

Control and monitoring system for hydrant pump based on PLC PAC Systems RX3i and HMI at PT Wilmar Nabati Indonesia Padang

Syifa Ayu Farasani¹, Muldi Yuhendri¹

¹Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia

Article Info

Article history:

Received February 23, 2026

Revised March 26, 2026

Accepted April 14, 2026

Keywords:

PLC PAC Systems RX3i

HMI CIMPLICITY

Hydrant pump system

Fire protection

NFPA 20

ABSTRACT

Hydrant pump systems at PT Wilmar Nabati Indonesia Padang currently employ conventional relay-based controls with limitations in real-time visualization, historical data recording, and remote monitoring capabilities. This research designs a control and monitoring system based on PLC PAC Systems RX3i and HMI CIMPLICITY to enhance fire protection system reliability. The Engineering Design Process methodology encompasses system requirement observation, hardware wiring diagram design, and PLC programming using Function Block Diagram and Ladder Diagram according to IEC 61131-3 standard [1]. HMI was designed using CIMPLICITY software featuring real-time monitoring, manual/automatic control modes, alarm and event viewer, and trending displays for pressure, level, and flow data. The system controls four pumps: jockey pump, electric pump, diesel pump, and supply pump, implementing pressure-based pump sequencing and level-based control logic according to NFPA 20 requirements [2]. Laboratory testing employed combined methods of 4-20 mA current injection with Fluke 715 calibrator [3], direct testing with actual devices, and digital signal simulation. Results demonstrate successful pump operation according to setpoints with maximum reading errors of 0.1% for pressure, 0.06% for level, and 0.04% for flow. All control functions for automatic mode, manual mode, alarms, trip reset, and VFD frequency regulation operate according to established requirements

Corresponding Author:

Syifa Ayu Farasani

Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang

Kampus UNP Pusat, Jl. Prof. Hamka, Air Tawar, Padang 25131, Indonesia

Email: syifaayufarasani1@gmail.com

1. INTRODUCTION

Fire protection systems represent critical safety aspects in industrial facilities, particularly palm oil processing industries with elevated fire risks due to flammable materials usage [1]-[4]. PT Wilmar Nabati Indonesia Padang, as a palm oil processing company, maintains a hydrant system as part of active fire protection requiring continuous emergency operation readiness. According to NFPA 20 (Standard for the Installation of Stationary Fire Pumps), fire pump systems must be equipped with reliable controls, pump status monitoring, and automatic protection ensuring operational readiness at all times [2]. This demonstrates that proper control systems constitute critical components of overall protection systems.

The existing hydrant pump system at PT Wilmar Nabati Indonesia Padang utilizes conventional relay-based control with manual operation and hardwired pressure switches as automatic start mechanisms. Field observations reveal the existing system exhibits several operational limitations. Absence of real-time visualization requires operators to perform direct panel control checks for system status verification. Lack of historical data recording for parameters such as pressure, flow rate, and tank level complicates performance analysis and predictive maintenance execution [5]. Alarm systems consist only of indicator lamps without

alarm logging, making fault investigation difficult. Troubleshooting processes consume considerable time due to manual relay circuit tracing requirements. Additionally, absence of remote monitoring capabilities necessitates constant operator presence at panel locations.

Programmable Logic Controllers provide appropriate solutions for enhancing hydrant pump control and monitoring system reliability. PLCs offer advantages including programming flexibility, simplified troubleshooting, communication capabilities with other systems, and high reliability in industrial environments [6]. PLC implementation enables more precise control logic design integrated with pressure-based pump sequencing for gradual pump activation according to system pressure reduction [7]. Modern PLCs support IEC 61131-3 standards, facilitating control logic development using programming languages such as Ladder Diagram and Function Block Diagram [8]. Human Machine Interfaces provide visual interfaces facilitating operator system condition monitoring in real-time and manual control execution when required [9]. Through HMIs, operators view each pump's operational status, reservoir tank water level, system pressure and flow rate, alarm conditions, and other important parameters in one informative display. HMIs play important roles in increasing operator decision making speed through structured data visualization and can store historical data and alarms for analysis and maintenance purposes [10]-[11].

For control system requirements in large-scale industrial areas, PT Wilmar Nabati Indonesia Padang employs PLC PACSystems RX3i as primary control. PACSystems RX3i represents high-performance modular controllers designed for critical industrial applications, featuring flexible expansion capabilities and supporting modern industrial communications [12]. These characteristics make it suitable for hydrant pump systems requiring high reliability and integrated monitoring capabilities. This research focuses on designing control programs using Function Block Diagram and Ladder Diagram for analog signal processing, pressure-based pump sequencing logic, and alarm systems, as well as designing HMI using CIMPLICITY software for real-time monitoring and control with trending features and integrated alarm viewer. The system is designed according to NFPA 20 standards [13] to improve fire protection system reliability at PT Wilmar Nabati Indonesia Padang.

