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Real-Time Performance Assessment of Process Control in Aluminium Wire Manufacturing Using Siemens S7-1200

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***Abstract*–This paper investigates the real-time performance of process control systems in aluminium (AL) wire manufacturing, with a focus on high-frequency wire drawing operations. A programmable logic controller (PLC)-based control strategy, implemented using the Siemens S7-1200 and integrated with a Human-Machine Interface (HMI), was employed to monitor and manage critical production parameters for the wire tension, drawing speed, motor torque, and dimensional accuracy. Real-time data acquisition enabled continuous performance assessment, fault detection, and immediate corrective action, leading to greater process reliability and efficiency. Experimental results indicate that the integrated system significantly improves product consistency, reduces process variability, and minimises downtime. The findings highlight the importance of real-time monitoring and control in modern wire manufacturing environments and provide a framework for future improvements in smart industrial automation.**

Keywords—Siemens S7-1200 PLC, Aluminium wire Drawing Process, Programmable Logic Controller, Ladder Logic

I. INTRODUCTION

Aluminium wire manufacturing is a critical process in various industries, including electrical, automotive, and aerospace sectors. Maintaining consistent quality and productivity in wire production requires precise control of key parameters such as tension, speed, and temperature [1, 2]. Traditional manual systems often fall short in ensuring the required accuracy and responsiveness [2]. With the advancement of automation technologies, Programmable Logic Controllers (PLCs) have become widely used in industrial control systems for their reliability and flexibility [3, 4]. The Siemens S7-1200 PLC, known for its real-time processing capabilities and ease of integration with Human-Machine Interfaces (HMIs), offers a robust solution for modern industrial automation [4]. This paper focuses on implementing a real-time control system using the Siemens S7-1200 PLC to monitor and optimise the aluminium wire drawing process [3, 5]. The aim is to assess the system's performance in maintaining production stability and enhancing overall process efficiency.

II. LITERATURE REVIEW

The widespread integration of advanced automation for improving manufacturing quality and productivity underscores the rising importance of real-time performance evaluation in 9.5 mm aluminium wire production [1, 2]. Recent research demonstrates that real-time monitoring implemented through PLC-based control systems provides early detection of process deviations, thereby reducing downtime and improving the consistency of the final product [3, 4]. The Siemens S7-1200 PLC is widely recognized for its reliability, integrated PID control, and high-speed communication capabilities, making it suitable for wire drawing applications [4]. The literature also highlights the value of HMI-based visualization, which supports operator decision-making and enhances closed-loop control [4].

Research on aluminium wire production has focused on sensors [1, 2]. The combination of PLC logic and real-time data analysis has been shown to significantly improve diameter accuracy, tensile strength

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uniformity, and overall process performance in modern manufacturing environments [3, 5].

III. PROCESS CONTROL IN WIRE DRAWING

Wire drawing processes are subject to mechanical and thermal variations, which can result in defects or wire breakage if not properly controlled [1]. Studies such as [4] have demonstrated that feedback-based control systems can mitigate these issues by maintaining steady-state operating conditions. Furthermore, closed-loop control systems utilising real-time sensors have been shown to significantly reduce process variability and enhance product consistency [1, 2].

A. Siemens S7-1200 PLC

The Siemens S7-1200 PLC provides modular architecture, integrated I/O and powerful programming capabilities via TIA Portal. Features such as Profinite communication, PID control blocks and high-speed counters make it suitable for precision control applications like wire drawing [3, 4].

B. Programmable Logic Controllers (PLCs)

PLCs are a cornerstone of modern industrial automation due to their reliability, modularity, and capability for real-time processing. The Siemens S7-1200 PLC offers features of high-speed communication, integrated PID control, and flexible I/O configurations, making it especially well-suited for complex wire drawing operations [3, 4]. Research presented in [2] confirmed the effectiveness of PLCs in dynamically controlling tension and torque in continuous metal forming systems.

C. Real-Time Monitoring and HMI Integration

Real-time monitoring plays a critical role in enhancing process visibility and control precision. When integrated with PLCs, Human-Machine Interfaces (HMIs) allow operators to make immediate adjustments to parameters and to detect system faults proactively.

A study conducted in [5] revealed that HMI dashboards significantly reduced operator response time and improved process transparency. Moreover, real-time data logging and trend analysis capabilities support predictive maintenance strategies, thereby improving long-term system reliability [3, 4].

