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IIoT-Based Control and Monitoring System for Three-Phase Induction Motor Forward-Reverse Operation Using Siemens LOGO! 8 PLC

Trio Bintang Pamungkas[1,*,a], Muhammad Rafli[1,b], Ronaldo Ronaldo[1,c], Naswar Naswar[1,d], Yusran Nasruddin[1,e], Muhammad Fadli Azis[1,f], Fahri Fahri[1,g], and Julianti Habibuddin[1,h]

[1]Machinery Systems Automation, Politeknik ATI Makassar, 220 Sunu St, Makassar, 90211, Indonesia

[*, a] 24osp113@atim.ac.id(Corresponding Author), [b]24osp089@atim.ac.id, [c]24osp106@atim.ac.id, [d]24osp095@atim.ac.id, [e]24osp121@atim.ac.id, [f]fadli@atim.ac.id, [g]fahri@atim.ac.id, [h]juliantihabibuddin@atim.ac.id

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Abstract

Conventional three-phase induction motor forward-reverse control relies on hardwired logic, requiring wiring changes to modify the sequence and additional interfaces for browser access. This study presents a laboratory implementation integrating timer-sequenced control and local-network browser monitoring on a Siemens LOGO! 8 PLC. The controller executes four 10-s stages: Forward, dwell, Reverse, and dwell. Software logic and cross-connected normally closed auxiliary contacts provide direction interlocking. Siemens LOGO! Web Editor enables login-protected monitoring and Start/Stop commands through the integrated web server. Verification included six Start/Stop trials, five stopwatch sequence trials, repeated dashboard checks across seven states, three Emergency Stop trials, and one TOR test-button trip. The intended sequence was completed in all five trials, and dashboard indications matched the observed PLC and panel states in all reported checks. Cycle durations calculated from stopwatch phase readings ranged from 40.09 to 40.18 s against the nominal 40 s. Emergency Stop and TOR inputs produced functional shutdown through the PLC program. The implementation demonstrates the integration of sequence control, direction interlocking, protection-input handling, and browser access on one compact controller for laboratory motor-control applications.

1. Introduction

Three-phase induction motors are widely used in industry for their simple construction, low maintenance cost, and high efficiency [1]. Many applications, such as conveyors, lifts, and cranes, require driving the motor in forward and reverse directions [2], [3]. Conventional forward-reverse control uses hardwired contactors and relays, interlocked so only one direction is energized at a time, with protection from a Thermal Overload Relay (TOR) and an emergency-stop button [2], [3]. Wiring changes are needed to modify the control sequence, the conventional circuit alone provides no browser-based monitoring, and diagnosing a fault requires an operator at the panel [2].

Programmable Logic Controllers (PLCs) replace hardwired relay logic with software logic that can be modified without rewiring, operating through input, processing, and output stages [4], [5]. This principle has been applied to induction-motor control in configurations such as star-delta starting [6] and PLC-based

forward-reverse control with dynamic braking [1]. The Siemens LOGO! family provides compact programmable logic for small automation tasks [7]. The selected model combines digital inputs, relay outputs, Ethernet, and an integrated web server in one module [8]. Its accessibility has also been shown in education, where a LOGO!-based trainer was evaluated as a learning medium for automatic-control teaching [9].

Recent work has extended LOGO! toward networked operation. Zulatama et al. [10] integrated a LOGO! PLC with a Siemens S7-300 to coordinate conveyor sequencing, with an S7-300 coordinating LOGO! clients and receiving safety-device and motor-running signals. Separately, web-based Human-Machine Interfaces (HMIs) let an operator view and interact with a process from a compatible device with network access to the controller without installing dedicated client software [11], and Internet of Things (IoT) techniques applied to induction motors have mostly targeted condition monitoring, such as vibration [12], temperature [13], or general health indicators [14], and electrical operating measurements [15]. Some of these systems also incorporate motor-control functions [13]-[15]. PLC architectures have also been investigated for driving three-phase induction motors using a variable-frequency drive [16].