2. METHOD

This research employed Engineering Design Process methodology consisting of systematic stages from requirement identification, system architecture design, hardware and software implementation, to testing and validation. System architecture was designed in block diagram form representing relationships among main components: level transmitter, pressure transmitter, flow transmitter, PLC PACSystems RX3i, pumps (jockey, electric, diesel, supply), Variable Frequency Drive, and PC for programming and monitoring. Figure 1 shows the complete system block diagram.

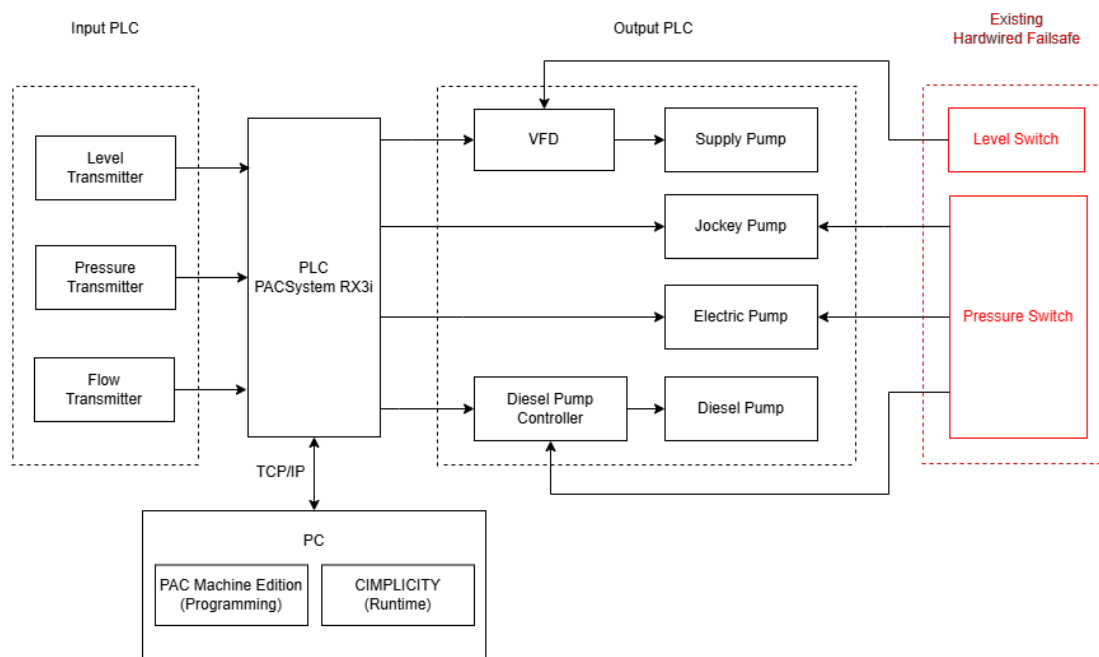


Figure 1. Effects of selecting different switching under dynamic condition

The system integrates with existing independent protection devices (level switches and pressure switches) operating hardwired according to NFPA 20 standards [2]. These devices do not depend on PLC programs, ensuring protection systems continue functioning even if transmitter or program logic failures occur. Communication between PC and PLC utilizes TCP/IP protocol through Ethernet network for stable data exchange and control command transmission [14]. Hardware configuration consists of PLC PACSystems RX3i modules including power supply (IC695PSD040), CPU (IC695CPE305), analog input module (IC694ALG223), analog output module (IC694ALG392), digital input module (IC694MDL660), and digital output module (IC694MDL940) [14]. Wiring diagrams were designed for each pump covering all necessary connections between PLC modules, sensors, actuators, and protection devices.

Jockey pump utilizes Direct online starter with contactor and overload relay as protection [16]. Electric pump employ star-delta starter to reduce starting current [17]. Diesel pump integrates with independent controller following NFPA 20 requirements, where PLC only sends request start signals without direct engine control. Supply pump uses VFD control for speed regulation according to operator setpoint through HMI.

PLC programming was conducted using PAC Machine Edition software [18] with two main programming languages according to IEC 61131-3 standard. Function Block Diagram (FBD) for analog signal processing including Raw value to engineering unit conversion, Engineering unit to raw value conversion and Analog signal comparison using CMP blocks. Analog signal comparison against control limits is implemented using CMP (Less Than, Equal, Greater Than) blocks. Comparison results are used as inputs for Ladder Diagram logic controlling pump operations and system alarms. Raw value to engineering unit conversion using equation :

$$EU = \frac{(RV - RV_{min})(EU_{max} - EU_{min})}{RV_{max} - RV_{min}} + EU_{min} \quad (1)$$

Where EU is engineering unit value (bar, %, m³/h), RV is Raw value from PLC analog input RVmin is Minimum raw value (0 for 4-20 mA input), RVmax is Maximum raw value (32000 for PLC PACSystems RX3i), Eumin is Minimum engineering unit (0 bar, 0%, 0 m³/h) and Eumax is Maximum engineering unit (16 bar, 100%, 300 m³/h).

