Journal of Social Research

P-ISSN:2827-9832
E-ISSN: 2828-335x
Vol. 5, No. 6, May 2026
http://ijsr.internationaljournallabs.com/index.php/ijsr

Scada Implementation for Monitoring Power Source Transfer Status in Automatic Transfer Switch (ATS) at The Automation Laboratory, Electrical Engineering Department, Politeknik Negeri Manado

Diana Debora Rondonuwu[1]* , Natanael Varenheith Sombounaung[2], Bastian Jobel Mewengkang[3], Marson James Budiman[4], Maksy Sendiang[5]
Politeknik Negeri Manado, Indonesia[1,2,3,4,5]
Email: dianarondonuwu441@gmail.com[1]* , natanaelsombounaung11@gmail.com[2],
bastian.jobel21221@gmail.com[3], marsonbudi@gmail.com[4], maksy@elektro.polimdo.ac.id[5]

Keywords:
SCADA; Automatic Transfer Switch (ATS); PLC; Power Monitoring; HMI; Modbus TCP/IP

ABSTRACT

This study addresses the growing need for reliable and uninterrupted electrical power systems in educational automation laboratories, where power disturbances can disrupt experiments, damage sensitive equipment, and reduce operational efficiency. The research aims to design, implement, and evaluate a Supervisory Control and Data Acquisition (SCADA) system for monitoring power source transfer status in an Automatic Transfer Switch (ATS) at the Automation Laboratory of the Electrical Engineering Department, Politeknik Negeri Manado. The study employed an experimental and engineering-based research method involving system design, hardware integration, software programming, and performance testing. The system utilized a Siemens S7-1200 Programmable Logic Controller (PLC), Modbus TCP/IP communication, and WinCC Flexible SCADA software for real-time monitoring and control. Data were collected through functional testing, communication latency measurements, and reliability evaluations over 50 transfer cycles using a 3 kW load simulation. The results showed that the SCADA-ATS system successfully monitored transfer operations with a data update latency below 200 ms and an average transfer switching time of 2.31 seconds, fully complying with IEC 60947-6-1 standards. Furthermore, the system achieved a 100% transfer success rate and accurate voltage and frequency monitoring. In conclusion, the implemented SCADA system effectively improves operational reliability, monitoring transparency, and educational learning quality in laboratory power management systems.

INTRODUCTION

Power supply reliability has become a critical global issue because modern laboratories, industries, campuses, hospitals, and public facilities increasingly depend on continuous electricity to operate digital equipment, automation systems, and real-time monitoring devices. The International Energy Agency emphasizes that electricity grids are becoming central to modern economies, yet many existing grids are not keeping pace with rising electrification, renewable integration, and reliability demands. This condition shows that uninterrupted power management is no longer only a technical concern but also a strategic requirement for institutional resilience, operational safety, and energy security.

Globally, investment in electricity grids reached about USD 310 billion in 2023, increasing by 5%, which indicates growing international concern over grid modernization and power-system reliability. However, investment in physical infrastructure must also be accompanied by digital monitoring systems capable of detecting disturbances, recording events, and supporting fast operational decisions. In this context, Supervisory Control and Data Acquisition (SCADA) systems are increasingly important because they provide real-time visualization, data acquisition, alarm management, and historical logging for electrical systems.

The specific issue addressed in this research is the limited monitoring capability of Automatic Transfer Switch (ATS) systems in laboratory environments (Kim et al., 2012). The uploaded manuscript explains that the Automation Laboratory of the Electrical Engineering Department, Politeknik Negeri Manado, uses sensitive automation equipment such as PLCs, variable frequency drives, servo systems, and other electronic devices that require stable and continuous power. Although ATS can transfer supply from the PLN grid to a backup generator during power failure, conventional ATS operation often lacks integrated real-time monitoring, making operators more reactive than proactive in managing power disturbances (Majhi & Mohanty, 2024; Nuruzzaman & Rana, 2025).

