achieve variable motor speeds, enabling smoother operation and significant energy savings by aligning motor performance with load requirements. The PLC facilitates customized control logic, allowing seamless integration of sensors, automated responses, and safety interlocks. This integrated approach not only optimizes motor performance and reduces mechanical wear but also lowers maintenance demands. The HMI provides a user-friendly graphical interface for real-time monitoring, parameter adjustment, and diagnostics, thereby improving operator interaction and system transparency. This integrated approach not only optimizes motor performance and reduces mechanical wear but also lowers maintenance demands. The combined use of VFD, PLC, and HMI represents a modern, intelligent automation strategy that delivers improved reliability, flexibility, and overall system efficiency in industrial motor control applications.*

Keywords: PLC, VFD, HMI, three phase induction motor, sensor integration, control logic.

I. INTRODUCTION

Motor speed control is a critical aspect of industrial automation, ensuring that machinery operates with optimal efficiency, precision, and safety. One of the most effective and widely adopted methods for achieving this control is through the integration of a PLC, VFD and HMI [1]-[4].

A VFD regulates the speed and torque of an AC induction motor by adjusting the frequency and voltage supplied to it, enabling precise control over motor performance [1], [9], [14]. The PLC serves as the central automation controller, executing user-defined logic based on real-time inputs from sensors and field devices [2], [5], [13]. It typically communicates with the VFD using RS-485 (Modbus RTU) or analog/digital I/O signals such as 4–20 mA or 0–10 V [1], [10].

The HMI acts as a graphical user interface, enabling operators to:

- Enter and adjust speed setpoints
- Monitor real-time system status (e.g., motor speed, voltage, current, and load)
- Receive fault and diagnostic alerts
- Interact with the control system through user-friendly touchscreen panels [3], [4], [11]

The PLC-HMI-VFD integration allows for advanced features including:

- Automated motor speed and direction control [3], [6]
- System diagnostics, safety interlocks, and alarms [4], [12]
- Data logging and remote access capabilities [11], [15]
- Seamless communication with SCADA or industrial networks [4], [15]

Proper electrical wiring, signal configuration, and logic programming are essential for successful implementation. The three-phase AC induction motor is connected to the VFD's output terminals (U, V, W), which are powered by a suitable three-phase AC supply. The PLC is programmed using industrial languages such as Ladder Logic, enabling real-time processing of inputs and execution of control strategies [5], [13].

This integrated approach improves:

- Energy efficiency by adjusting motor speed to match load demands [10]
- System flexibility to suit a variety of industrial processes [8]
- Safety and reliability through protective interlocks and error handling [6], [7]
- Performance in both open-loop and closed-loop configurations [1], [7]

Thus, the combined use of VFD, PLC, and HMI forms a robust, scalable, and cost-effective solution for modern industrial motor control systems [1]–[16].

II. LITERATURE SURVEY

Khudier et al. [1] proposed an automated speed control system for induction motors that integrates a PLC and a VFD within a closed-loop control architecture. The system accepts a user-defined speed setpoint through the HMI, which is then processed by the PLC. A tachometer measures the actual motor speed, which is converted to a digital signal via an Analog-to-Digital Converter (ADC). The PLC computes the error signal—the difference between the actual and desired speed—and sends corresponding control signals to the VFD to modulate frequency and voltage. This real-time feedback control mechanism ensures constant speed operation under variable load conditions, improving system efficiency and stability. The approach was successfully validated on both two-pole and four-pole induction motors, demonstrating its broad industrial applicability.

Birbir et al. [2] developed a PLC-based monitoring and control system for three-phase induction motors fed by PWM inverters. Their study shows that PLC-controlled architectures offer significantly better speed control and protection mechanisms compared to traditional Volts-per-Hertz (V/f) control methods, especially at higher operational speeds. The system provides essential protections against abnormal conditions, including overloads and phase failures, thereby enhancing reliability and safety in industrial motor control.

Prabhakaran et al. [3] presented a PLC and SCADA-based condition monitoring system for three-phase induction motors. The setup utilizes VFDs for motor speed and direction control, while the SCADA interface allows operators to perform real-time monitoring and remote diagnostics. The system enables fault detection and preventive maintenance, leading to longer equipment lifespan and improved safety. This architecture is particularly suited for facilities requiring continuous supervision and automated alerting systems.

Dorjee et al. [4] implemented an automated conveyor belt system powered by a three-phase induction motor using PLC and SCADA integration. The system uses sensor feedback and ladder logic programming to execute automated actions based on process requirements. Real-time control and visualization are achieved through a PC-based SCADA interface, demonstrating the potential for smart automation in material handling and production line optimization.