PLC-based motor control, web HMIs and IoT motor monitoring are established approaches. This study examines their practical integration for timer-sequenced forward-reverse operation using one compact LOGO! controller. The focus is control-state monitoring, complementing the sensor-based approaches in [12], [13], [14], [15]. Here, IIoT denotes the networked laboratory prototype, without demonstrated internet or cloud access. The study provides an implementation reference for small-scale applications.

The novelty of this study lies in four aspects. First, four functions that are normally distributed across separate devices are consolidated onto a single compact controller: timer-sequenced forward–reverse operation, direction interlocking, protection-input handling for the thermal overload relay and the emergency stop, and login-protected browser monitoring with Start/Stop access are all executed by one Siemens LOGO! 8 module through its integrated web server, without an external HMI panel, a gateway or a separate web host. Second, direction protection is implemented in two independent layers, since software interlocking in the PLC program is combined with cross-connected normally closed auxiliary contacts in the power circuit, so that simultaneous energisation of both directions remains blocked electrically even if the program logic is altered or fails. Third, the quantity exposed to the network is the control state of the drive rather than sensor condition data, because the dashboard mirrors the discrete operating states of the controller and the panel; this complements the vibration, temperature and health-indicator approaches reported for IoT-based induction-motor work, which monitor the condition of the machine but not the state of its control sequence. Fourth, the implementation is verified quantitatively instead of being presented as a working demonstration, through six Start/Stop trials, five stopwatch-timed sequence trials in which the measured cycle duration ranged from 40.09 to 40.18 s against the nominal 40 s, repeated dashboard checks across seven operating states, three emergency-stop trials and one thermal-overload trip test, with the supporting I/O mapping reported. The scope of the term IIoT is also stated explicitly as a networked laboratory prototype without demonstrated internet or cloud access, so that the claimed capability is bounded by what was actually tested.

2. Research Methodology

2.1. System Design

The system was designed around three functional blocks, namely input devices, the PLC controller, and output actuators, following the standard PLC input-processing-output principle [4], [5]. Figure 1 shows the block-diagram architecture. Input signals from the Start/Stop push buttons, Emergency Stop, and Thermal

Overload Relay (TOR) feed into the Siemens LOGO! 8 PLC, which drives the forward and reverse contactors that control the induction motor.

Figure 2 summarizes the four-stage sequence: Forward (T1), dwell (T2), Reverse (T3), and dwell (T4), each set to 10 s. Both direction outputs are OFF during dwell. Stop, Emergency Stop and TOR inputs clear the internal run command M_Run, which enables the direction outputs. Software mutual exclusion is supplemented by the NC auxiliary contacts shown in Figure 3. Figure 2 is a conceptual summary, without specifying complete ladder logic or timer-reset behavior.

Figure 3 separates the motor power and control circuits. The power circuit uses an MCB, two contactors and a TOR, with two phases exchanged for reverse rotation. The PLC supply and input circuits operate at 24 VDC. Start, Stop, Emergency Stop and the TOR trip contact connect to I1-I4, respectively. Relay outputs Q1 and Q2 switch the K1 Forward and K2 Reverse coils on the AC branch between phase R and neutral N. NC K2 (21–22) is in series with coil K1, and NC K1 (21–22) is in series with coil K2, providing electrical direction interlocking. No interposing relay is used. Q3 and Q4 switch lamps L1 and L2 from the same AC branch. Emergency Stop and TOR act through the PLC program and do not independently interrupt the coil supply.