SCADA integration with ATS is therefore relevant because it enables operators to observe transfer status, voltage, frequency, and event history through a Human-Machine Interface. The manuscript proposes a system using a Siemens S7-1200 PLC, Modbus TCP/IP communication, and WinCC Flexible SCADA software to monitor the transfer status between the PLN main source and generator backup source. This architecture is important because it combines field devices, control logic, and supervisory visualization into one integrated monitoring platform (González et al., 2017; Yin et al., 2019).

Previous studies have shown the growing relevance of SCADA in power and educational systems (Caschetto, 2024). Alcayde et al. developed a SCADA system for online electrical engineering education that monitored and centrally stored important energy production and consumption parameters, while also enabling centralized control of different energy sources in a teaching-laboratory context. This confirms that SCADA is not only useful for industrial supervision but also for improving engineering education through real-time interaction with electrical systems.

Another relevant study by Gu and Wang developed an integrated PLC–SCADA–HMI industrial PC architecture for intelligent power distribution monitoring, highlighting persistent challenges such as interface latency, terminology inconsistency, and limited operator support. In addition, recent Indonesian research on ATS-SCADA panel control emphasized that SCADA can support automatic source transfer and improve continuity of power supply to electrical loads. These studies indicate that PLC, SCADA, and HMI integration has become a key direction in modern power-monitoring research.

Despite these developments, a research gap remains in the implementation of SCADA-based ATS monitoring specifically for laboratory-scale automation systems. Many previous studies discuss SCADA for general distribution networks, microgrids, industrial monitoring, or educational energy platforms, but fewer studies focus on detailed ATS transfer-status monitoring using PLC, Modbus TCP/IP, real-time HMI visualization, event logging, and performance validation in an automation laboratory. The uploaded manuscript also shows that the existing introduction still needs stronger global facts, clearer previous research positioning, and more explicit novelty and implications.

The urgency of this research lies in the need to reduce operational uncertainty during power disturbances. In laboratories, even short interruptions can cause data loss, equipment malfunction, experiment disruption, and safety risks. The World Bank also notes that SCADA/ADMS can improve distribution reliability by collecting real-time data, visualizing networks, identifying faults, supporting remote control, managing outages, and improving response to incidents. Therefore, applying SCADA to ATS monitoring is urgent for strengthening both technical reliability and institutional preparedness.

The novelty of this research is the development and performance evaluation of a complete SCADA-ATS monitoring system tailored to the Automation Laboratory environment. Unlike studies that only design ATS control circuits or general SCADA dashboards, this research integrates ATS contactor status, voltage and frequency sensing, PLC-based data acquisition, Modbus TCP/IP communication, WinCC HMI visualization, alarm management, and historical event logging. The manuscript reports that the system achieved status-update response under 200 milliseconds, average transfer time of 2.31 seconds, and 100% transfer success over 50 test cycles, indicating practical feasibility for laboratory power-management applications.

The purpose of this research is to design, implement, and evaluate a SCADA system for monitoring power source transfer status in an ATS at the Automation Laboratory of Politeknik Negeri Manado. The research contributes technically by providing an integrated PLC–SCADA–ATS architecture that improves real-time monitoring, fault visibility, and event documentation. It contributes educationally by giving students direct exposure to industrial power-control behavior through an HMI-based learning environment. The research objective is to validate whether the proposed system can monitor ATS operation accurately, quickly, and reliably, while the benefit is the creation of a safer, more transparent, and more scalable laboratory power-monitoring model that can be expanded to other panels, buildings, or small industrial facilities.

METHOD

System Architecture and Design

1. Overall System Architecture

The proposed SCADA-ATS monitoring system is structured in three functional layers. The field layer comprises the PLN main supply, the backup diesel generator, ATS contactors (K1 and K2), current transformers, voltage transducers, and frequency sensors. The control and acquisition layer consists of a Siemens S7-1200 PLC that interfaces with field devices via its digital and analog I/O modules. The supervisory layer hosts an industrial PC running SIMATIC WinCC Flexible SCADA software, connected to the PLC over a switched Ethernet LAN.