D. Basic Factor for Wire Drawing

In wire drawing, to achieve the required diameter and ensure proper work hardening without wire breakage, a step-by-step wire drawing system is used [1, 2]. Wire drawing machines fixed in the Aluminium Conductor Steel Reinforced (ACSR) Plant operate at a fixed speed. To ensure smooth connection with the take-up system and meet the required production sizes, drawing dies must be used step by step from the final stage to the first stage [4]. The basis of wire drawing in die setting is that the Mass Flow Rate (or Volume Flow Rate) of each wire drawing die must be the same. If the volume flow rate in each step is not equal, the wire will break [3].

Real-Time performance assessment of calculation data for 9.5 mm aluminium wire:

$$e(t) = SP(t) - PV(t) \quad (1)$$

, where error = $e(t)$, setpoint speed = $SP(t)$ and actual speed = $PV(t)$.

Mean Absolute Error (MAE),

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}|SP_i - PV_i| \quad (2)$$

, where n = total number of observations, SP_i = set point for the i-th sample and PV_i = process value for the i-th sample.

Root Mean Square Error (RMSE),

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(SP_i - PV_i)^2} \quad (3)$$

Integral of Absolute Error (IAE),

$$\text{IAE} = \int_0^T |e(t)|\, d(t) \quad (4)$$

Standard Deviation,

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(PV_i - \overline{PV})^2} \quad (5)$$

Rise Time (T_r) = 10 % to 90% of SP
Setting Time (T_s) = ±5% of SP
Overshoot (%) = Peak Value Exceeding SP
Steady-State Error (ESS) = Final Offset From SP
Wire Length Drawn = Speed × Time (6)
Energy Consumption = Integrated Motor Power × OverTime (7)
Downtime = Total Fault Time Recorded

$$\text{Rejection Rate} = \frac{Defective\ Length}{Total\ Length} \times 100 \quad (8)$$

$e(t)$ = [3, 2, 1, 0, 0 – 1, 0, 1, 2, 3]

$$\text{MAE} = \frac{1}{10}(\,|3| + |2| + |1| + |0| + |0| + |1| + |0| + |1| + |2| + |3|)$$
$$= \frac{13}{10}$$
$$= 1.3 \text{ m/min}$$

$$\text{RMSE} = \sqrt{\frac{1}{10}(\,|3|^2 + |2|^2 + |1|^2 + |0|^2 + |0|^2 + |1|^2 + |0|^2 + |1|^2 + |2|^2 + |3|^2}^{\,2}$$

$$= \sqrt{\frac{29}{10}} = 1.70 \text{ m / min}$$

$\overline{PV} = 98.9, \sigma = 1.20\ m/min$
Average Wire Tension = 117 N
Average Motor Current = 7.08 A
Average Die Temperature = 49.6˚C

E. Performance Evaluation and Data Analysis

To evaluate the real-time performance of the Siemens S7-1200 PLC-based control system in aluminium wire manufacturing, a 10-minute test was conducted under constant setpoint conditions [3, 4]. Key parameters, including wire drawing speed, tension, motor current, and die temperature, were recorded at 1-minute intervals to monitor process stability [1, 2]. During the test, the setpoint speed was maintained consistently at 100 m/min, allowing assessment of the system's responsiveness and effectiveness in maintaining steady-state operation, as highlighted in previous studies on PLC-based wire drawing control [2, 4].

F. Real-Time Speed Error Analysis

The actual wire drawing speed was compared against the setpoint to compute the control error. Table I presents the logged data, and Table II summarises key performance metrics.

Table I. Real-time data recorded over 9 minutes.

Time (min)	SP (m/min)	PV (m/min)	Error (e)	Tension (N)	Motor Current (A)	Temperature (˚C)
0	100	97	3	115	7.1	48
1	100	98	2	118	7.2	49
2	100	99	1	117	7.0	50
3	100	100	0	116	6.9	50
4	100	100	0	115	6.8	50
5	100	101	-1	117	7.0	51
6	100	100	0	118	7.1	51
7	100	99	1	119	7.2	50
8	100	98	2	118	7.3	49
9	100	97	3	117	7.2	48

To assess the effectiveness of the PLC-based control system in aluminium wire drawing, real-time measurements were collected over a 9-minute test run under stable operational conditions. The system, implemented using a Siemens S7-1200 PLC, recorded key parameters, including speed, tension, and current, at one-minute intervals. Performance metrics, including Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Standard Deviation, were calculated to evaluate the system's accuracy, stability, and responsiveness.