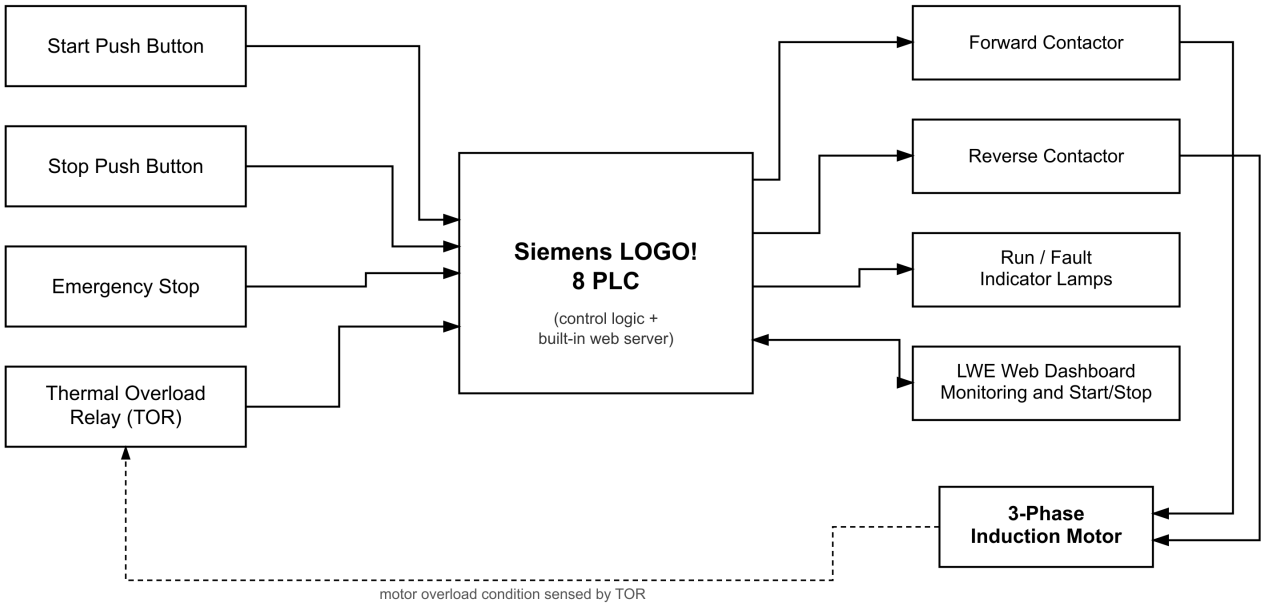


FIGURE 1. Block diagram of the control system.

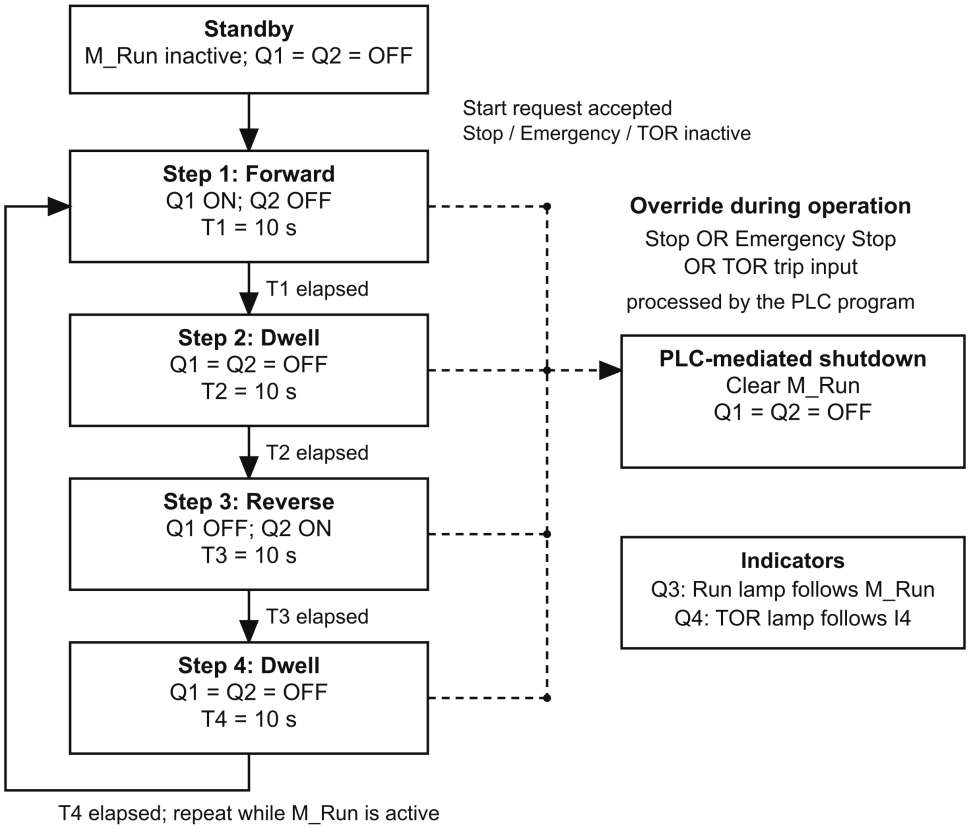


FIGURE 2. Control sequence with PLC-mediated shutdown.