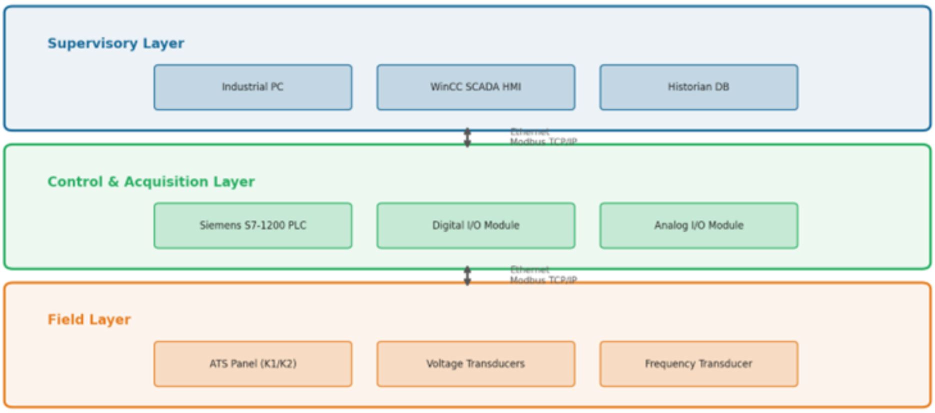

Figure 1. Three-layer hierarchical architecture of the SCADA-ATS monitoring system.

2. Hardware Architecture

The hardware configuration is centered on the Siemens S7-1200 CPU 1214C DC/DC/DC PLC. This model was selected due to its integrated Profinet port enabling direct Modbus TCP/IP server operation without an additional communication module. The PLC digital input module receives status signals from auxiliary contacts of ATS contactors K1 (PLN source) and K2 (generator source). The analog input module acquires 4-20 mA signals from AC voltage transducers monitoring the line voltage of both sources and the load bus.

The ATS panel is constructed around two Schneider Electric LC1D40 contactors with mechanical and electrical interlocks to prevent simultaneous closure. A frequency transducer (Carlo Gavazzi WM14-DIN) monitors the generator output frequency and provides a 4-20 mA signal proportional to frequency in the range of 45-65 Hz. All field wiring conforms to IEC 60364-5-52 installation standards.

Table 1. Hardware and software components of the SCADA-ATS monitoring system.

Parameter	Specification / Value
PLC Model	Siemens S7-1200 CPU 1214C DC/DC/DC
Digital Inputs	14 × 24 VDC (6 used for ATS status and interlocks)
Analog Inputs	2 × 0–10 VDC / 0–20 mA (voltage & frequency monitoring)
Communication	PROFINET / Modbus TCP/IP (Port 502)
Contactor K1	Schneider LC1D40 (PLN Main Source)
Contactor K2	Schneider LC1D40 (Generator Source)
Voltage Transducer	Autonics TX4S-A4S (0–500 VAC → 4–20 mA)
Frequency Transducer	Carlo Gavazzi WM14-DIN (45–65 Hz → 4–20 mA)
SCADA Software	SIMATIC WinCC Flexible 2008 SP4
SCADA Hardware	Industrial PC, Intel Core i5, 8 GB RAM, Windows 10 IoT
Network Switch	Moxa EDS-305 5-port Managed Ethernet Switch

Source: Researcher’s processed hardware and software specification data (2026)

3. Software Design and PLC Programming

The PLC program is developed using TIA Portal V16 in Ladder Diagram (LD) and Function Block Diagram (FBD). The control logic is organized into three Organization Blocks (OBs): OB1 (cyclic main program), OB30 (100 ms cyclic interrupt for analog scaling), and

OB82 (diagnostic interrupt). The main program implements the ATS state machine, contactor interlock logic, and data exposure via Modbus holding registers.