Abdulwahid et al. [5] explored a hybrid control system using both PLC and Arduino Nano to operate a three-phase induction motor. The inclusion of a tachometer provides real-time speed measurement, while Arduino adds cost-effective flexibility for educational or small-scale automation. This approach is especially valuable in prototyping and lab-scale experimentation, while still maintaining reliable control and monitoring functions.

Mohammed et al. [6] focused on speed control of a single-phase induction motor using a PLC-only setup. The system adjusts the applied voltage to control motor speed, demonstrating fast response and adaptability to varying load conditions. Their findings highlight that PLC-based control is not limited to large industrial three-phase systems but is also effective in low-power or domestic motor applications.

Hussein et al. [7] introduced a vector control algorithm employing d–q (direct-quadrature) axis transformation, which transforms three-phase inputs into a two-axis reference frame. This enables independent control of torque and flux, allowing the system to dynamically modulate the voltage and frequency while maintaining a constant V/f ratio. Implemented in MATLAB/Simulink, the approach provides high-speed and high-torque accuracy, making it suitable for demanding industrial drive applications.

Rekha et al. [8] proposed an advanced control strategy to address stress issues in VFDs when supplied from single-phase AC sources. Their method combines Modified Quasi-Adaptive Control (M-QAC), Torque Ripple Compensation (TRC), and Switched-Type PSO (STP-PSO) to enhance system robustness. The strategy outperforms traditional fold-

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back techniques by minimizing torque ripple, reducing harmonic distortion, and improving load response, thereby increasing both motor life and system reliability.

III. METHODOLOGY

The block diagram illustrates the control system architecture for a three-phase AC induction motor as shown in Fig.1. A 24V DC supply powers the Siemens Simatic S7-1200 PLC, which communicates with the Emotron VSS series VFD via Profinet communication protocol. The VFD receives a 230V AC single-phase input and delivers a three-phase output to drive the motor.

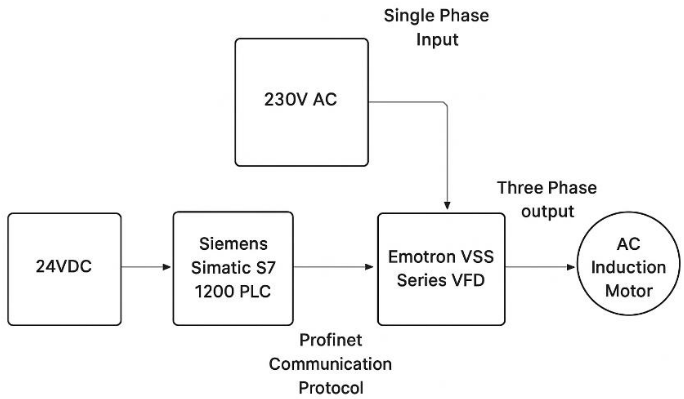

Fig. 1 Block diagram of PLC integrated VFD control for three-phase induction motor

The hardware setup was designed to control a three-phase, 4-pole induction motor using a VFD as shown in Fig.2. This setup illustrates a real-time motor control system consisting of the following components:

- Laptop with HMI Software: The laptop is running a HMI application-likely developed in WinCC, Factory I/O, software-which is used to visualize and interact with the control process. It allows the operator to input speed setpoints, monitor live motor performance, and display alarms or status updates from the system. Siemens PLC Trainer Kit: The trainer includes a Siemens S7-1200 PLC with I/O terminals, programming ports, and power supply. It is wired to control and monitor the VFD and motor, executing logic programmed in TIA Portal using Ladder Logic (LAD). The PLC is responsible for receiving speed commands from the HMI, reading feedback from the motor, and issuing control instructions to the VFD.
- Variable Frequency Drive (VFD): The VFD module, of an Emotron VSS series VFD, converts the single-phase AC input to a variable-frequency three-phase output to control the motor speed. It receives analog/digital commands from the PLC and adjusts output frequency accordingly.
- Three-Phase Induction Motor: A small-scale three-phase squirrel cage induction motor is used for demonstration. Connected to the VFD output (U, V, W), the motor's speed can be dynamically varied based on process logic.
- Tachometer: The system likely includes a tachometer to measure actual motor speed
- Wiring and Communication Interfaces: The system uses 24VDC supply and signal wiring. Likely communication protocols include RS-485, analog signals (e.g., 0–10 V, 4–20 mA) to interface between the PLC, VFD, and HMI.