Figure 1 illustrates the real-time behavior of the key control metrics - speed, tension, and motor current throughout the aluminium wire drawing process. The speed curve shows that the system initially experiences minor deviations but quickly stabilizes and follows the setpoint, demonstrating effective closed-loop control. The tension profile displays small oscillations caused by mechanical interactions within the drawing dies, yet it remains within acceptable operational limits. The motor current waveform corresponds closely with the tension variations, indicating that electrical load changes are driven by mechanical fluctuations in the wire drawing process. Throughout the operation, all three parameters remain stable, confirming the reliability of the PLC-based control strategy. The synchronized trends of speed, tension, and current highlight the system's ability to respond quickly to disturbances and maintain steady-state operation. Overall, the combined graph verifies that the Siemens S7-1200 PLC ensures precise control, efficient performance, and consistent process quality in real-time aluminium wire manufacturing.

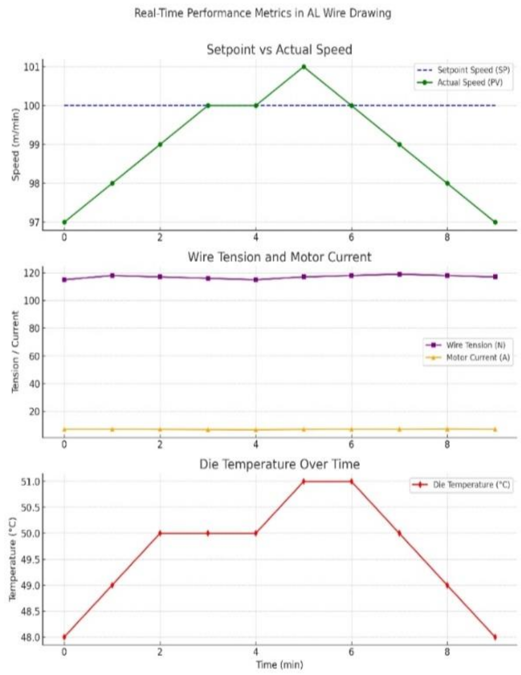

Fig. 1. The combined performance graph of real time data recorded over 9 minutes.

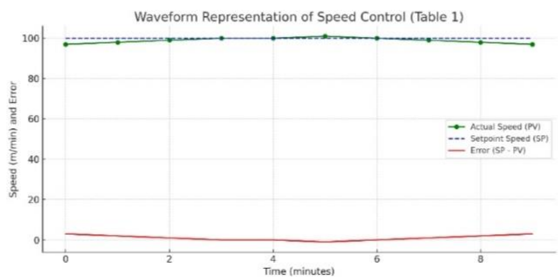

Fig. 2. Real-time error signal waveform.

Figure 2 shows the real-time comparison between the setpoint speed and the actual wire-drawing speed over a 10-minute period. The actual speed waveform exhibits small fluctuations as the system adjusts to minor disturbances in the process. The error waveform highlights moments of under- and overshoot, helping to visualize how closely the control system tracks the setpoint. Over time, the error magnitude decreases, indicating improved stability and effective closed-loop regulation. Overall, the waveform demonstrates that the Siemens S7-1200 PLC maintains accurate and consistent speed control during aluminium wire drawing.

G. Power Circuit Operation of Motors Used in the Aluminium Wire Drawing

Figure 3 shows the power circuit of the single block wire drawing machine, rod breakdown machine and spooling machine of aluminium wire drawing section.

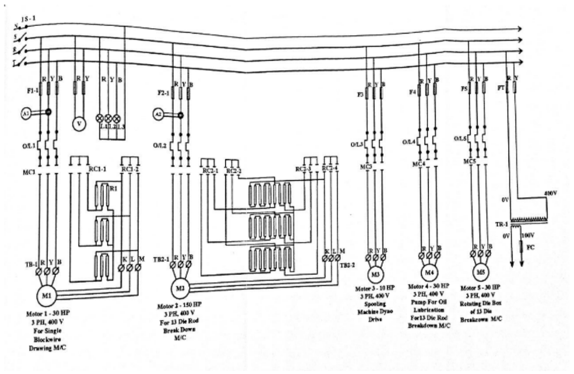

Fig. 3. The power circuit of the single block wire drawing machine, rod breakdown machine and spooling machine of aluminium wire drawing.