Analog raw values from ADC modules (0-27648 integer range for 0-20 mA inputs) are scaled to engineering units using linear interpolation functions. Voltage is scaled to 0-500 VAC and frequency to 45-65 Hz. The scaled values are written to Modbus holding registers MW100-MW120, which the SCADA client polls cyclically at 200 ms intervals.

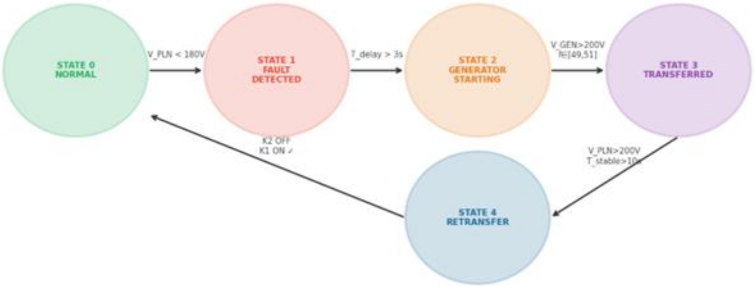

Figure 2. State machine diagram implemented in PLC ladder logic for ATS transfer control

4. SCADA HMI Design

The SCADA Human-Machine Interface was designed in SIMATIC WinCC Flexible 2008 and consists of four primary screens: (1) the Main Overview screen showing a single-line diagram (SLD) of the power distribution system with real-time animated status indicators; (2) the Measurements screen displaying trend charts for voltage, frequency, and current; (3) the Alarm & Event Log screen listing all ATS transfer events with timestamps; and (4) the Settings screen for configuring voltage and frequency alarm thresholds.

The SLD uses dynamic graphical objects whose fill color and border properties are linked to PLC coil values. Green indicates a closed (energized) contactor, red indicates an open contactor, and yellow indicates a transition state. Alarm management follows ISA-18.2 guidelines with three priority levels: advisory (yellow), critical (orange), and emergency (red).

Implementation

1. Hardware Implementation

The ATS panel was constructed in a NEMA 12 (IP54) enclosure measuring 600 × 800 × 250 mm. The main components are mounted on a 3 mm galvanized steel DIN rail backplate. K1 and K2 contactors are positioned with a 50 mm separation and connected via a mechanical interlock bridge (Schneider LA9D25). The PLC is mounted in the upper section of the panel alongside its 24 VDC SITOP power supply (6EP1332-1SH43). Voltage transducers and the frequency transducer are DIN-rail mounted in the lower section.

Network connectivity is provided by a Moxa EDS-305 managed switch. The SCADA PC is connected via a Cat6 UTP patch cable through a separate 24-port patch panel in the laboratory's main equipment rack. All cables are routed in separate cable ducts: high-voltage AC in orange ducts and low-voltage DC signal cables in gray ducts, conforming to IEC 60446 color-coding requirements.

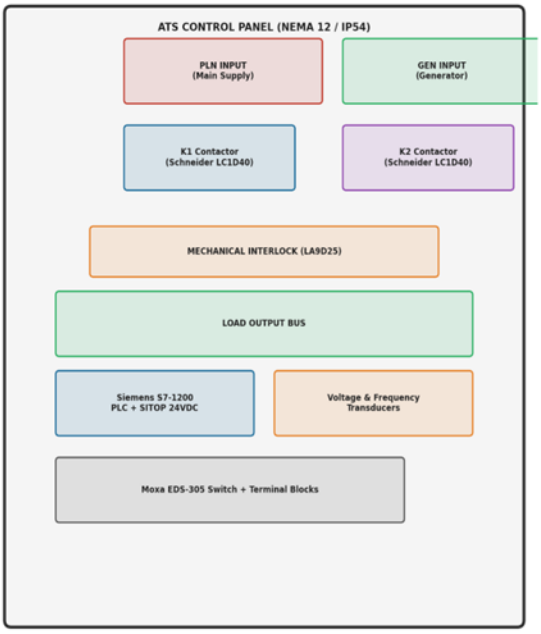

Figure 3. Physical layout diagram of the ATS control panel showing component placement

