International Journal of Multidisciplinary Approach Research and Science
E-ISSN 2987-226X P-ISSN 2988-0076
Volume 2 Issue 3, September 2024, Pp. 1184-1190
DOI: https://doi.org/10.59653/ijmars.v2i03.925

Implementation of a Three Phase Motor Protection System Using PLC and HMI

Yuli Prasetyo[1*], Budi Triyono[2], R. Jasa Kusumo H[3], Santi Triwijaya[4]
Politeknik Negeri Madiun, Indonesia[1]
Politeknik Negeri Madiun, Indonesia[2]
Politeknik Negeri Madiun, Indonesia[3]
Politeknik Perkeretaapian Indonesia Madiun, Indonesia[4]
Corresponding Email: yuliprasetyo2224@gmail.ac.id*

Received: 15-05-2024 Reviewed: 25-05-2024 Accepted: 15-06-2024

Abstract

Three-phase electric motors are essential components in industrial production processes, playing a crucial role as the driving force for almost all industrial machinery. These motors are susceptible to various electrical disturbances, such as overcurrent caused by overloads or short circuits. Common issues that frequently occur with three-phase motors include high starting currents, overcurrent, and short circuits. To mitigate the losses caused by these disturbances, an effective protection system is necessary. This study analyzes the implementation of a protection system using Programmable Logic Controller (PLC) and Human Machine Interface (HMI) to control and monitor the protection mechanisms for electric motors. The proposed protection system aims to safeguard the motors from disturbances such as high starting currents, overcurrent, and short circuits. By leveraging the real-time monitoring and control capabilities of PLCs and the user-friendly interface of HMIs, the system can accurately detect and respond to abnormal conditions, thereby minimizing the risk of damage to critical three-phase motors. The development of this protection system ensures the reliability and longevity of three-phase motors in industrial applications, reducing downtime and enhancing overall operational efficiency.

Keywords: Electric Motor, Disturbance, protection system, PLC, HMI

Introduction

Three-phase electric motors are crucial components in industrial production processes, serving as the primary driving force for almost all machinery in factories (Rifaldo & Yuhendri, 2022). The superiority of three-phase motors over single-phase ones lies in their higher efficiency, ability to handle heavy loads, and smoother operation. Therefore, they are widely utilized in various industrial applications such as pumps, compressors, conveyors, and other heavy-duty machinery requiring reliable operation.

In industrial environments, the smooth operation heavily relies on the reliability of three-phase electric motors. Any disturbance to these motors can result in significant losses, including costly production downtime and equipment damage. Given the importance of three-phase electric motors in industrial operations, having an effective protection system is paramount to safeguarding them from various electrical disturbances (Abdelmoaty & Soliman, 2020; Mugaruka Josue & Biru Worku, 2021; Pradipta et al., 2023).

Although three-phase electric motors are highly reliable, they are not immune to various electrical disturbances. Common disturbances include high starting currents, overcurrent, and short circuits (Triyono et al., 2021). Each of these disturbances has the potential to cause serious damage to the motor if not promptly identified and addressed. When initially powered on, three-phase motors can draw a significantly higher current than their normal operational current. This high inrush current can induce thermal stress on the motor windings and associated electrical components, potentially leading to premature failure if not managed properly. Overcurrent occurs when the motor draws a current exceeding its nominal capacity, often due to excessive loads or short circuits. Prolonged overcurrent can result in excessive heating, insulation damage, and motor winding failure. Short circuits in motors can occur due to insulation failure, mechanical damage, or other electrical faults, creating a direct path for current flow and causing severe damage to the motor and related circuits.

Reducing the losses caused by these disturbances requires a comprehensive and effective protection system. The primary objective of this research is to develop and implement a protection system capable of quickly detecting and responding to abnormal conditions to prevent motor damage and minimize production downtime in industrial environments. The proposed protection system utilizes Programmable Logic Controller (PLC) and Human Machine Interface (HMI) to control and monitor the protection mechanisms of electric motors (Khairullah & Sharkawy, 2022; Ningrum, 2021; Prakoso et al., 2023; Prasetyo et al., 2023). It involves continuous monitoring of motor operational parameters such as current, voltage, temperature, and frequency, rapid and accurate identification of abnormal conditions, appropriate corrective actions such as motor shutdown or adjustment of operating conditions to prevent damage, and provision of a user-friendly interface for operators to manage and configure the protection system according to industrial application requirements.

Literature Review

In this research, we focus on developing a comprehensive protection system for three-phase electric motors using Programmable Logic Controller (PLC) and Human Machine Interface (HMI) technologies. The key concepts and components utilized in this study include:

Three-Phase Electric Motors

Three-phase electric motors are essential components in industrial production processes, serving as the primary driving force for various machinery. They offer superior efficiency, robustness, and capacity to handle heavy loads compared to single-phase motors.

