Mitsubishi Type-Q PLC Based Press Roll Automatic Control System On Building Tire Machine

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Abstract

In an industrial automation system a controller is needed, one of which is a Programmable Logic Controller (PLC). PLC is made to change the working system of machines that used to work conventionally into a system that is controlled by using a computer. This research aims to design an automatic control system using PLC on a press roll in one of the building tire machines. The focus of the research conducted on the press roll control system includes the installation of a PLC control panel and PLC program with software GX-Works 2. The PLC used is a Mitsubishi PLC type-Q with input modules QX41 and QX42 and output modules QY41P and QY10. The method used in this research is Research and Development (R&D) method, which is a method for developing a pre-existing system. System testing is done by measuring the working voltage at the input and output terminals of the PLC and testing the overall performance of the control system. The results obtained on the input terminal test state that the input system works normally. Then in the output terminal test, the percentage error value (% error) obtained at the Y68 output terminal is 0,08%, and the Y7F output terminal is 0,04% with a standard voltage of 24 VDC. While the output terminal Y91 has a voltage error percentage value of 1,31% with a standard voltage of 220 VAC. In testing the overall performance of the system works normally according to the PLC program that has been made.

Keyword: Controller, Error Percentage, GX-Works 2, PLC, Press Roll.

I. INTRODUCTION

The manufacturing industry sector, especially the automotive sector, has experienced significant growth. According to data from the Indonesian Central Statistics Agency (BPS), in 2019 out of 133,617,012 motorized vehicle users, 84.40% were motorcycle users. This was an increase of 0.09% from 2018 which was only 84.31% of motorcycle users from 126,508,776 motorized vehicle users in Indonesia (Central Bureau of Statistics, 2020). This also affects the tire industry. According to the production data of a tire company, in the 4th quarter of 2020, the average production of motorcycle tires was 2,001,219 pcs per month. With the need for a very large amount of production, technology is needed that supports the production process, one of which is an automation system.

One technology that is able to implement an automation system is the application of a Programmable Logic Controller (PLC). Microcontroller has the same working principle as PLC based on a microprocessor. However, the microcontroller has a smaller size and durability that is not good enough to operate large machines in the industrial world (Al'Amin, Notosudjono and Soebagia, 2019). PLC is made with the aim of changing the system or work process of a conventional machine with computer technology (Fadillah and Wirawan, 2019). With a working system using a PLC, the production process will be easier because the machine's performance can be controlled using a computer system.

In previous research, PLC can be used to control the sequential process of the machine through the I/O module based on the program that has been made. The PLC will activate the output in the form of solenoid up, solenoid down, which gets triggers from sensors and time (Saputra and Hendriarto, 2020). In addition, PLC can be applied as an automatic controller of a machine, namely the Building Automation System where the PLC can be used with input in the form of sensors (Yuhendri, 2018). For making PLC programs or ladders, you can use GX-Works 2 as PLC programming software. (Fadillah and Wirawan, 2019).

Research conducted by Pensi Asmaleni, Dedy Hamdani, and Indra Sakti, one of the research methods to develop a previously existing system to be more effective and efficient so that it can be accounted for can use the reaseach and development (R&D) method (Asmaleni, Hamdani and Sakti, 2020). To prove system performance, it can be done by calculating the % error in the system in the form of power supply voltage, obstacle avoidance IR module sensors, DC motors, relays and PLCs (Al'Amin, Notosudjono and Soebagia, 2019). In addition, testing of research results can also be done by measuring voltage and analyzing the voltage applied to photoelectric sensors, limit switches, and loads (Ardiansyah, Taryana and Nataliana, 2013).

The purpose of this research is to design a control system on the press roll in one of the building tire machines. As for the limitations of the problems carried out in conducting research on the press roll control system, namely conducting research on the press roll system only on the building tire machine. Where the research is focused on the press roll control system including the installation of a PLC control panel and PLC program using a Mitsubishi PLC type-Q with QX41 and QX42 input modules and QY41P and QY10 output modules with GX-Works2 software.