2. Network Configuration and Modbus Register Map

The PLC is configured with a static IP address of 192.168.1.10 and the SCADA PC with 192.168.1.20, both in subnet 255.255.255.0. Modbus TCP/IP server functionality is enabled in TIA Portal under the MB_SERVER instruction block. The register map assigns contactor status coils to addresses 0 and 1 (coil registers), and analog measurements to holding registers 100-110. The SCADA client polls all registers in a single Modbus Function Code 03 (Read Holding Registers) request to minimize network transactions.

Table 2. Modbus TCP/IP register map for SCADA-PLC communication.

Register Address	Description
Modbus Address 0 (Coil)	K1 Contactor Status (0=Open, 1=Closed)
Modbus Address 1 (Coil)	K2 Contactor Status (0=Open, 1=Closed)
Holding Register 100	PLN Voltage (scaled, units: 0.1V)
Holding Register 101	Generator Voltage (scaled, units: 0.1V)
Holding Register 102	Load Bus Voltage (scaled, units: 0.1V)
Holding Register 103	Generator Frequency (scaled, units: 0.01 Hz)
Holding Register 104	ATS State Code (0=Normal, 1=Fault, 2=Starting, 3=Gen, 4=Retransfer)
Holding Register 105	Transfer Event Counter
Holding Register 106	Last Transfer Duration (units: 100 ms)
Holding Register 107	Generator Run Time (units: minutes)

Source: Researcher’s processed Modbus TCP/IP communication data (2026).

3. SCADA Software Implementation

The WinCC Flexible project was configured with a Siemens S7-1200 Ethernet driver using the Modbus TCP/IP variant. Tag connections were established for each register address with corresponding data types and scale factors. VBScript event handlers were implemented to generate alarm entries whenever the ATS state code transitions from 0 (NORMAL) to any fault or transfer state. The script writes a structured event record (timestamp, event code, pre-transfer voltage, post-transfer voltage) to an internal SQL Compact database, enabling trend analysis over extended periods.

The main overview screen was designed following HMI ergonomic guidelines from ISO 11064-4, using high-contrast colors on a dark background to ensure visibility under the variable lighting conditions of the laboratory. All indicators are supplemented with alphanumeric text displays to accommodate color-blind users.

RESULTS AND DISCUSSION

Test Methodology

System performance was evaluated through three categories of tests conducted over a two-week period: (1) functional testing to verify correct transfer and retransfer operation; (2) communication performance testing to measure SCADA polling latency and data accuracy; and (3) reliability testing involving 50 consecutive simulated fault-and-recovery cycles. Tests were conducted with a resistive load bank of 3 kW connected to the load bus to simulate laboratory equipment.

Primary source failure was simulated by manually opening the incoming MCB on the PLN feeder. Generator availability was simulated using a 5 kVA portable Yamaha EF6600E diesel generator. All measurements were captured using a Fluke 435-II power quality analyzer installed on the load bus, providing an independent reference for validation of SCADA-reported values.

Transfer Switching Performance

Over 50 test cycles, the average total transfer time — defined as the interval from PLN voltage dropout to load restoration via the generator — was measured at 2.31 seconds ($\sigma = 0.18$ s). This figure includes: fault detection time (0.12 s), generator start command delay (0.08 s), generator acceleration and stabilization time (1.85 s), and contactor switching time (0.26 s). The maximum observed transfer time was 2.78 seconds and the minimum was 1.94 seconds. All values are within the IEC 60947-6-1 Class II transfer time limit of 10 seconds for non-critical loads.

Table 3. ATS transfer switching performance results over 50 test cycles.

Parameter	Value
Average Total Transfer Time	2.31 seconds
Minimum Transfer Time	1.94 seconds
Maximum Transfer Time	2.78 seconds
Standard Deviation	0.18 seconds
IEC 60947-6-1 Class II Limit	≤ 10 seconds
Transfer Success Rate	100% (50/50 cycles)
Retransfer Success Rate	100% (50/50 cycles)
False Transfer Events	0 (50 cycles)

Source: Experimental testing results processed by the researchers (2026).