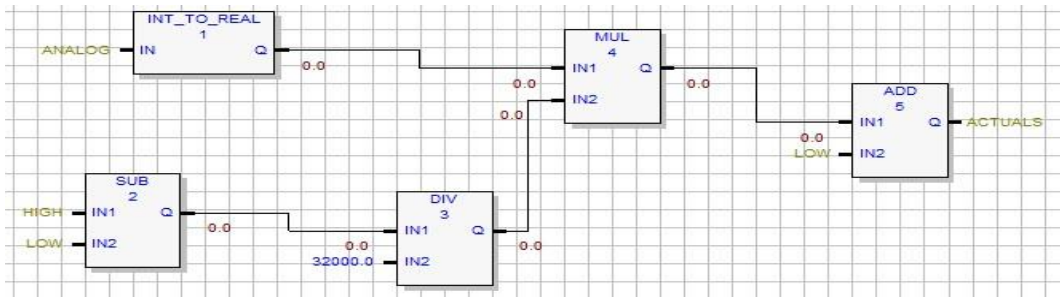


Figure 2. Raw value to Engineering Unit Conversion (FBD Instrument)

In the actual PLC program implementation shown in Figure 2, these parameters are named as Actuals (EU), Analog (RV), Low (Eumin), and High (Eumax). Engineering unit to raw value conversion using equation :

$$RV = \frac{(EU - EU_{min})(RV_{max} - RV_{min})}{(EU_{max} - EU_{min})} + RV_{min} \quad (2)$$

Where RV is Raw value to PLC analog output, EU is Engineering unit value from HMI setpoint (0-50 Hz), Rvmin is Minimum raw value (0), Rvmax is Maximum raw value (32000). Eumin is Minimum engineering unit (0 Hz) and Eumax is Maximum engineering unit (50 Hz). In the actual implementation shown in Figure 3, these parameters are named as Output (RV), Input (EU), Lscale (Eumin), and Hscale (Eumax). Ladder Diagram (LD) for control logic implementation covering pressure-based pump sequencing: jockey pump (start <9.7 and stop >10 bar), electric pump (start <8.5 bar), diesel pump (start <7.5 bar); level-based supply pump control: start at L (25%) and LL (10%), stop at H (85%) and HH (95%); manual/automatic mode selection logic; alarm and trip protection system; flow totalizer and reset functions; and VFD frequency control (0-50 Hz) through analog output.

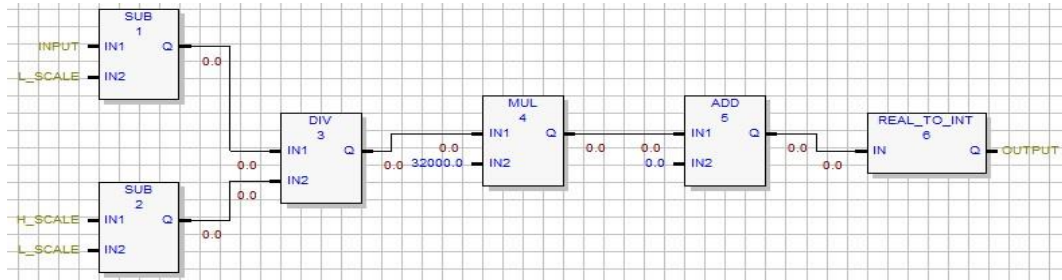


Figure 3. Engineering Unit to Raw Value Conversion (FBD Motor)

HMI was designed using CIMPLICITY software with TCP/IP communication configuration to PLC. Tag mapping was performed consistently with PLC addressing to ensure stable data communication. HMI interface design includes overview screen displaying overall system status and integrated alarm and event viewer, control screens for each pump with start/stop buttons and manual/automatic mode selection, and trend screens for pressure, level, and flow historical data monitoring. HMI design in this research follows the ANSI/ISA-101.01-2015 standard (Human Machine Interfaces for Process Automation Systems), which defines display hierarchy, consistent color usage for status indication, and effective alarm management principles to support operator decision-making. Figure 4 shows the HMI design.