Electrical Disturbances

Electrical disturbances such as overcurrent, overvoltage, under voltage, under frequency, and short circuits pose significant risks to the operation and longevity of three-phase electric motors. Addressing these disturbances requires an effective protection system (Yakhni et al., 2023).

Programmable Logic Controller (PLC)

PLCs are digital computers designed for industrial automation, capable of executing control functions based on programmed logic. They offer real-time monitoring, control, and data processing capabilities, making them ideal for motor protection applications (Prasetyo et al. 2024, n.d., 2021; Triwijaya et al., 2020).

Human Machine Interface (HMI)

HMIs provide a user-friendly interface for operators to interact with control systems. They facilitate visualization of data, monitoring of operational parameters, and configuration of system settings (Prasetyo et al., 2024; Ridwan et al., 2023).

Research Method

Testing is a process conducted after a designed system has been completed and meets the expected requirements. Testing is performed multiple times to achieve optimal results. The stages of testing involve conducting tests on several critical parts of the system. The results from these tests are then used as a comparison with the initially planned system.

Here are the general stages in the system testing process:

1. **Test Planning**: Determining the objectives, scope, approach, and resources needed for testing.
2. **Test Design**: Designing test scenarios, test cases, and test data based on the system specifications and requirements.
3. **Test Execution**: Performing the tests by executing the designed test cases. Each critical part of the system is tested to ensure that every component functions correctly.
4. **Monitoring and Reporting**: Recording the test results and reporting any bugs or issues found. These results are compared with the initial expectations and specifications to assess conformity.
5. **Test Evaluation**: Evaluating the test results to determine if the system meets the acceptance criteria and is ready for deployment.
6. **Bug Fixing and Re-testing**: Fixing any bugs found during testing and conducting re-tests to ensure that the fixes are successful.

Comprehensive and repeated testing is crucial to ensure that the built system not only meets specifications but is also reliable and ready for use in a real-world environment.

Result and Discussion

Below is the documentation of the motor protection system testing conducted according to Figure 1. The testing was carried out by running the motor in both no-load and loaded conditions, then observing the results displayed on the HMI screen. Subsequently, tests were performed for several current values passed through the motor to determine whether the motor protection system could function properly. The motor protection system will activate if the current value read exceeds the set current value, causing the system to shut down the motor. If the current value read is less than the set current value, the system will operate normally.

Figure 1. Motor Protection System Testing

Table 1. Motor Test Results

No.	Variation	Starting Current (A)	Nominal Current (A)	RPM
1	No Load Motor	0.80	0.46	2997
2	Full Load Motor	6.12	1.94	2960

Table 2. Motor Protection System Test Results

No.	I setting (A)	I rated (A)	Condition	System
1	0.5	0.2	Normal	ON
2	0.5	0.8	Overcurrent	OFF
3	0.5	0.4	Normal	ON
4	0.5	0.2	Normal	ON
5	0.5	0.6	Overcurrent	OFF

The current setting value of 0.5 A is the reference value or the maximum safe limit set for the system or electrical device. Current exceeding this value can cause issues such as equipment damage or safety hazards. Current values below the setting limit (<0.5 Ampere) can be considered safe and normal. Current values exceeding the setting limit of 0.5 Ampere, such as when the current reaches 0.6 or 0.8 Ampere, indicate that an overcurrent condition is detected. Overcurrent is a condition where the electric current flowing in the circuit exceeds the maximum allowable limit (>0.5 A). Several factors that cause overcurrent include short circuits in the circuit, excessive load, and component failures.

Figure 2. Motor Protection System Testing

There are several conditions where the current flowing has already exceeded the safe limit set, which is more than 0.5 Ampere. If this condition continues, it can cause damage to equipment or other hazards. Therefore, corrective actions need to be taken, such as:

1. **Inspecting and Reducing the Load**: Reducing the number of loads connected to the circuit.
2. **Inspecting the Circuit for Short Circuits**: Identifying and repairing short circuits if they exist.
3. **Using Overcurrent Protection**: Installing protective devices such as fuses or circuit breakers that will automatically disconnect the current when an overcurrent is detected.

Conclusion

Three-phase electric motors are crucial components in industrial settings, and protecting them from electrical disturbances such as overcurrent, and short circuits is essential to mitigate potential losses and ensure operational efficiency. The implementation of PLC and HMI technologies underscores the growing importance of automation in industrial processes.

These technologies enable efficient control and monitoring of motor conditions, enhancing overall system reliability.