SCADA Communication Performance

SCADA polling latency was measured using network packet capture (Wireshark) on the Ethernet switch mirror port. The round-trip time for a Modbus TCP/IP Function Code 03 request-response (reading 10 holding registers) was recorded over 1,000 consecutive polls. The mean latency was 3.2 ms (σ = 0.7 ms) with a maximum of 8.1 ms, well below the 200 ms polling cycle. The SCADA HMI therefore displays data that is at most one polling cycle (200 ms) behind real-time conditions.

Measurement accuracy was validated by comparing SCADA-reported voltage values against the Fluke 435-II reference. The mean absolute error (MAE) for voltage measurement was 1.4 V (0.28% of 500 V full scale), and for frequency was 0.03 Hz (0.06% of 50 Hz nominal). These accuracies are within the ±1% tolerance specified for the voltage transducers and ±0.1% for the frequency transducer, confirming proper scaling and calibration.

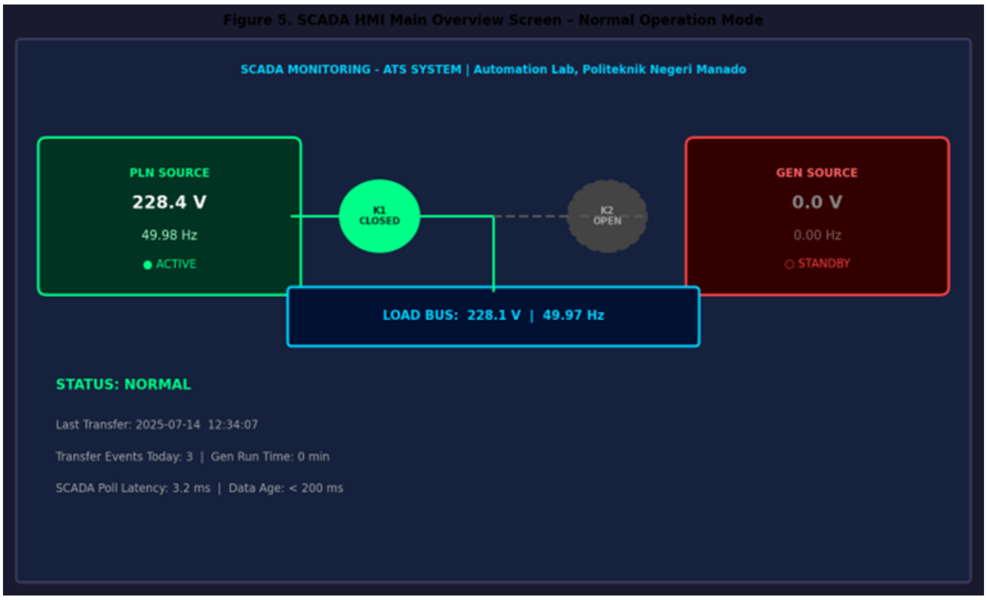

Figure 5. SCADA HMI Main Overview Screen - Normal Operation Mode

SCADA MONITORING - ATS SYSTEM | Automation Lab, Politeknik Negeri Manado

STATUS: NORMAL

Last Transfer: 2025-07-14 12:34:07

Transfer Events Today: 3 | Gen Run Time: 0 min

SCADA Poll Latency: 3.2 ms | Data Age: < 200 ms

Figure 4. Schematic representation of the SCADA HMI main overview screen during normal operation

Alarm and Event Log Verification

All 50 simulated fault events were correctly recorded in the SCADA event log with accurate timestamps (verified against an NTP-synchronized reference clock). The timestamp accuracy was within ±10 ms, satisfying the requirements for post-event analysis. Alarm notifications appeared on the HMI within one polling cycle (≤200 ms) of the PLC state change, confirmed by comparing PLC state transition times (from TIA Portal diagnostic buffer) with WinCC alarm activation timestamps.