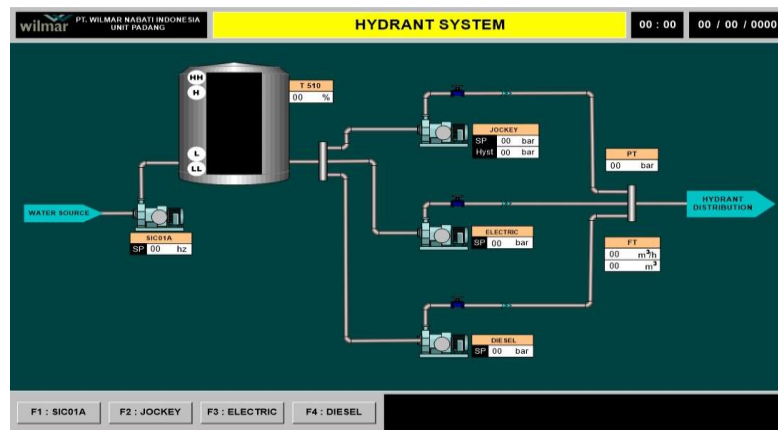


Figure 4. HMI Overview Screen

3. RESULTS AND DISCUSSION

Laboratory testing was conducted using combined methods as shown in Figure 5: (1) Current injection of 4-20 mA using Fluke 715 calibrator [3] to simulate transmitter signals (pressure: 0-16 bar, level: 0-100%, flow: 0-300 m³/h), (2) Direct testing with actual devices for run feedback from contactor auxiliary contacts, and (3) Digital signal simulation directly to PLC input modules for conditions not using actual devices (trip, fail to start, fault, low battery, low fuel). This approach ensures comprehensive system validation covering analog processing accuracy, digital input response, and fault condition handling.

Automatic mode testing demonstrates system capability to operate pumps according to established setpoints. Table 1 presents jockey pump testing results with start and stop functions based on pressure readings.

Table 1. Jockey Pump Automatic Mode Testing Results

Parameter	Start Test	Stop Test
Current Injection	13 mA	15 mA
Simulated Pressure	9 bar	11 bar
PLC Raw Value	17,988	21,984
Scaled Pressure	8.994 bar	10.992 bar
Reading error	0.006 bar (0.07%)	0.008 bar (0.07%)
Setpoint	9.7 bar (start)	10 bar (stop)
Result	Passed	Passed

Results show the system successfully transmits start and stop signals according to established setpoints. Very small reading differences exist between simulated pressure and PLC scaled pressure, with average error of 0.07%, within calibrator accuracy tolerance and PLC analog input module specifications.