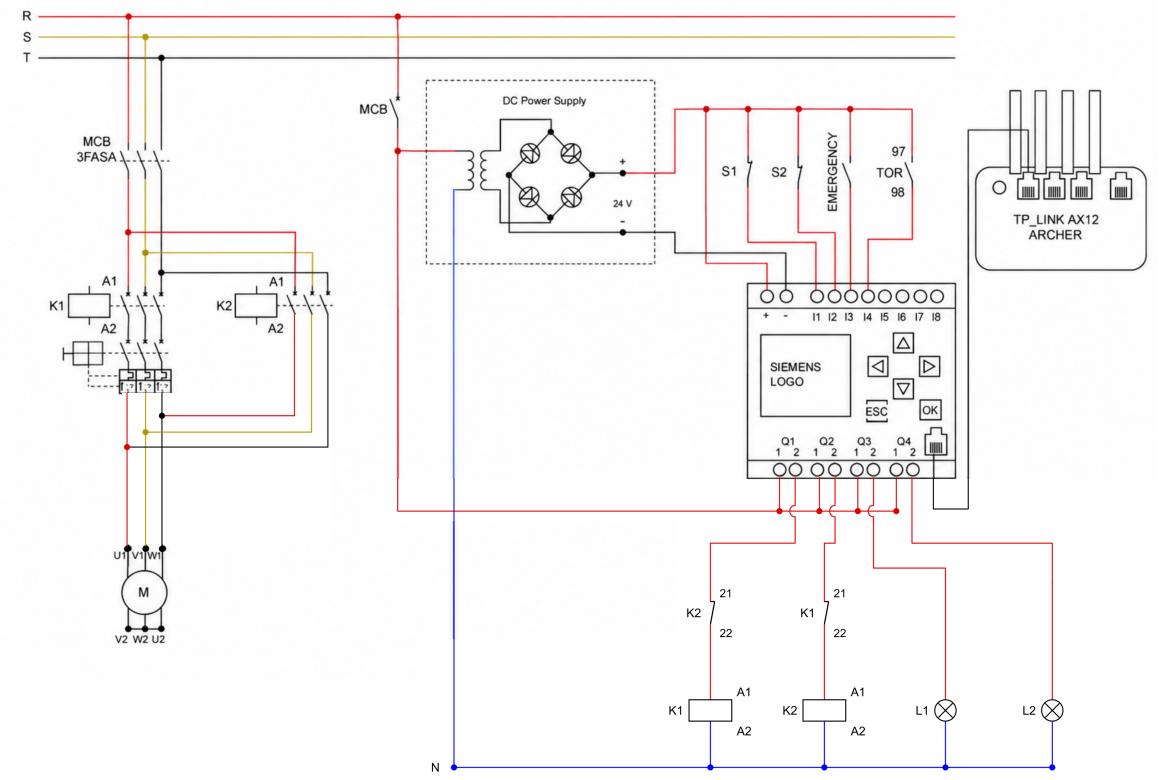


FIGURE 3. Wiring diagram of the power and control circuit.

2.2. Component Selection

Table 1 lists the component functions and documented specifications. The purchased controller is identified as LOGO! 12/24RCE, article number 6ED1052-1MD08-0BA2, corresponding to LOGO! 8.4 [8]. Unverified component ratings are identified explicitly.