M1 and M2 denote the slip-ring motors used in the single-block wire drawing machine and the rod breakdown machine, respectively. M3, M4, and M5 denote the spooling machine, oil lubrication pump, and rotating die box of the 13-die rod breakdown machine, respectively. Initially, the switch is turned on, and isolator IS-1 must close first, enabling current to flow through the R, Y and B lines, which is shown by indicators L1, L2, and L3.

In the case of M1, the current flows through fuse F1-1and overload relay O/L1, then reaches magnetic contactor MC-1. It energises and also RC1-lis closed. Current flowing through terminal 3 ways TB-1 and reached the motor stator winding. RC1-1 is energised first because the rotor winding starts with complete resistance to reduce the starting current.

After three seconds, the motor reaches its full load speed, resulting in RC1-1 being shorted and RC1-2 being energised, with the motor running at full speed.

M2 performs similarly to M-1. The system contains a fuse, an overload relay, and a magnetic contactor. Current passes through F2-1 and O/L2 before energising MC-2. RC2-1 is initially energised, and RC2-2 and RC2-3 are energised after three seconds. Two seconds later, RC2-3 shorts and RC2-4 energises, causing the motor to run at full speed.

M3, M4, and M5 each include a fuse, overload relay, magnetic contactor, and three-way terminal. Current flows through the fuse and overload relay to the magnetic contactor, which energises and enables current to pass through the three-way terminal to the motor, causing it to run at full speed [5].

H. Control Circuit of Single Block Wire Drawing Machine Operation by using Siemens S7-1200 PLC

Figure 4 shows Control Circuit Diagram of Main Motor (40 HP) for 6+1 Bobbin Tubular Stranding Machine. M2 operates similarly to M1. It has been a fuse, an overload relay, and magnetic contactors.

Current flows through F2-1 and O/L2 before reaching MC-2, which energises. RC2-1 energises first; after three seconds, RC2-2 and RC2-3 energise. After another two seconds, RC2-3 shorts, RC2-4 energises, and the motor runs at full speed [5].

M3, M4, and M5 each have a fuse, overload relay, magnetic contactor, and three-way terminal block, respectively. Current flows through the fuse and overload relay before reaching the magnetic contactor. When energised, current passes through the three-way terminal block and reaches the motor, causing it to run at full speed.

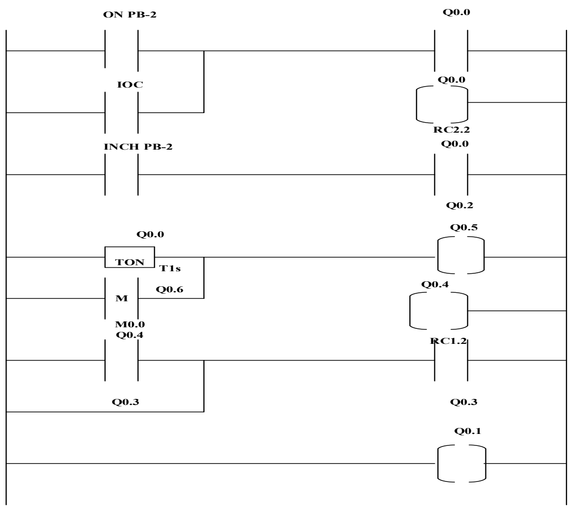

Fig. 4. Control circuit diagram of main motor (40 HP) for 6+1 Bobbin Tubular Stranding Machine.

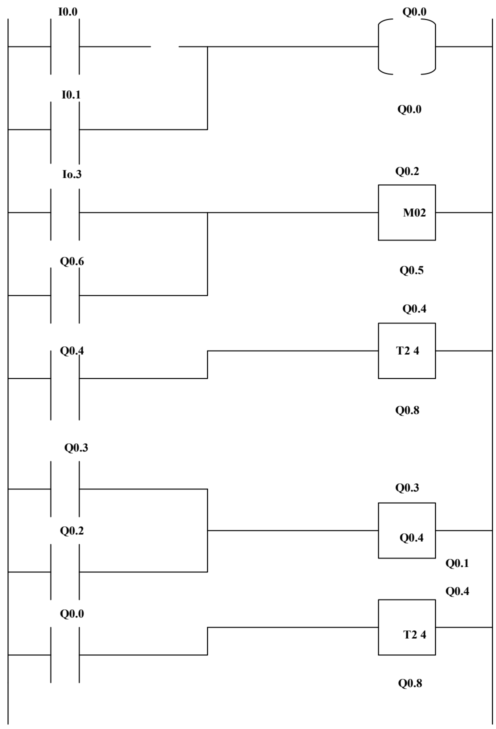

Fig. 5. Control circuit diagram of motor 2.