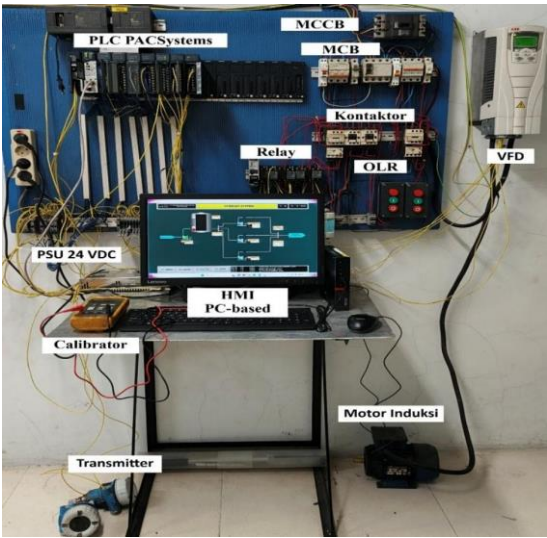


Figure 5. Hardware Testing Setup

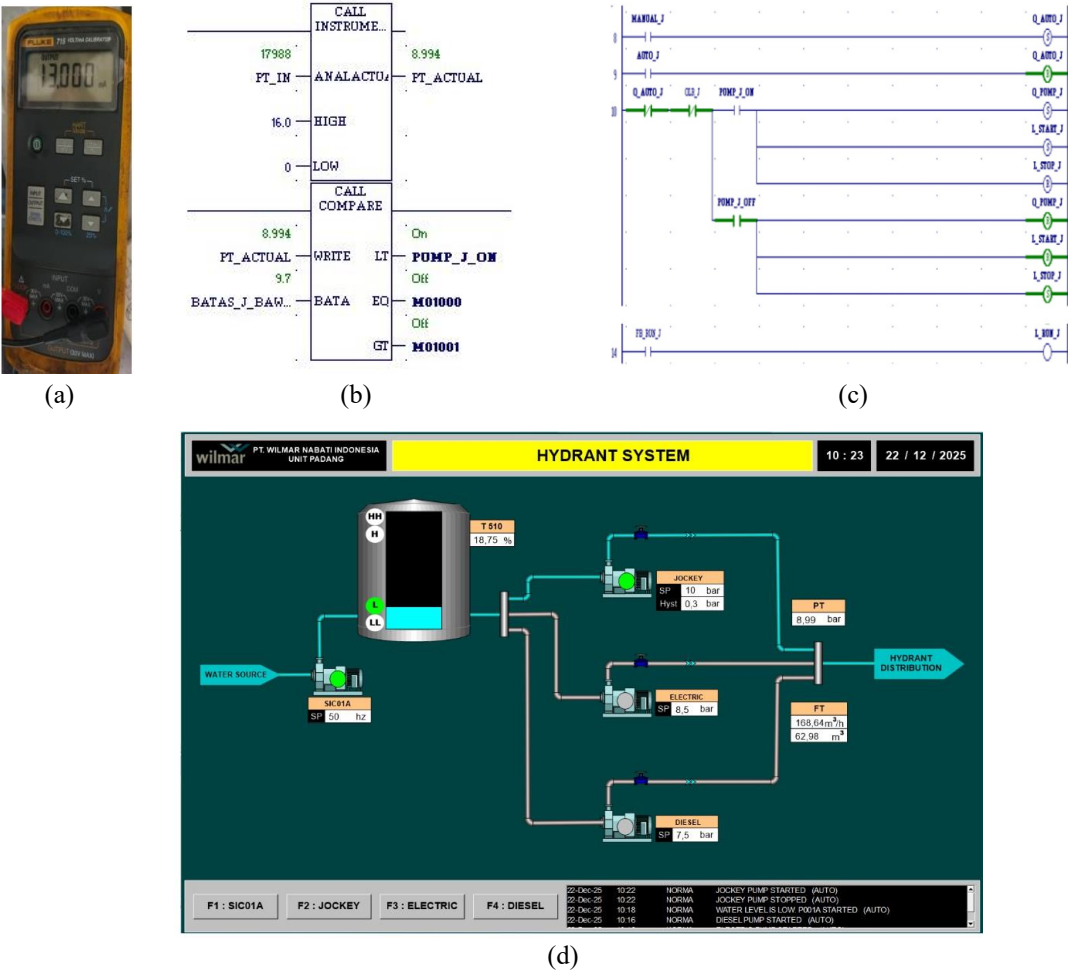


Figure 6. Jockey Pump Automatic Start Testing: (a) Current Injection, (b) Ladder Logic Process, (c) Ladder Logic I/O, (d) HMI Display

Similar testing for electric pump (setpoint 8.5 bar) yielded reading error of 0.025%, while diesel pump (setpoint 7.5 bar) produced 0.1% error, all within acceptable tolerance limits. For supply pump level-based control, testing was conducted for four conditions: LL (10%), L (25%), H (85%), and HH (95%). Table 2 presents testing results summary.

Table 2. Supply Pump Level-Based Control Testing Results

Level	Current	Simulated	Scaled	Error	Result
LL	5 mA	6.25%	6.29%	0.04%	Passed
L	7 mA	18.75%	18.75%	0.003%	Passed
H	18 mA	87.5%	87.48%	0.02%	Passed
HH	20 mA	100%	99.94%	0.06%	Passed

Results demonstrate the system successfully activates supply pump when level falls below L and LL setpoints, and stops pump when level exceeds H and HH setpoints. Maximum reading error of 0.06% remains within acceptable tolerance. Alarm activation for LL and HH conditions function correctly on HMI, providing early warning to operators. Manual mode testing validates operator capability to control each pump directly through HMI. Results show the system successfully transmits start and stop signals when corresponding buttons are pressed on HMI, with run feedback from contactors received correctly by PLC and displayed on HMI. Figure 7 shows the HMI control screen during manual start testing.

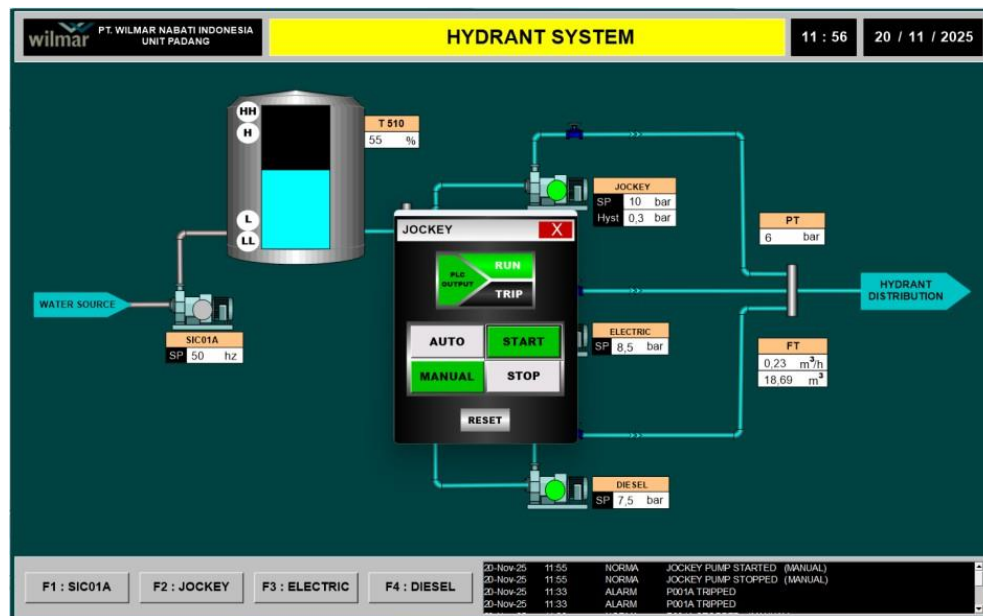


Figure 7. HMI Control Screen for Jockey Pump Manual Start Testing

Transmitter reading accuracy testing was conducted by injecting various current values to verify PLC and HMI reading consistency. Table 3 presents pressure reading testing results.