TABLE 1. System Components

Component	Function	Documented model or specification
Siemens LOGO! 8	Sequence control and I/O processing	12/24RCE, 6ED1052-1MD08-0BA2, 12/24 VDC supply, 8 digital inputs (4 analog-capable), 4 relay outputs, Ethernet and integrated web server [8]
Siemens LOGO! Web Editor (LWE)	Browser dashboard	Free web-page editor [17], installed software version not recorded
Three-phase induction motor	Forward/reverse load	Three-phase induction motor, nameplate power, current and speed not recorded
Contactors K1 and K2	Forward/reverse power switching and electrical interlocking	AC coils supplied through Q1/Q2 via the opposite contactor's NC auxiliary contact (21–22), model, coil voltage and contact ratings not verified
Thermal Overload Relay (TOR)	Overload trip input	Auxiliary trip contact connected to I4, model, current range and setting not recorded
Emergency Stop button	Programmed shutdown input	Connected to I3 in the 24 VDC input circuit
Start and Stop push buttons	Operator inputs	Connected to I1 and I2 in the 24 VDC input circuit
Router	Local Ethernet/Wi-Fi access	Router used for local-network access, installed model not verified
Single-pole and three-pole MCBs	Control and power branch protection	Nominal current and breaking capacity not recorded
Indicator lamps	Run and TOR indication	Q3 follows M_Run and Q4 follows I4, lamp ratings not recorded
24 VDC power supply	PLC and input supply	24 VDC output, model and rated output current not verified

The Siemens LOGO! 12/24RCE was selected based on laboratory availability and its suitability for the application's four physical inputs and four outputs. Its relay outputs, Ethernet interface and integrated web server support the demonstrated control and local-network browser functions within one compact controller. LWE supports graphical web-page creation without HTML programming [17]. The implementation uses no separate supervisory controller or interposing relay.

2.3. Hardware Assembly

The selected components were mounted on a standing pegboard panel per the wiring diagram (Figure 3), with the PLC mounted on a DIN rail alongside the power supply and terminal blocks. Power and control wiring were physically separated for safety and maintainability, and all connections were re-inspected before energizing the system (Section 2.7). The assembled panel is shown in Figure 4. The additional PLC visible on the panel was not used in this experiment.

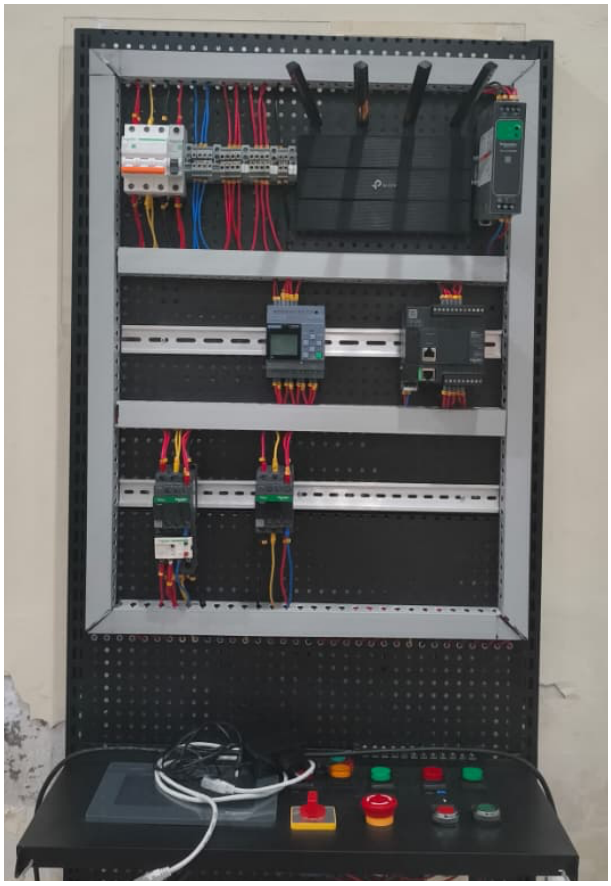


FIGURE 4. Assembled hardware panel.

2.4. Program Development

The program was developed in Siemens LOGO! Soft Comfort using ladder logic. The run latch M_Run (M1) accepts Start requests when Stop and fault conditions are inactive. Stop, Emergency Stop I3 and TOR I4 clear the latch. Q1 requires M_Run, the Forward stage and Q2 OFF. Q2 requires M_Run, the Reverse stage and Q1 OFF. This software interlock uses PLC output states, supplemented by the NC contacts in Figure 3. Timers T1-T4 generate the four-stage sequence. Q3 follows M_Run for RUN indication, while Q4 follows I4 for TOR indication.