II. THEORY

A. Programmable Logic Controller (PLC)

Programmable Logic Controller (PLC) is a very user friendly device based on a microprocessor, a special computer that contains various types and complexities of control functions. PLCs can be programmed, controlled, and operated by someone who is not very good at operating a Personal Computer (PC) (Yuhendri, 2018). PLC uses a special programming language, namely ladder diagrams to program the PLC system. Ladder diagram is a derivative of conventional relay technology, making it easier for operators to use PLC for controlling industrial machines. Figure 1 below shows a general PLC block diagram.

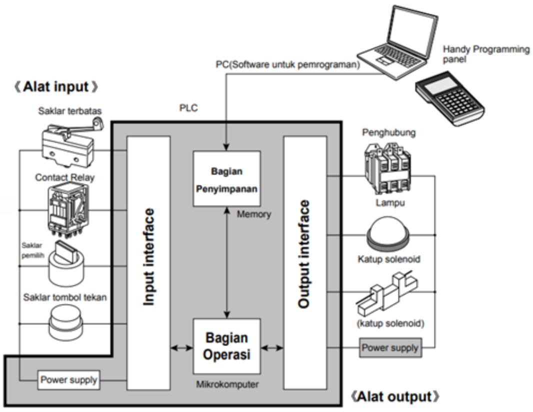

Figure 1. PLC Diagram Block
(Source : Mitsubishi Electric, 2016)

1. PLC Main Components

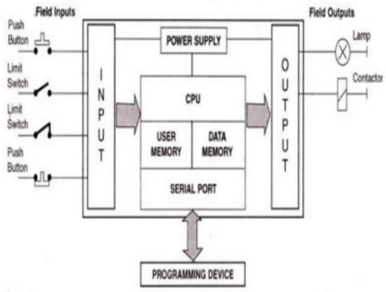

Figure 2. 1. PLC Main Components
(Source: Mubyarto et al., 2017)

In Figure 2, it is found that there are 4 main components that make up a PLC system. All these components must exist and work properly to be able to run the PLC system normally (Yuhendri, 2018). In PLC hardware there are several main parts, namely:

1) The power supply is used to provide power to all components of the PLC.

2) CPU (Central Processing Unit) is the brain of the PLC, which is used to carry out mathematical and logical operations of the PLC brain and store data or send data.

3) Programmer/monitor is a tool or tool that can function to communicate on the PLC system. Programmers have various functions, namely:

4) The input/output module is a component as an interface that connects the PLC with input/output equipment on the PLC operating system.

2. Melsoft GX-Developer/GX-Works Software

GX-Developer/GX-Works is a software from Mitsubishi PLC which is used to write a PLC program using a programming language, namely ladder diagram. GX-Developer/GX-Works has programming command symbols, namely input (X), output (Y), Timer (T), Counter (C). Then there are the basic logic commands AND, OR, SET, RESET, PULSE, Timer, and Counter (Mubyarto et al., 2017).

B. Photoelectric Sensor

Photoelectric sensors are devices used to detect the presence of objects that are usually solid. This sensor uses light energy that comes from electrical energy as a detector. Based on the working principle, these sensors are generally divided into two types. The first type is the reflection type, where the light emitting device (transmitter) and light receiver (receiver) are in the same place (Kadirun, Hasanuddin and Aryanto, 2016). An example of an OMRON photoelectric sensor is the E3JM-R4M4-G type. Table I below are the specifications for the E3JM-R4M4-G type OMRON photoelectric sensor.

TABLE 1. E3JM-R4M4-G . Photoelectric Sensor Specifications

No	Item	Specifications
1	Sensing Methode	Retro-reflective model (with MSR function)
2	Sensing Distance	4 meter
3	Power Supply Voltage	12 to 240 VDC±10%, ripple (p-p): 10% max.
		24 to 240 VAC±10%, 50/60 Hz
4	Power Consumtion	AC = 2 W max.
		DC = 2 W max.
5	Control Output	Relay output, SPDT
		250 VAC, 3A (cosφ=1) max.
		5 VDC, 10 mA min
6	Respon Time	Operate or reset: 30 ms max.