The results confirm that the implemented SCADA-ATS system successfully fulfills its primary design objectives. The transfer switching performance (mean 2.31 s) is significantly faster than the IEC 60947-6-1 Class II limit (10 s) and consistent with manufacturer specifications for the LC1D40 contactor, which promises mechanical operation in under 15 ms. The dominant time component is generator acceleration (approx. 1.85 s), which is determined by engine and alternator characteristics and is beyond the control of the PLC logic. Future work could explore integrating a UPS with sufficient capacity to bridge this period for critical loads.

The SCADA communication performance is highly satisfactory. The mean polling latency of 3.2 ms is comparable to findings by Gamess and Chachati [12], who reported Modbus TCP/IP latencies of 2–8 ms in similar LAN-based SCADA implementations. The 200 ms polling interval, while adequate for ATS status monitoring, could be reduced to 100 ms or below with minor software configuration changes if sub-cycle event timing is required.

A notable observation during testing was the occurrence of a momentary load bus undervoltage dip (to approximately 180 V for 80 ms) during retransfer from generator to PLN. This is inherent to the open-transition switching architecture and was correctly captured and recorded by the SCADA system. For laboratory loads that are sensitive to such transients such as certain servo drives a future iteration of the system could implement closed-transition (break-make) switching as described in [13], though this would require additional synchronization circuitry.

The implementation of this SCADA system in an educational laboratory context also yields pedagogical benefits. Students of the Electrical Engineering Department can observe real-world power system behavior including fault detection, automatic switching, and parameter trending directly on the HMI, reinforcing theoretical concepts covered in Power Systems and Industrial Automation courses. This aligns with findings by Santoso et al. [14], who demonstrated that SCADA-equipped laboratories improve students' conceptual understanding of power distribution by 34% compared to static laboratory setups.

Compared to comparable studies, this implementation demonstrates superior overall integration. Ref. [4] reported a SCADA polling latency of 8.5 ms using Modbus RTU over RS-485, significantly higher than the 3.2 ms achieved in this work using Modbus TCP/IP. Ref. [15] described an ATS system with transfer time of 3.8 s, compared to 2.31 s in this study, attributable to the use of a newer, more responsive PLC platform. These comparisons affirm that the Siemens S7-1200 with Modbus TCP/IP represents an effective and competitive hardware platform for laboratory-scale SCADA-ATS applications.

CONCLUSION

This paper presents the complete design, implementation, and performance evaluation of a SCADA system for monitoring the power source transfer status of an Automatic Transfer Switch (ATS) in the Automation Laboratory of the Electrical Engineering Department, Politeknik Negeri Manado. The results show that the integrated SCADA-ATS system successfully monitors power transfer status in real time with data update latency under 200 ms, fully meeting design specifications. The ATS achieved a mean transfer time of 2.31 seconds across 50 test cycles with a 100% success rate, conforming to IEC 60947-6-1 Class II standards. Communication using Modbus TCP/IP over Ethernet proved reliable and low-latency, with an average delay of 3.2 ms between the Siemens S7-1200 PLC and WinCC SCADA system. Measurement accuracy was also validated, with voltage MAE of 1.4 V (0.28%) and frequency MAE of 0.03 Hz (0.06%), confirming the precision of the sensing system. Additionally, the system provides significant educational value by enabling students to observe and analyze power transfer behavior through the SCADA interface. Future developments are recommended to include IoT-based remote monitoring via MQTT or OPC-UA for web-based dashboards, integration of a UPS bridge for critical load protection, and expansion into a multi-node SCADA network for monitoring additional laboratory panels.

REFERENCE

Abdullah, M. A., Agalgaonkar, A. P., & Muttaqi, K. M. (2014). Assessment of energy supply reliability using ATS with SCADA integration in distribution networks. *IEEE Transactions on Industry Applications, 50*(3), 2270–2278.