2.5. Web-Based Monitoring Interface Design

The interface was built in Siemens LOGO! Web Editor and served through the PLC's web server. Figure 5 shows the green RUN and red TOR-fault indicators, timer stages T1-T4, and Forward/Reverse indicators. RUN denotes the control state, without independent motor-speed measurement. Browser Start/Stop operation was tested separately (Table 3). Commands request the programmed functions, while sequence timing, interlocking and shutdown logic execute in the PLC. Laboratory access required the built-in web-server login [18], which permitted monitoring and Start/Stop operation.



FIGURE 5. LOGO! Web Editor dashboard.

2.6. Network Integration

The PLC Ethernet port was connected to a router, a static IP address (192.168.0.3) was configured in LOGO! Soft Comfort, and the built-in HTTP web server was enabled. A PC or smartphone on the same network accessed the dashboard through a browser after login. Tests were confined to the laboratory LAN/Wi-Fi network. Internet and cloud access were not configured or tested.

2.7. Testing Procedure

Five tests were conducted to verify system functionality before reporting the results in Section 3. First, the continuity test used a multimeter to check cable continuity, power-supply polarity, and panel grounding before energization. Second, the Start/Stop test evaluated control operations using physical push buttons, PLC on-device buttons, and the LWE web application. Third, the control-function (timer-sequence) test evaluated the Forward–Reverse sequence with timers T1–T4 set to 10 s each, producing a nominal 40 s cycle. Five trials were performed using successive laps on a smartphone stopwatch, with phase boundaries identified through direct contactor observation: K1 activation to release (Forward), K1 release to K2 activation (first dwell), K2 activation to release (Reverse), and K2 release to the next K1 activation (second dwell). Cycle durations were calculated by summing the four intervals, while signed deviations were determined by subtracting the nominal phase or cycle durations. Because operator reaction time could lengthen one interval and shorten the next, these measurements did not isolate PLC timing error. Fourth, the web-monitoring test compared dashboard indications with PLC status and panel lamps across the seven states listed in Table 5. All reported checks matched, with at least five checks per condition stated conservatively because exact counts were not retained. Finally, the PLC-mediated shutdown test evaluated Emergency Stop activation during Forward, Reverse, and dwell periods, with shutdown directly observed at the panel. The TOR test button was also used to trigger a trip signal, verifying the PLC shutdown response rather than the thermal trip characteristic under actual overload. Contactor OFF status, motor stopping, and dashboard indications were recorded qualitatively, while shutdown latency and behavior under PLC or output failure were not measured.

3. Results and Discussion

3.1. Results

Table 2 summarizes the implemented system specifications. Functional test results are presented below.

TABLE 2. System Specification

Parameter	Value
Main power supply	380 VAC, three-phase, 50 Hz
Control power supply	220 VAC and 24 VDC
Main controller	Siemens LOGO! 8, 12/24RCE, 6ED1052-1MD08-0BA2
Monitoring interface	Siemens LOGO! Web Editor (LWE)
Communication mechanism	Built-in PLC web server (HTTP) over Ethernet/Wi-Fi
Network access mode	Laboratory LAN/Wi-Fi through the router, no tested internet or cloud access
Shutdown and interlock functions	PLC-mediated shutdown from Emergency Stop and TOR inputs, software output interlock and cross-connected NC auxiliary contacts in the coil circuits
Monitoring access devices	PC and smartphone

1. Pre-Energization Continuity Test

Pre-energization multimeter checks found the wiring connected as designed, with no short circuits or polarity errors.

2. Start/Stop Function Test

Start and Stop were exercised through three independent input paths, namely the physical push buttons, the PLC's on-device buttons, and the LWE web application. All six trials (Table 3) produced the expected motor ON/OFF response.