(Source: Omron, 2020)

C. Proximity Sensor

Proximity sensor is a sensor that is able to detect objects or objects nearby without physical contact (non-contact). This sensor utilizes an electromagnetic field to detect nearby objects. Proximity sensors are categorized into two types, namely inductive proximity and capacitive proximity. In the inductive proximity sensor, objects that can be detected are metal objects such as iron, steel, aluminum, and others. While capacitive proximity is a type of proximity sensor that is able to detect objects other than metal (non-metal) such as wood, plastic, glass, and others (Rukshna et al., 2015). The characteristics of this sensor can only read objects or objects with very close distances ranging from 1 mm to a few cm (Guntara and Famytra, 2017). One of the proximity sensors that are quite a lot in the market is OMRON type E2E-X2E1-M1 with 3 wire output configuration. The sensor is an inductive proximity sensor type with an NPN output so that it produces data in the form of a negative voltage (-). For more details, the following are the specifications for the OMRON E2E-X2E1-M1 proximity sensor in table II.

TABLE II. OMRON E3E-X2E1-M1 . Proximity Sensor Specifications

No	Item	Specifications
1	Sensor Type	Inductive
2	Output Type	3-Wire Direct Current (DC), Negative-Positive-Negative (NPN)
3	Sensing Distance	2 mm ± 10%
4	Detectable Ovject	Ferrous Metal
4	Voltage	12 to 24 VDC, ripple(p-p): 10% max. (10 to 30 VDC)
5	Contact Configuration	Normally Open (NO)

(Source: Omron Industrial Automation, 2017)

D. Relay

Relay is an electrical component that works electrically with mechanical contact. In principle, the relay works when the coil gets a current source in the form of alternating current (AC) or direct current (DC) depending on the type of coil used. When the coil on the relay has worked, it will move the contact points to work. So that the relay is able to work with small currents but can deliver larger currents through its contact points (Saleh and Haryanti, 2017). One example of MY4N type OMRON relay. This type of relay has two types according to the working voltage of the coil. There is an OMRON MY4N 24VDC relay, which is a relay with a direct current or DC coil. There is also an OMRON MY4N 220VAC relay, where the working voltage of the relay coil is 220 V with alternating current or AC. Table III follows the specifications for the OMRON MY4N 220VAC and 24VDC relays.

TABEL III. Relay MY4N Specifications

No	Item	Specifications
Coil Ratings		
1	Rated Voltage (V) Coil	220/240 Volt, 50/60 Hz; 24VDC
2	Rated Curred (mA) Coil	AC = 50 Hz = 4,8 / 5,3 mA; 60 Hz = 4,2 / 4,6 mA
		DC = 36,3 A
3	Coil Resistance	AC = 18,7 kΩ
		DC = 662 Ω
Contact Ratings		
1	Rated Load	
	a. Resistive Load	3 A at 220 VAC; 3 A at 24 VDC
	b. Inductive load (cos φ = 0.4, L/R = 7 ms)	0.8 A at 220 VAC; 1.5 A at 24 VDC
2	Maximum contact voltage	250 VAC, 125 VDC
3	Contact configuration	4PDT

(Source: Omron, 2018)

III. RESEARCH METHODS

The method used in conducting this research is a development method with descriptive and quantitative data collection. The method of development or research and development (R&D). The flow of the research process carried out is shown in Figure 3 as follows.

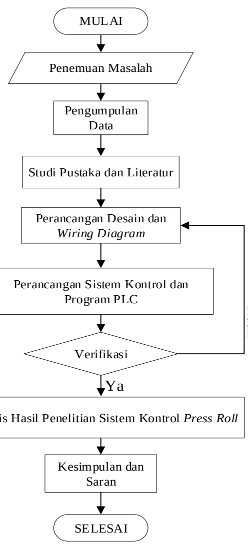

Figure 3. Research Flow

Development of a working system based on the Mitsubishi Type-Q PLC. Making a PLC program or ladder using the GX-Works 2 software. Figure 4 is an algorithm for the press roll control system.