Table 3. Pressure Reading Accuracy Testing Results

Current	Simulated	Scaled	HMI Display	Error	Result
12 mA	8 bar	7.998 bar	8 bar	0.0125%	Passed
13 mA	9 bar	8.994 bar	8.99 bar	0.0375%	Passed
15 mA	11 bar	10.992 bar	10.99 bar	0.05%	Passed

Results indicate the system can read and display pressure accurately in real-time with maximum error of 0.05%. Similar testing for level and flow yielded maximum errors of 0.06% and 0.04% respectively, all within acceptable tolerance limits demonstrating good analog signal processing quality. Data trending functions on HMI operate well as shown in Figure 8, displaying historical graphs for pressure, level, and flow. Flow totalizer accurately calculates cumulative flow and reset totalizer function successfully resets accumulated values to zero when operator presses reset button on HMI.

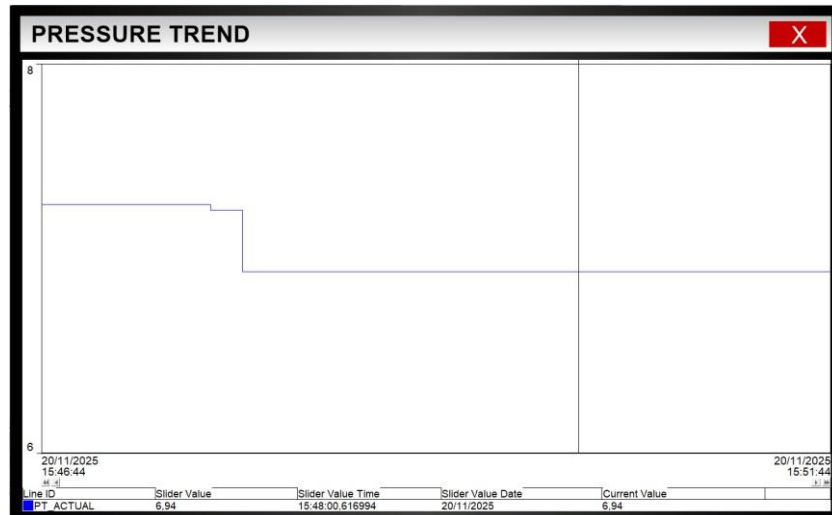


Figure 8. HMI Pressure Trend Screen During Pressure Reading Test

VFD frequency control testing was conducted by setting various frequency values on HMI (10-50 Hz) and verifying analog output signals and actual VFD frequency readings. Table 4 presents testing results.

Table 4. VFD Frequency Control Testing Results

Setpoint	Expected	Measured	Error	VFD Display	Result
10 Hz	7.2 mA	7.203 mA	0.003 mA	10 Hz	Passed
30 Hz	13.6 mA	13.605 mA	0.005 mA	30 Hz	Passed
50 Hz	20 mA	19.982 mA	0.018 mA	49.9 Hz	Passed

Results demonstrate the system successfully controls VFD frequency according to setpoints with maximum error of 0.018 mA, within PLC analog output module tolerance [14]. VFD responds accurately, displaying frequencies matching setpoints, enabling precise speed control for supply pump operation [16]. Figure 9 shows the testing process for 10 Hz setpoint.