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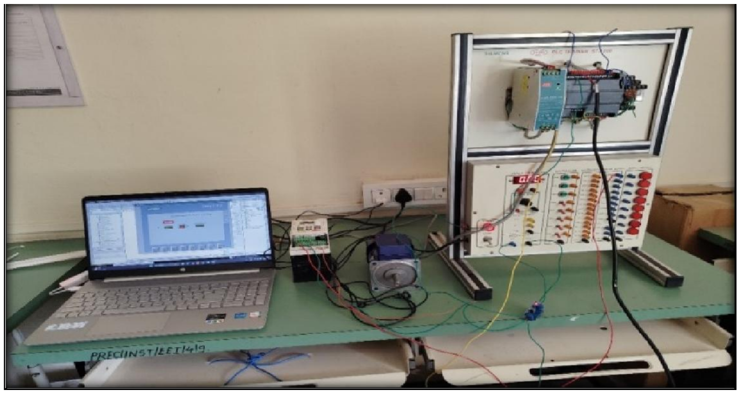

Fig. 2 Hardware setup for PLC integrated VFD control for three-phase induction motor

The PLC serves as the brain of the system, executing logic to control motor operations such as start, stop, and speed adjustments. It can send commands to the VFD through digital outputs or communicate via analog signals (e.g., 0–10V for speed reference) or serial protocols like Modbus RTU, depending on the configuration. The Emerton VSS series VFD controls the speed of the motor by adjusting the output frequency and voltage delivered to the motor. It uses sensor less vector control to ensure high torque performance and stable operation across a wide speed range. Internally, the VFD rectifies the AC input to DC and inverts it back to a controlled AC output, modulated according to the PLC's instructions. The motor in this setup is usually a three-phase AC induction motor, where its speed is determined by the frequency of the voltage supplied by the VFD. As the PLC adjusts the frequency command, the VFD modifies its output to either accelerate or decelerate the motor accordingly. Communication between the PLC and the VFD is established using digital I/O, analog outputs over RS-485. The choice depends on the system's complexity and the required precision. Safety is a critical component of this control system. Both the PLC and VFD include protective features such as overload detection, emergency stop circuits, and grounding systems. The VFD also monitors parameters like overvoltage, phase loss, and motor overheating, and will trip if a fault is detected. Emergency stop buttons and interlocks are hardwired to the PLC to ensure immediate motor shutdown in hazardous situations. Proper grounding, shielding, and fail-safe circuit design are essential to maintain safe and reliable system operation.

System Configuration and Control Logic:

The S7-1200 PLC was programmed using the TIA Portal to interpret the user's speed input (in Hz) from the HMI and convert it into a corresponding analog output signal. The HMI, developed in WinCC, allows the operator to enter a desired motor speed within the range of 0 to 50 Hz. This input is mapped to a PLC tag and processed within the PLC program as shown in Fig. 3.

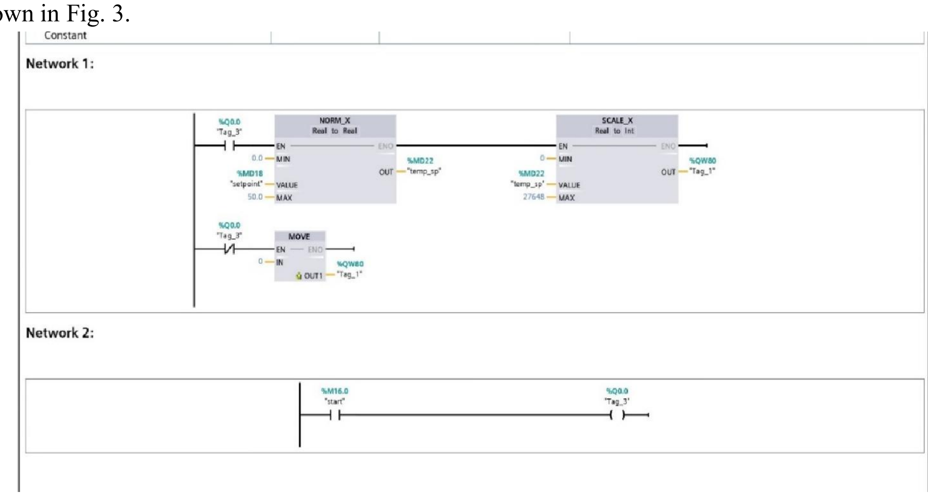

Fig. 3 PLC logic for motor speed control using VFD

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To generate the appropriate analog output, the user-defined speed value is passed through a scaling routine utilizing standard Siemens instructions such as NORM_X and SCALE_X. These functions translate the 0–50 Hz input into a raw digital count ranging from 0 to 27,648, corresponding to a 0–10 V analog output range. This analog signal is then transmitted from the PLC's analog output channel to the frequency command input of the Emetron VSS VFD. The VFD is configured to interpret the 0-10 V input as a speed reference, where 0 V equates to 0 Hz and 10 V equates to 50 Hz output frequency. As a result, a user-defined frequency setpoint fs entered via the HMI translates to an analog voltage of (fs/50)×10 volts delivered to the VFD. The analog output module offers a 15-bit resolution (0–27,648 counts), enabling a voltage resolution of approximately 0.00036 V per step well within the accuracy requirements for motor speed control. The system operates in open-loop mode, with no feedback from the motor.