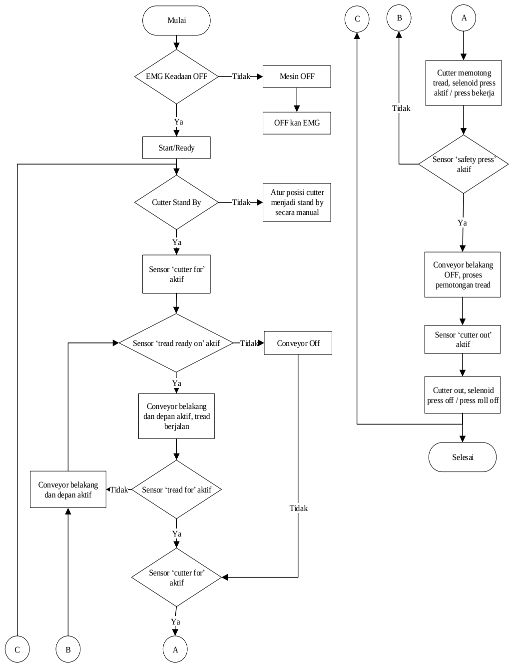

Figure 4. Control System Algorithm

The block diagram design can be seen in Figure 5 below.

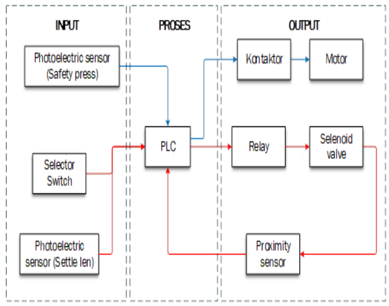

Figure 5. Press Roll Control System Block Diagram

This study calculates the error percentage (% error) that occurs in the system output with equation (1) as follows.

$$|\%error| = \frac{(V\ measurement - V\ standard)}{V\ standard} \times 100\% \quad (1)$$

IV. RESULTS AND DISCUSSION

A. System Design Results

The press roll control system consists of several components located inside the control panel and outside the control panel. The control panel consists of PLC, MCB, Relay, and connecting terminals. In Figure 6 the following is the result of the design in the control panel.

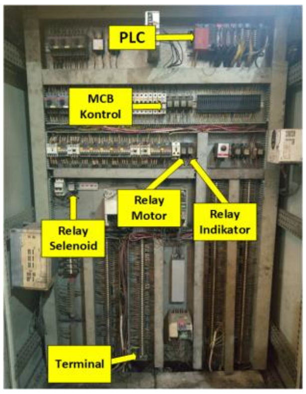

Figure 6. Control Panel Design Physical Appearance

While the components installed outside the panel consist of push buttons, selector switches, proximity sensors, photoelectric sensors, solenoid valves, and motors. For more details can be seen in Figure 7 below.

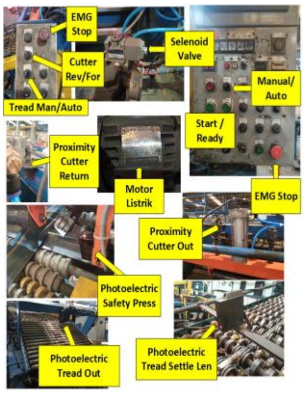

Figure 7. Physical Display of Input and Load Control System

B. Wiring Diagram

1. Input Module

The wiring diagram of the press roll control system for the QX42 input module can be seen in Figure 8 and the QX41 input module in Figure 9.

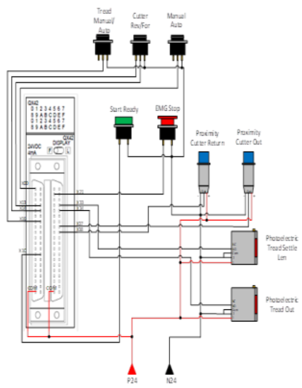

Figure 8. Wiring Input Module QX42

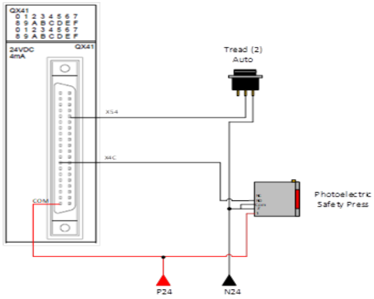

Figure 9. Wiring Input Module QX41

2. Output Module

The output wiring used in the press roll system this time is QY41P in Figure 10 and QY10 in Figure 11.