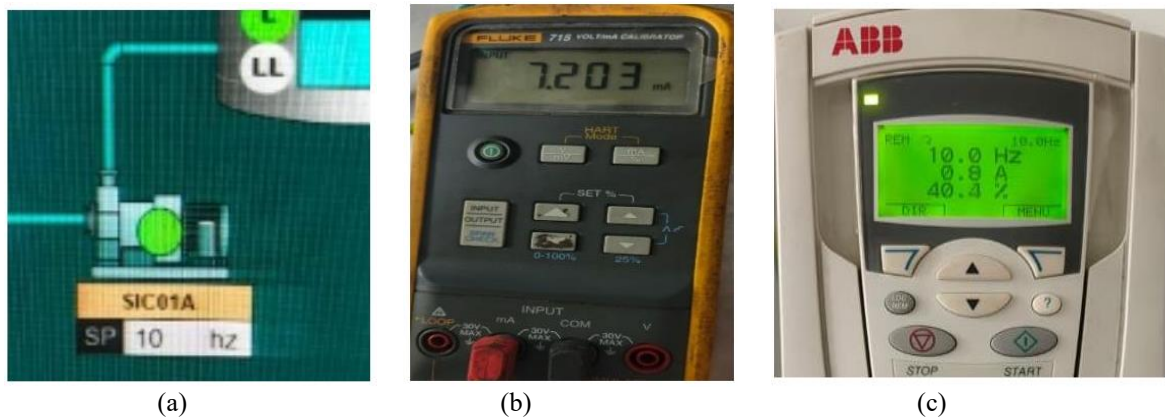


Figure 9. Frequency Control Testing at 10 Hz: (a) HMI Setpoint Entry, (b) Analog Output Measurement, (c) VFD Frequency Display

Protection and alarm system testing was conducted by providing digital input signals to PLC modules to simulate various fault conditions. Testing covered trip conditions for all pumps, and fault, fail to start, low fuel, and low battery conditions for diesel pump. Results show the system successfully detects trip signals and responds by activating interlocks preventing pump operation. Trip indicators activate in red on HMI and alarms appear on alarm and event viewer with appropriate messages. Trip reset function operates correctly, with operators able to press trip reset buttons on HMI to clear trip indicators and alarms after trip conditions are eliminated. The system returns to normal condition and is ready to operate, demonstrating proper interlock logic implementation according to safety requirements.

Overall testing results demonstrate the designed control and monitoring system successfully fulfills hydrant pump system operational requirements according to NFPA 20 standards. Implementation of pressure-based pump sequencing using PLC enables more precise and flexible pump control compared to conventional relay-based systems. Integration with HMI provides real-time visualization facilitating operators in monitoring system conditions and performing manual control when required. Using FBD for analog signal processing and LD for control logic proves effective and follows IEC 61131-3 standards. This programming approach facilitates program development, testing, and future maintenance. Tag mapping consistency between PLC and HMI ensures stable data communication and accurate real-time monitoring. Reading accuracy achieved by the system (maximum error 0.1% for pressure, 0.06% for level, 0.04% for flow) demonstrates good analog signal processing quality sufficient for fire protection system control requirements. Alarm and event viewer integration on HMI provides significant added value compared to existing systems using only indicator lamps. Alarm logging enables operators to track fault histories and facilitates troubleshooting and root cause analysis. Data trending features support performance analysis and predictive maintenance based on historical operational data. System design maintains NFPA 20 standard compliance by integrating with existing independent protection devices (pressure switches and level switches) operating hardwired. This approach ensures protection systems continue functioning even if PLC or program failures occur, maintaining minimum safety standards.

4. CONCLUSION

Control and monitoring system design for hydrant pumps based on PLC PACSystems RX3i and HMI CIMPLICITY at PT Wilmar Nabati Indonesia Padang has been successfully completed and tested. Control programs have been designed using FBD for analog signal processing and LD for control logic following IEC 61131-3 standards, covering pressure-based pump sequencing, level-based control, alarm systems, and VFD frequency control. HMI has been designed with real-time monitoring features, manual/automatic control, integrated alarm and event viewer, and data trending for pressure, level, and flow. Laboratory testing results demonstrate all system functions operate according to established requirements with reading accuracy within acceptable tolerance (maximum 0.1% for pressure, 0.06% for level, 0.04% for flow). The system successfully implements automatic mode operation based on pressure and level setpoints, manual mode control through HMI, protection and alarm detection with appropriate indicators, and VFD frequency control with high precision. The designed system fulfills control and monitoring needs by providing real-time visualization, data trending, alarm logging, and simplified troubleshooting, enhancing fire protection system reliability and supporting data-based predictive maintenance execution at PT Wilmar Nabati Indonesia Padang according to NFPA 20 standards.

ACKNOWLEDGEMENTS

The author expresses gratitude to PT Wilmar Nabati Indonesia Padang for facility provision and support during research execution, and to the Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang for guidance and support.