TABLE 3. Start/Stop Test Results

No.	Function	Input Method	Motor Condition	Result
1	START	Physical push button	ON	Successful
2	STOP	Physical push button	OFF	Successful
3	START	PLC on-device button	ON	Successful
4	STOP	PLC on-device button	OFF	Successful
5	START	LWE web application	ON	Successful
6	STOP	LWE web application	OFF	Successful

3. Control-Function (Timer-Sequence) Test

Across five stopwatch-timed trials, phase readings ranged from 9.82 to 10.22 s, with signed deviations from the 10 s setting ranging from -0.18 to +0.22 s (Table 4). Calculated cycle durations ranged from 40.09 to 40.18 s, with deviations from 40 s ranging from +0.09 to +0.18 s. The mean calculated cycle duration was 40.134 s, with a sample standard deviation of 0.034 s. These descriptive statistics summarize the recorded readings, not measurement accuracy. The Forward, dwell, Reverse, dwell sequence was completed in all five trials, with no simultaneous direction activation reported.

TABLE 4. Stopwatch phase readings and calculated cycle durations

Trial	T1 (s)	T2 (s)	T3 (s)	T4 (s)	Calculated cycle (s)
1	10.15 (+0.15)	9.92 (-0.08)	10.08 (+0.08)	9.98 (-0.02)	40.13 (+0.13)
2	9.88 (-0.12)	10.14 (+0.14)	9.95 (-0.05)	10.12 (+0.12)	40.09 (+0.09)
3	10.22 (+0.22)	9.85 (-0.15)	10.18 (+0.18)	9.90 (-0.10)	40.15 (+0.15)
4	9.95 (-0.05)	10.20 (+0.20)	9.82 (-0.18)	10.15 (+0.15)	40.12 (+0.12)
5	10.08 (+0.08)	10.03 (+0.03)	10.11 (+0.11)	9.96 (-0.04)	40.18 (+0.18)

Values in parentheses are signed deviations in seconds from the 10 s phase settings or the 40 s nominal cycle. Cycle duration is calculated from the four phase readings and is not treated as an independently measured quantity. Two decimal places reproduce the recorded readings and do not establish 0.01 s measurement accuracy.

4. Web-Based Monitoring Test

Dashboard indications matched PLC status and panel lamps in all reported checks across the seven conditions (Table 5). Repetition counts are described in Section 2.7. Display latency was not measured.

TABLE 5. Web Monitoring Test Results

No.	System condition	LWE dashboard indication	Reported outcome
1	Standby	Forward and Reverse indicators OFF	All checks matched
2	Forward phase	Forward indicator ON	All checks matched
3	Dwell phase 1 (T2)	T2 indicator ON	All checks matched
4	Reverse phase	Reverse indicator ON	All checks matched
5	Dwell phase 2 (T4)	T4 indicator ON	All checks matched
6	Emergency Stop active	Program halted	All checks matched
7	TOR trip	Red TOR-fault indicator ON	All checks matched

5. PLC-Mediated Shutdown Test

Emergency Stop was activated during Forward, Reverse and dwell phases. Motor stopping and contactors OFF were observed at the panel in all three tests (Table 6). The TOR test-button trip also stopped operation and activated the dashboard fault indicator. These qualitative observations do not quantify shutdown latency or motor stopping time.

TABLE 6. Emergency Stop Test Results

Trial	Phase at E-Stop Activation	Reported motor stopped	Reported contactors OFF	Result
1	Forward	Yes	Yes	Successful
2	Reverse	Yes	Yes	Successful
3	Dwell	Yes	Yes	Successful

3.2. Discussion

The tests demonstrate integration of sequence control, direction interlocking and browser-state monitoring on a single compact controller. Emergency Stop and TOR inputs produced functional shutdown through the PLC. The green dashboard indicator denotes RUN, while the red indicator denotes TOR fault (Figure 5).

The cited motor-monitoring studies examine vibration [12], temperature [13], health and fault indicators [14], or voltage and current [15]. Some also include shutdown or motor-control functions [13], [14], [15]. The present prototype focuses on the programmed forward-reverse sequence, dwell stages and protection-input state, complementing these sensor-based approaches. Compared to the LOGO!-to-S7-300 PLC-to-PLC integration [10], this implementation serves its dashboard from the control module itself. The present implementation is evaluated through functional tests and documented I/O mapping.