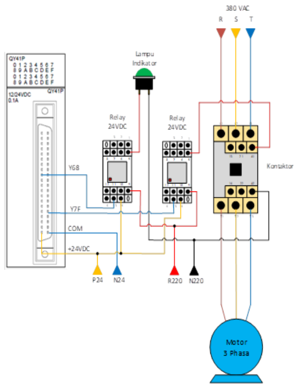

Figure 10. Wiring Output Module QY41P

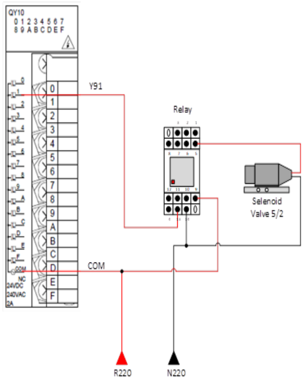

Figure 11. Wiring Output Module QY10

C. PLC Module Addressing

In the building tire machine, the PLC used is a Mitsubishi Q-Series PLC with a Q00CPU CPU type. The PLC uses a base unit type Q38B which has 8 PLC module slots. The QX42 input module is installed in slot 0 with 64 bits, and in slot 1 the QX41 input module with 32 bits. Meanwhile, the output module installed in slot 2 is QY41P with 32 bits, and slots 3, 4, 5 are QY10 output modules with 16 bits. For slot 6 installed counter module type QD62.

For the terminal pins used in the press roll control system the input and output addresses used are described in table V.

TABLE V. PLC Module Input and Output Addressing

No.	Addressing	I/O	Description
1	X0	I	Selector switch manual/auto machine
2	X13	I	Selector switch cutter forward
3	X14	I	Selector switch cutter reverse
4	X16	I	Selector switch tread manual/auto
5	X1C	I	Push button start/ready
6	X21	I	Push button emergency stop
7	X33	I	Photoelectric sensor tread settle
8	X34	I	Photoelectric sensor tread out
9	X37	I	Proximity sensor cutter out
10	X38	I	Proximity sensor cutter return
11	X4C	I	Sensor photoelectric safety press
12	X54	I	Selector switch conveyor manual/auto
13	Y68	O	Indikator start/ready
14	Y7F	O	Motor conveyor belakang forward
15	Y91	O	Selenoid valve press roll

D. Ladder PLC Design

On the ladder machine building tire machine, a safety system is made where Y68 is an indicator of the start / ready engine control system. For more details, see Figure 12.

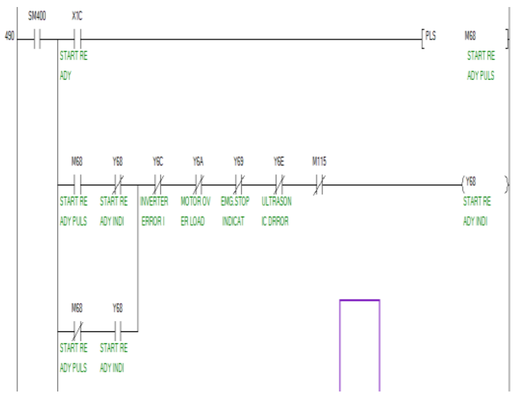

Figure 12. System Security Ladder

From figure 12, that when X1C or start/ready is active it will turn on the M68 as an internal relay for start/ready. When the M68 is active, the Y68 or the start/ready indicator will be active. Y68 is said to be a security because if Y68 is not active then the ladder press roll control system will be inactive.

Figure 13. Ladder Internal Relay Press ON

In Figure 13, when the X33 is working, it will activate the M116 internal relay by pulse where the pulse working system only lights up for a while then turns off again. When M116 has been pulsed, it will activate M211. To disable the M211 need a RESET command because the system uses SET.

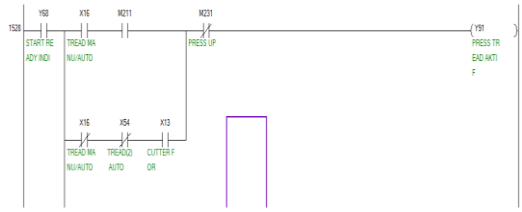

Figure 14. Ladder Trigger Solenoid Press ON

Figure 14, Y91 can work if the position of the selector switch X16 is in the auto position or normally closed (NC). The Y91 can also be activated manually, using the cutter forward or X13 selector switch. Where the ladder is made in parallel between M211 and X13 with manual tread selector switch conditions (X16) and tread (2) auto (X54) in manual conditions. So that the press roll can work with two conditions, namely automatically and manually.