Setting parameters for protection, including start current, voltage drop, interphase voltage, nominal current, frequency, and start time limits, is critical for maintaining motor performance and preventing damage. The developed protection system aims to swiftly and accurately address various electrical disturbances, safeguarding the motor from potential damage and minimizing production downtime in industrial environments. Effective motor protection enhances operator safety and equipment availability, reducing the risk of accidents and unexpected downtime.

Declaration of conflicting interest

The authors declare that there is no conflict of interest in this work.

References

Abdelmoaty, G., & Soliman, S. (2020). Smart Technology Applications in Tourism and Hospitality Industry of The New Administrative Capital, Egypt. *Journal of Association of Arab Universities for Tourism and Hospitality*, *0*(0), 0–0. https://doi.org/10.21608/jaauth.2020.47549.1085

Khairullah, S. S., & Sharkawy, A.-N. (2022). Design and Implementation of a Reliable and Secure Controller for Smart Home Applications Based on PLC. *Journal of Robotics and Control (JRC)*, *3*(5), 614–621. https://doi.org/10.18196/jrc.v3i5.15972

Mugaruka Josue, M., & Biru Worku, G. (2021). Study of Power Reliability and Power Quality Problems of the Ethiopian-Djibouti Railway Distribution Networks. *American Journal of Electrical Power and Energy Systems*, *10*(6), 100. https://doi.org/10.11648/j.epes.20211006.11

Ningrum, R. C. (2021). Desain Pengepakan Barang Dengan Counter Otomatis Menggunakan Plc Omron. *Jurnal Ilmiah Mahasiswa Kendali dan Listrik*, *1*(2), 51–57. https://doi.org/10.33365/jimel.v1i2.634

Pradipta, A., Triwijaya, S., Winjaya, F., Darmawan, A., & Prasetyo Edi W, A. (2023). Study Quality of Voltage on Single Track AC Railway Traction Electrification. *Journal of Railway Transportation and Technology*, *2*(1), 41–49. https://doi.org/10.37367/jrtt.v2i1.21

Prakoso, D. N., Prasetyo, Y., Winarno, B., & Triyono, B. (2023). *Design System Warning & Safety Escalator dengan HMI Berbasis PLC*. *4*(2).

Prasetyo, Y., Hidayatullah, N. A., Artono, B., & Danu S, B. (2021). Power Factor Correction Using Programmable Logic Control Based Rotary Method. *Journal of Physics: Conference Series*, *1845*(1), 012045. https://doi.org/10.1088/1742-6596/1845/1/012045

Prasetyo, Y., Prakoso, D. N., Wicaksono, R., Triyono, B., & Triwijaya, S. (2023). *Analysis of Transformer Protection Systems Using Smart Relays for Electrical Energy Stability*. *07*(03).

Prasetyo, Y., Triyono, B., Prakoso, D. N., & Haryo, R. J. K. (2024). Desain Human Machine Interface (HMI) Pada Sistem Pencetak Genteng Otomatis. *Journal Of Electrical Engineering And Technology*, *5*(1).

Prasetyo, Y., Triyono, B., Prakoso, D. N., Triwijaya, S., & Multazam, T. (n.d.). *Implementasi Sistem Cerdas pada Ruangan Berbasis PLC dengan Pemrograman Function Blok Diagram*. *1*.

Ridwan, M. H., Yuhendri, M., & Sardi, J. (2023). *Sistem Kendali Dan Monitoring Pompa Air Otomatis Berbasis Human Machine Interface*. *4*(2).

Rifaldo, I., & Yuhendri, M. (2022). *Sistem Monitoring Kecepatan Motor Induksi dengan HMI Berbasis PLC*. *3*(2).

Triwijaya, S., Darmawan, A., Pradipta, A., & Feriando, D. A. (2020). Cable Car Speed Control Using Programmable Logic Control Based on Fuzzy Logic. *Journal of Electronics, Electromedical Engineering, and Medical Informatics*, *2*(3), 125–129. https://doi.org/10.35882/jeeemi.v2i3.7

Triyono, B., Prasetyo, Y., Winarno, B., & Wicaksono, H. H. (2021). Electrical Motor Interference Monitoring Based On Current Characteristics. *Journal of Physics: Conference Series*, *1845*(1), 012044. https://doi.org/10.1088/1742-6596/1845/1/012044

Yakhni, M. F., Cauet, S., Sakout, A., Assoum, H., Etien, E., Rambault, L., & El-Gohary, M. (2023). Variable speed induction motors' fault detection based on transient motor current signatures analysis: A review. *Mechanical Systems and Signal Processing*, *184*, 109737. https://doi.org/10.1016/j.ymssp.2022.109737