The control circuit shown in Fig. 5 operates the power circuit in Figure 1 for motor M-2.

When the pushbutton I0.0 (PB-3, ON) is pressed, output Q0.0 energises. Once Q0.0 is ON, it latches itself through a parallel branch, forming a classic latching circuit.

If input I0.1 is ON, then output Q0.2 is activated. When I0.3 and internal timer, likely set with a 4-second delay (assuming T-2 = 4s). memory bit M0.2 are both ON, output Q0.5 is energized. If both Q0.6 and Q0.4 are ON, Timer T-2 is activated. T-2 is a relay If both Q0.4 and Q0.3 are ON, output Q0.8 energises. Additionally, when both Q0.2 and Q0.0 are ON, Q0.4 is turned ON. The operator presses the button for activating Timer T-2 in its rung, which requires Q0.1 and Q0.4 to be ON.

I. Control Circuit Operation of Spooling Machine, Pump for Oil Lubrication, and Rotating Dies Box

Figure 5 illustrates the ON/OFF (high/low) status of inputs (such as pushbuttons and overload relays), outputs (including contactors, relays, and motors), as well as the activation and delay durations of timers.

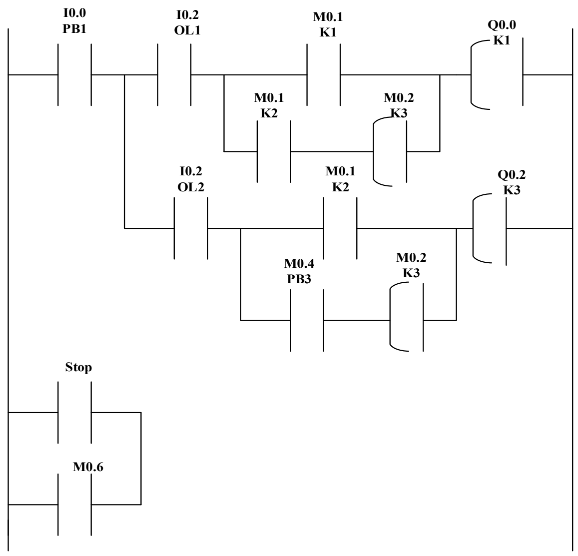

Fig. 6. Control circuit diagram of motors M3, M4 and M5.

The control circuit shown in Fig. 6 operates the power circuit in Figure 1 for motors M3, M4, and M5. The control circuit begins its operation when the Start pushbutton (I0.0) is pressed, energizing relay M0.1 (K1) provided that the overload contact OL1 (I0.2) is in a healthy state.

Once energized, relay M0.1 establishes a latching path that maintains system operation even after the Start button is released. The second branch incorporates overload OL2 (I0.3) and relay M0.4 (K2) to create an interlock mechanism, ensuring that subsequent stages do not operate in the event of a fault. Upon activation, relay M0.4 energizes relay M0.2 (K3), which initiates the next output stage in the sequence. Output Q0.0 is controlled by relay M0.1 and represents the first active motor or device in the system.

Similarly, output Q0.2 is energized through relay M0.2, enabling a second device only after all preceding conditions have been satisfied. A Stop pushbutton in combination with memory relay M0.6 provides a safe and reliable shutdown path, ensuring the system can be fully de-energized when required.

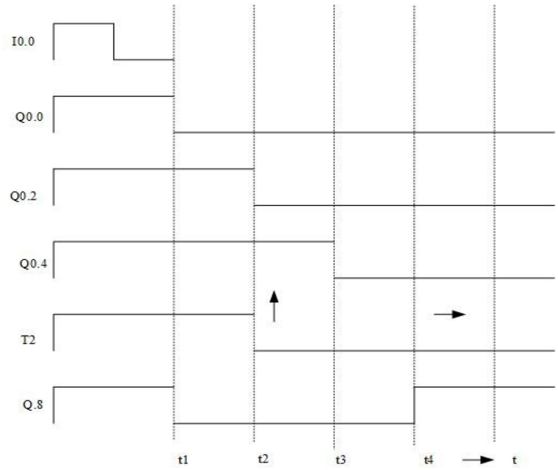

Fig. 7. Waveform of control circuit diagram of main motor and M2, M3, M4 and M5 (horizontal time axis and vertical transitions).