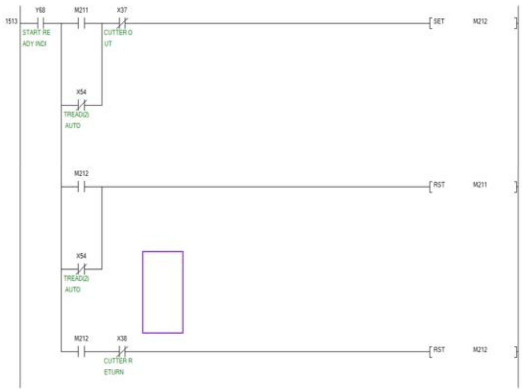

Figure 15. Ladder Disables Internal Relay

Figure 15 shows the ladder for deactivating the internal relay which is the trigger for the solenoid valve press roll. Where the initial condition of the X37 which is the cutter out sensor is in an open condition or NO, because the X37 sensor does not detect the presence of a cutter, the cutter position is in a return condition. When the X37 sensor is active, it will activate

M212, where when M212 is active, M211 will be RESET.

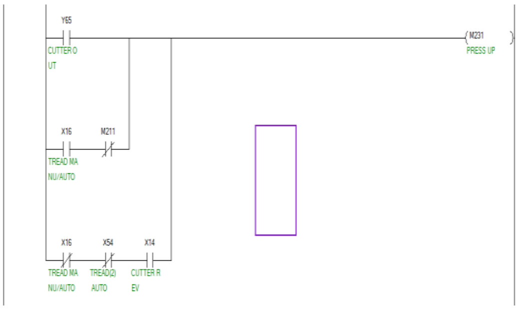

Figure 16. Ladder Disables Solenoid Valve

In figure 16, to activate the M231 it can be done in various ways because the ladder is made in parallel. Where M231 can be active when Y65 or cutter output is active. In addition, the M231 can work when the M211 is active, which is described in Figure 49. The M231 can also work manually, using the X14 or reverse cutter, but when this condition occurs, the X16 and X54 must be in the manual position. When M231 is active it will disconnect Y91 in Figure 14.

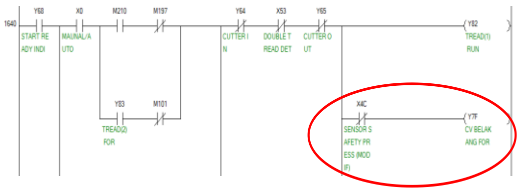

Figure 17. Ladder Safety Press Roll

When the press roll is working or active, it will be detected by the X4C sensor. Where this sensor is for safety, when X4C is active then Y7F which is the rear tread input conveyor cannot work as shown in Figure 17. So that there is no tread buildup before the press and cutting process is complete.

E. Control System Test

1. Input Test

Input testing is carried out on the input components consisting of push buttons, selector switches, and sensors used in the press roll control system. Table VI is the voltage test data taken at the PLC input terminal at the push button terminal.

TABLE VI. PLC Push Button Input Terminal Voltage Testing

Push Button Circuit	Condition		Voltage (VDC)	
	Open	Close	Open	Close
Start/Ready (X1C)	High	Low	23,34	0,05
Emergency (X21)	Low	High	0,04	23,89

Furthermore, in table VII, the voltage test at the terminal selector switch as PLC input is carried out.

TABLE VII. PLC Selector Switch Input Terminal Voltage Test

Selector Switch Circuit	Condition		Voltage (VDC)	
	Open	Close	Open	Close
Manual/Auto (X0)	High	Low	23,76	0,01
Cutter Forward (X13)	High	Low	23,34	0,01
Cutter Reverse (X14)	High	Low	23,34	0
Tread Manual/Auto (X16)	High	Low	23,94	0
Cv. Manual/Auto (X54)	High	Low	24,01	0,04

In table VIII, the voltage test at the sensor input is also carried out. Where the sensors used are photoelectric sensors and proximity sensors. Each sensor has a working voltage of 24 VDC.