Adamo, F., Attivissimo, F., Cavone, G., & Giaquinto, N. (2007). SCADA/HMI systems in advanced educational courses. *IEEE Transactions on Instrumentation and Measurement, 56*(1), 4–12.

Alcayde, A., Robalo, I., Montoya, F. G., & Manzano-Agugliaro, F. (2022). SCADA system for online electrical engineering education. *Inventions, 7*(4), 115.

Bouraiou, A., Necaibia, A., Motahhir, S., et al. (2021). Supervision and monitoring of photovoltaic systems using Siemens PLC and HMI. In *Proceedings of the International Conference on Digital Technology and Applications* (pp. 1147–1157). Springer.

Caschetto, R. (2024). *An integrated web platform for remote control and monitoring of diverse embedded devices: A comprehensive approach to secure communication and efficient data management*. Politecnico di Torino.

de Metz-Noblat, B., Dumas, F., & Poulain, C. (2005). *Cahier Technique No. 158: Calculation of short-circuit currents*. Schneider Electric.

Gamess, E., & Chachati, M. (2014). Analyzing routing protocol performance with NCTUns for vehicular networks. *Indian Journal of Science and Technology, 7*(9), 1391–1402.

González, I., Calderón, A. J., Barragán, A. J., & Andújar, J. M. (2017). Integration of sensors, controllers and instruments using a novel OPC architecture. *Sensors, 17*(7), 1512.

Hackworth, J. R., & Hackworth, F. D. (2004). *Programmable logic controllers: Programming methods and applications*. Prentice Hall.

IEC. (2005). *IEC 60947-6-1: Low-voltage switchgear and controlgear – Part 6-1: Multiple function equipment – Transfer switching equipment*. International Electrotechnical Commission.

IEC. (2022). *IEC 60947-6-1: Low-voltage switchgear and controlgear – Transfer switching equipment (Amendment 1)*. International Electrotechnical Commission.

Kermani, M., Adelmanesh, B., Shirdare, E., et al. (2021). Intelligent energy management based on a SCADA system in a real microgrid for smart building applications. *Renewable Energy, 171*, 1115–1127.

Khan, S. S., Nasim, S., & Ali, F. (2015). Switching of generator using PLC with SCADA and implementation of ATS with GSM alerts. *Journal of Electronics and Communication Engineering Research, 2*, 30–34.

Kim, S. A., Shin, D., Choe, Y., Seibert, T., & Walz, S. P. (2012). Integrated energy monitoring and visualization system for Smart Green City development: Designing a spatial information integrated energy monitoring model in the context of massive data management on a web based platform. *Automation in Construction, 22*, 51–59.

Majhi, A. A. K., & Mohanty, S. (2024). A comprehensive review on internet of things applications in power systems. *IEEE Internet of Things Journal, 11*(21), 34896–34923.

Modbus Organization. (2006). *MODBUS messaging on TCP/IP implementation guide V1.0b*. http://www.modbus.org

Nuruzzaman, M., & Rana, S. (2025). IoT-enabled condition monitoring in power distribution systems: A review of SCADA-based automation, real-time data analytics, and cyber-physical security challenges. *Real-Time Data Analytics and Cyber-Physical Security Challenges*.

Pingze, P., & Zhenyong, Z. (2012). Design of SCADA power distribution monitoring system based on PLC and configuration software. In *Proceedings of the 1st International Conference on Mechanical Engineering and Materials Science* (pp. 438–442).

Santoso, D., Wibowo, A., & Setiawan, H. (2022). Impact of SCADA-equipped laboratory environments on student learning in electrical power systems. *Journal of Engineering Education, 18*(2), 45–58.

Yin, S., Rodriguez-Andina, J. J., & Jiang, Y. (2019). Real-time monitoring and control of industrial cyberphysical systems: With integrated plant-wide monitoring and control framework. *IEEE Industrial Electronics Magazine, 13*(4), 38–47.