Network 1 converts user-entered frequency (e.g., 0–50 Hz) into a raw analog signal (0–27648) suitable for sending to the VFD.

Network 2 provides the start/stop control logic for enabling/disabling the VFD output to the motor.

Consequently, the VFD adjusts its output frequency solely based on the received analog voltage, simplifying the system architecture by eliminating the need for feedback wiring and closed-loop control elements such as PID regulation, though this does introduce typical open-loop limitations.

IV. RESULT AND DISCUSSION

To assess system performance, the motor was tested at multiple frequency set points: 0 Hz, 10 Hz, 20 Hz, 30 Hz, 40 Hz, and 50 Hz. The expected motor speeds at each frequency were determined based on a linear Voltage-to-Frequency (V/f) control strategy in an open-loop configuration.

As anticipated, the actual rotor speed was marginally lower than the synchronous speed due to inherent slip. Precise motor speed control was achieved through the integration of the VFD with PLC programming. The system enabled smooth motor acceleration and deceleration, thereby reducing mechanical stress. The implemented PLC logic ensured efficient management of speed transitions. Consequently, the motor exhibited stable performance across varying speeds, along with improved energy efficiency as shown in Fig.4 and Fig.5.

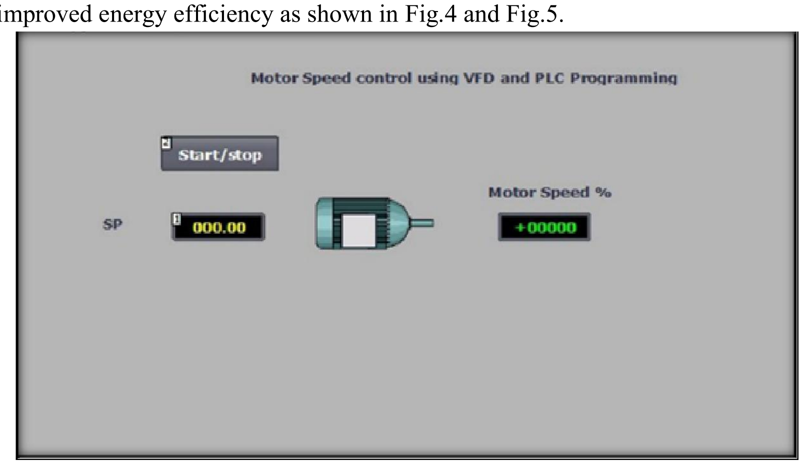

Fig. 4 Frequency set at 0 Hz through HMI for the motor speed control at 0 rpm

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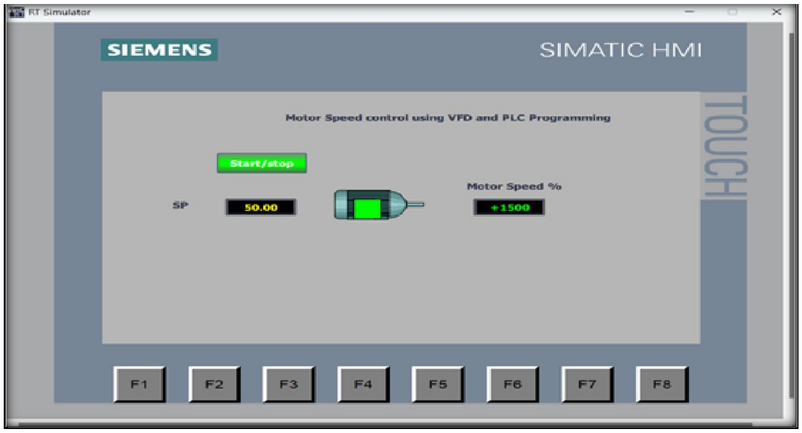

Fig. 5 Frequency set at 50 Hz through HMI for the motor speed control at 1500 rpm

V. CONCLUSION

Motor speed control using a VFD in conjunction with a PLC is a reliable and efficient method for optimizing industrial motor performance. The integration of PLC and VFD enables accurate speed regulation, enhanced energy efficiency, and advanced automation capabilities, thereby improving overall system productivity. This study highlights how the flexible control logic enabled through PLC programming allows real-time adjustments and continuous monitoring of motor operations. By significantly reducing energy consumption and mechanical stress, a VFD extends the motor's lifespan and lowers maintenance costs.