TABLE VIII. PLC Sensor Input Terminal Voltage Testing

Sensor Circuit	Condition		Voltage (VDC)	
	Open	Close	Open	Close
Sensor Tread Settle Len (X33)	High	Low	23,99	0
Sensor Tread Out (X34)	High	Low	24,01	0,02
Sensor Cutter Out (X37)	High	Low	24,03	0,01
Sensor Cutter Return (X38)	High	Low	23,97	0,01
Sensor Safety Press (X4C)	High	Low	24	0

From each test voltage at the PLC input terminal can be obtained that the working voltage on the system is appropriate.

2. Output Test

Testing on the output terminal is done by taking 10 samples of voltage when the system is active or ON. The following is the test data in table IX.

TABLE IX. PLC Output Terminal Voltage Test Data

Sample to-	Output Terminal Voltage		
	QY41P (VDC)		QY10 (VAC)
	Y68	Y7F	Y91
1	24,12	24,02	221,5
2	23,99	23,78	222,9
3	23,97	24,05	221,8
4	23,99	23,99	223,8
5	24,14	23,96	224,7
6	23,89	24,04	224,6
7	24,12	24,03	224,5
8	23,99	24,01	223,1
9	23,98	24,07	221,6
10	24,04	23,99	220,7
Average	**24,02**	**23,99**	**222,9**

From these data, the % error of the stress that occurs can be calculated using equation (1). At the outputs Y68 and Y7F have a standard voltage of 24 VDC, so the % error of the voltage is as follows:

$$|\%error| = \frac{(24{,}02-24)}{24} \text{ x } 100\% = 0{,}08\% \quad (2)$$

$$|\%error| = \frac{(23{,}99-24)}{24} \text{ x } 100\% = 0{,}04\% \quad (3)$$

The results of the calculation of equation (2) and equation (3) can be interpreted that the Y68 terminal voltage test has a %error of 0.08% and Y7F has a %error of 0.04%. Furthermore, at the Y91 terminal the standard voltage is 220 VAC, the following calculations %error according to equation (1).

$$|\%error| = \frac{(222{,}9-220)}{220} \text{ x } 100\% = 1{,}31\% \quad (4)$$

From the calculation of equation (4), it can be interpreted that the % error of the voltage at the Y91 terminal measurement is 1.31%. So that Y91 works normally according to standard voltage.

3. Final Testing of the System

Table X below is a descriptive test result regarding the performance of the control system.

TABLE X. Testing Data for Final Results of Press Roll Control System

Test Type	Output Condition			Ket.
	Y68	Y7F	Y91	
PB Start/Ready ditekan	High	Low	Low	Appropriate
Posisi Auto				
Sensor tread out ON	High	Low	Low	Appropriate
Sensor tread out OFF	High	High	Low	Appropriate
Sensor tread settle ON	High	Low	High	Appropriate
Sensor tread settle OFF	High	High	Low	Appropriate
Sensor cutter out ON	High	Low	Low	Appropriate
Sensor cutter return ON	High	High	Low	Appropriate
Posisi Manual				
Selector cv. Manual/auot	High	Low	Low	Appropriate
Selector tread manual/auto ON	High	High	Low	Appropriate
Selector tread manual/auto OFF	High	Low	Low	Appropriate
Seelctor cutter forward ON	High	Low	High	Appropriate
Seelctor cutter reverse ON	High	Low	Low	Appropriate

From the data in table X obtained in the final test results, it can be interpreted that the system works according to the design and in accordance with the program that has been made.

V. CONCLUSION

The design of a Programmable Logic Controller (PLC) based automatic control system is tailored to the needs of an increasingly advanced industry in the field of technology. From the test results, the data obtained shows that the PLC input and output controls work according to the program that has been made. In testing the % error value obtained at the Y68 output terminal is 0.08%, and the Y7F output terminal is 0.04% with a standard voltage of 24 VDC. While the Y91 output terminal has a voltage % error value of 1.31% with a standard voltage of 220 VAC. Thus the output voltage at each output module works according to the standard. In the final test, the performance of the system can work according to the commands given, so that the system can work as it should.

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