REFERENCES

- [1] H. Jiang, "Mobile Fire Evacuation System for Large Public Buildings Based on Artificial Intelligence and IoT," in *IEEE Access*, vol. 7, pp. 64101-64109, 2019, doi: 10.1109/ACCESS.2019.2915241.
- [2] V. Akbar, H. Rasyid, and R. Hidayat, "Fire protection system based on the Internet of Things," *J. Ind. Autom. Electr. Eng.*, vol. 01, no. 02, pp. 22–27, 2024.
- [3] A. Kalaiarasi., D. D. Kumar, B. Bharathraj, v. N. Vishak, S. Jasith and L. Raja, "Industry – specific Intelligent Fire Management System: A survey," *2023 International Conference on Computer Communication and Informatics (ICCCI)*, Coimbatore, India, 2023, pp. 1-5, doi: 10.1109/ICCCI56745.2023.10128265.
- [4] M. I. Kim, J.-B. Baek, and M. J. Lee, "Experimental study on thermal properties and fire risk according to acid value change in palm oil," *Fire*, vol. 8, no. 1, Jan. 2025, Art. no. 25, doi: 10.3390/fire8010025.
- [5] B. Rubini, G. Kalaiarasi, S. Vasuki, S. Pradeep Kumar, S. Murugan and C. Arul Stephen, "On-site Testing and Preventive Maintenance for a Fire Automation System Employing PSO, FA and ANN Algorithms," *2023 International Conference on Emerging Research in Computational Science (ICERCS)*, Coimbatore, India, 2023, pp. 1-7, doi: 10.1109/ICERCS57948.2023.10434115.
- [6] I. Rifaldo and M. Yuhendri, "Sistem Monitoring Kecepatan Motor Induksi dengan HMI Berbasis PLC," *JTEIN J. Tek. Elektro Indones.*, vol. 3, no. 2, pp. 319–325, 2022..
- [7] R. Jannah and M. Yuhendri, "Pembuatan Jobsheet Kendali Motor Induksi menggunakan Human Machine Interface," *J. Pendidik. Tek. Elektro*, vol. 3, no. 2, pp. 184–191, 2022.
- [8] F. Azizah and M. Yuhendri, "Solar Panel Monitoring and Control System Using Human Machine Interface," *Andalasian Int. J. Appl. Sci. Eng. Technol.*, vol. 2, no. 03, pp. 149–158, 2022, doi: 10.25077/aijaset.v2i03.64.
- [9] R. Mayangsari and M. Yuhendri, "Sistem Kontrol dan Monitoring Pembangkit Listrik Tenaga Surya Berbasis Human Machine

- Interface dan Internet of Thing,” *JTEIN J. Tek. Elektro Indones.*, vol. 4, no. 2, pp. 738-749–738 – 749, 2023.
- [10] A. Kusuma, J. Sardi, and R. Maulana, “Thrust Roller control in Kiln using PLC and HMI,” *J. Ind. Autom. Electr. Eng.*, vol. 02, no. 01, pp. 1–8, 2025.
- [11] F. Febrianto and Risfendra, “SCARA Robot application for automatic Vending Machine movement based on HMI and IoT,” *J. Ind. Autom. Electr. Eng.*, vol. 01, no. 02, pp. 49–56, 2024.
- [12] Emerson Automation Solutions, “PACSystems RX3i System Manual,” Emerson Electric Co., Charlottesville, VA, USA, Tech. Rep. GFK-2314T, 2019.
- [13] S. Lathar, “AI-Powered Firefighting Robot to Manage High-Risk Situations While Improving Standard Fire Response Time -Robot FireX,” *2024 IEEE Integrated STEM Education Conference (ISEC)*, Princeton, NJ, USA, 2024, pp. 1-1, doi: 10.1109/ISEC61299.2024.10664945.
- [14] A. Üstündağ and Ç. Gençer, “Control of automatic fire extinguishing operation for 5 forest areas with SCADA,” *2021 5th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, Ankara, Turkey, 2021, pp. 535-538, doi: 10.1109/ISMSIT52890.2021.9604546.
- [15] I. A. Kovalev, R. A. Nezhmetdinov and P. A. Nikishechkin, “Approach to Assessing the Possibility of Functioning of CNC and PAC Systems on Various Software and Hardware Platforms,” *2019 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*, Vladivostok, Russia, 2019, pp. 1-5, doi: 10.1109/FarEastCon.2019.8933999.
- [16] A. A. Allahloh, G. A. A. Qasem, A. S. Allahloh, A. A. Shaher, A. A. Alhuthayfi and M. F. Abdualah, “ZoneShield: A Fixed-Zone Robotic Fire-Suppression Prototype with Pressure-Staged Pumping for Oil and Gas Facilities,” *2026 International Conference on Digital Transformation, Innovation & Sustainable Development (DTISD)*, Aden, Yemen, 2026, pp. 1-8, doi: 10.1109/DTISD69661.2026.11668342.
- [17] S. N. S. Hubais, C. B. Moorthy, J. Santiago, S. S. S. Masan and Y. S. Al Din Arfah, “IoT Star-Delta Starter for Remote Control of 3-Phase Motors,” *2022 IEEE 5th Student Conference on Electric Machines and Systems (SCEMS)*, Busan, Korea, Republic of, 2022, pp. 1-5, doi: 10.1109/SCEMS56272.2022.9990667.
- [18] Emerson, “PAC Machine Edition 10: Integrated software for PACSystems devices,” Emerson Electric Co., Austin, TX, USA, Product data sheet 00813-0100-0159, 2023.