The integration of a VFD with a PLC presents a robust and efficient solution for industrial motor speed control. This combination offers precise speed regulation, improved energy efficiency, and advanced automation functionalities, which collectively contribute to enhanced system productivity. The adaptability of PLC programming facilitates real-time monitoring and dynamic control, enabling responsive and optimized motor operations. Furthermore, the use of a VFD not only minimizes energy consumption and mechanical wear but also extends motor lifespan and reduces overall maintenance costs. This study underscores the effectiveness of PLC-VFD integration as a strategic approach to modern industrial automation and sustainable motor management.

REFERENCES

[1]. Khudier, K. H., Mohammed, K. G., & Ibrahim, M. S., "Design and implementation of constant speed control system for the induction motors using programmable logic controller (PLC) and variable frequency derive (VFD)," *IOP Conference Series: Materials Science and Engineering*, Vol. 1076, No. 1, p. 012007, February 2021.

[2]. Birbir, Y., & Nogay, H. S, "Design and implementation of PLC-based monitoring control system for three-phase induction motors fed by PWM inverter," *International journal of systems applications, engineering & development*, *2*(3), 128-135, 2008.

[3]. Prabhakaran, K. "VFD based Speed Control of Three Phase Induction Motor by PLC and SCADA," *journal of Research*, *3*(10) 2017.

[4]. Dorjee, R. G. "Monitoring and control of a variable frequency drive using PLC and SCADA," *International Journal on Recent and Innovation Trends in Computing and Communication*, *2*(10), 3092-3098, 2014.

[5]. Abdulwahid, M. M. "Design and Implementation of Motor Speed Control Model by using a PLC," *Informatica: Journal of Applied Machines Electrical Electronics Computer Science and Communication Systems*, *1*(1), 54-62, 2020.

[6]. Mohammed, A. F., Flaifly, A., & Mohammed, H. S. "Programmable Logic Controllers Application in Speed Control of Single-Phase Induction Motor," 2018.

[7]. Hussein, H. I., & Jaber, A. I. "Open Loop & Closed Loop Vector Control of VFD Three Phase Version Induction Motor Drives," *Diyala Journal of Engineering Sciences*, 27-38, 2014.

[8]. Rekha, M., & Malligunta, K. K. "Variable frequency drive optimization using torque ripple control and self-tuning PI controller with PSO," *International Journal of Electrical and Computer Engineering*, *9*(2), 802, 2019.

[9]. Jain, P., & Agrawal, S., "PLC Based Speed Control of Induction Motor using VFD," *International Journal of Engineering Research & Technology (IJERT)*, Vol. 3, No. 5, pp. 2763–2766, 2014.

[10]. Basavarajappa, R., & Shridhara, H. S., "Energy Saving in Induction Motor Using VFD and PLC," *International Research Journal of Engineering and Technology (IRJET)*, Vol. 4, No. 8, pp. 281–285, 2017.

[11]. Mehta, P., & Mehta, R., "Monitoring and Control of Three-Phase Induction Motor using PLC and SCADA," *International Journal of Scientific & Engineering Research*, Vol. 6, No. 7, pp. 1294–1299, 2015.

[12]. Al-Rubaye, A. A., "Design and Simulation of a PLC-Based VFD Control System for an Induction Motor," *Journal of Electrical Engineering*, Vol. 10, No. 2, pp. 88–94, 2019.

[13]. Tiwari, R., & Joshi, R. K., "Speed Control of Three-Phase Induction Motor Using PLC and PID Controller," *International Journal of Science and Research (IJSR)*, Vol. 3, No. 6, pp. 1300–1304, 2014.

[14]. Sahu, A., & Tripathi, R., "Review on Speed Control Techniques of Induction Motor," *International Journal of Emerging Technology and Advanced Engineering*, Vol. 4, No. 5, pp. 140–145, 2014.

[15]. Jena, M. R., & Padhee, S., "PLC and SCADA based Automation of Induction Motor Drive System," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 2, No. 7, pp. 3253–3259, 2013.

[16]. Pillai, G. K., & Arora, H., "Industrial Implementation of VFD in Electrical Drives," *International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)*, Vol. 5, No. 10, pp. 17569–17574, 2016