Figure 7 shows the relationship between input I0.0, outputs Q0.0, Q0.2, Q0.4, Q0.8, and timer T2 over time. When I0.0 goes high, Q0.0 immediately turns on, while Q0.2 and Q0.4 follow specific timing sequences. T2 starts timing when triggered, indicated by the rising edge at t2, and influences the activation of Q0.8.

Q0.8 turns on after T2 completes its preset delay, showing a delayed response relative to I0.0. The diagram illustrates the sequence of immediate and delayed output responses in a PLC circuit with a timer-based control logic.

Table. II. Input and output tag mapping of main motor and M2, M3, M4 and M5.

Time	I0.0 PB-3	Q0.0	Q0.2	Q0.4	T2	Q0.8
t0	0	0	0	0	0	0
t1	1(press)	1	1	1	↑	0
t2	0	1	1	1	ON	0
t3	-	1	1	1	→	1
t4	-	1	1	1	→	1

Table II shows the sequence of inputs and outputs for a PLC-controlled system over time. At t0, all inputs (I0.0) and outputs (Q0.0, Q0.2, Q0.4, Q0.8) are OFF, and the timer T2 is at 0.

When the push button PB-3 (I0.0) is pressed at t1, outputs Q0.0, Q0.2, and Q0.4 turn ON, and the timer T2 starts counting. At t2, after the timer completes its preset time, T2 turns ON, but Q0.8 remains OFF until t3, when it activates. From t3 to t4, the outputs maintain their states, showing the system's stable operating condition after the timer delay.

IV. RESULTS AND DISCUSSION

Real-time data recorded over a 9-minute period was used to capture the dynamic behavior of the aluminum wire drawing process under actual operating conditions. This duration allowed for monitoring both transient and steady-state responses of key parameters such as motor current, tension, speed, and temperature, which may fluctuate rapidly during operation. Comparing the conditions before and after the process provides valuable insights: the data recorded before operation represents the baseline, including idle machine states and initial material conditions, while the data after operation reflects the system's response under active processing. This comparison enables assessment of process stability, verification of PLC control effectiveness, identification of deviations or anomalies, and evaluation of whether the setpoints were achieved and maintained throughout the operation.

V. CONCLUSION

The implementation of a real-time control system based on the Siemens S7-1200 PLC in aluminium wire manufacturing has demonstrated significant enhancements in process stability, product quality, and operational efficiency. By continuously monitoring critical parameters such as wire tension, drawing speed, and diameter uniformity, the system enables prompt corrective actions, thereby reducing downtime and minimising defects.

Experimental results confirm that the integration of real-time data acquisition with automated control improves both the reliability and responsiveness of the wire drawing process. This study highlights the practical advantages of advanced PLC technologies in modern manufacturing environments and establishes a foundation for the further advancement of intelligent automation in aluminium wire production.

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AUTHOR CONTRIBUTIONS

Mya Thu Zar Moe: Experimental Design, Methodology, Investigation, Data Curation, Formal Analysis, Validation, Visualization, Testing, Data Analysis, Implementation, Validation, Writing – Original Draft Preparation, Review & Editing, Manuscript Refinement, and
Win Kyaw Myint: Project Administration, Conceptualization, Supervision, Resources, Technical Guidance, Investigation, Writing – Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests was disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

REFERENCES

[1] *Inndagaw ACSR Plant, Basic ACSR Technology*, Myanmar Machine Tools and Electrical Industries (MTEI), Ministry of Industry 2, 2002.
[2] *Conductor Technical Manual*, Angelique International Ltd., India, 2002.
[3] SIMATIC S7-1200 Programmable Controller System Manual, Siemens, 2021. [Available Online] https://support.industry.siemens.com.
[4] H. Berger, *Automating with SIMATIC S7-1200: Configuring, Programming and Testing with STEP 7 Basic*, 3rd Edn. Publicis Publishing, 2018.
[5] *Inndagaw ACSR Plant, Operation Instruction of Single Block Wire Drawing Machine and Rod Break Down Machine*, Myanmar Machine Tools and Electrical Industries (MTEI), Ministry of Industry 2, 2002.