Compared with conventional contactor-and-relay control, the PLC program provides the Forward–dwell–Reverse sequence, while the integrated web server adds local-network browser monitoring and Start/Stop access. Contactors and the TOR remain part of the power and protection-input circuits. LOGO! was selected for its suitability for the required I/O and browser functions.

Table 7 documents the physical I/O, on-device controls, network inputs and output conditions. Browser commands are program requests. Complete dashboard element-to-variable bindings and button pulse settings were not verified.

TABLE 7. I/O and Control Mapping

Signal	Assignment	Program function
I1	Physical Start button	Requests the run latch while Stop and fault conditions are inactive
I2	Physical Stop button	Clears the run latch
I3	Emergency Stop button	Clears the run latch through PLC logic
I4	TOR trip contact	Clears the run latch and provides TOR indication
C1 (C_Start)	PLC on-device Start control	Requests the run latch in parallel with I1 and NI1, subject to Stop and fault conditions
C2 (C_Stop)	PLC on-device Stop control	Clears the run latch
NI1 (V0.0)	Network input labelled PB_Start	Requests the run latch, subject to Stop and fault conditions
NI2 (V0.1)	Network input labelled PB_Stop	Clears the run latch
NI3 (V0.2)	Network input labelled Emergency	Clears the run latch through PLC logic
M1 (M_Run)	Internal run latch	Enables the programmed sequence and direction-output logic
Q1	K1 Forward coil through NC K2 (21–22)	Requires M_Run, the Forward timer stage, and Q2 OFF
Q2	K2 Reverse coil through NC K1 (21–22)	Requires M_Run, the Reverse timer stage, and Q1 OFF
Q3	Run indicator lamp	Follows M_Run
Q4	TOR indicator lamp	Follows I4
T1-T4	Sequence timers	Forward, dwell, Reverse, dwell, each set to 10 s
Web Start/Stop	Browser command functions	Requests the programmed Start/Stop functions, dashboard bindings and pulse settings not verified

The tested login supported monitoring and Start/Stop commands on the laboratory network. Evaluation of separate observer/operator permissions, authentication security, network loss, reconnection, stale indications and pending web commands remains outside the completed tests. Communication-loss and restoration behavior therefore require further characterization.

Three Emergency Stop tests and one TOR test-button trip demonstrated PLC-mediated functional shutdown under the evaluated laboratory conditions. Shutdown depends on PLC input processing, program execution and output switching. The cross-connected NC contacts provide direction interlocking; Emergency Stop and TOR signals act through the PLC rather than independently interrupting the coil supply. The assembly provides no contactor-position feedback to the PLC. Industrial safety validation would require an independent safety circuit and evaluation of PLC/output failure, welded contacts and power outages. These failure conditions, shutdown response time, motor standstill during dwell, and timer-reset or restart behavior after interruption were not characterized in this study. The functional tests therefore do not establish fail-safe performance or detection of welded main contacts.

The stopwatch readings provide descriptive evidence of the observed sequence. Manual timing includes operator reaction effects and does not isolate intrinsic PLC timer accuracy. The smartphone model, application and display resolution were not recorded. Dashboard matching was assessed against PLC status and panel lamps; independently time-stamped comparisons would be needed to quantify latency and support statistical interpretation.

Future work includes motor-condition sensing and operator-adjustable timing, together with development and independent validation of a safety circuit. Network-loss and reconnection behavior should also be characterized before extending access beyond the laboratory network.

4. Conclusion

The Siemens LOGO! 8 prototype integrated timer-sequenced forward-reverse control, software and electrical direction interlocking, and login-protected browser monitoring and Start/Stop access. Functional tests demonstrated the intended sequence, matching dashboard states and PLC-mediated shutdown from Emergency Stop and TOR inputs under the evaluated laboratory conditions. The study provides a documented implementation of control and local-network browser access on one compact controller. Motor-condition sensing, adjustable timing and independent safety-circuit validation remain future work (Section 3.2).

Acknowledgements

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Data Availability Statement

The recorded measurements, summarized functional test results, and implementation details supporting this study are presented in the article. Manufacturer specifications are attributed to the cited sources.

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