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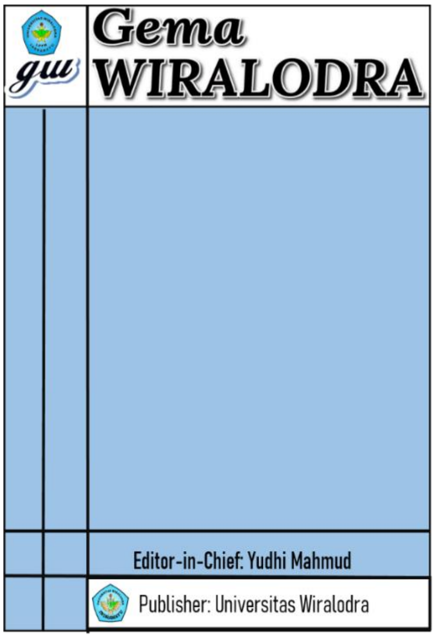

Design and control of an automatic cable-cutting machine with the implementation of a stepper control program using PLC

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Original Article

Design and control of an automatic cable-cutting machine with the implementation of a stepper control program using PLC

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Abstract
Proper control design will reduce energy losses and production costs for the industry. Control system design also reduces the role of humans in production. An automatic cable-cutting control system can reduce cable manufacturing time so that a company's human resources do not need to carry out the cable-cutting process manually. This cable cutter uses a PLC for its central control, which will convert the length value into the number of pulses and calculate the number of cables to be cut. The HMI inputs the length of the cable to be cut and the number of cables to be missed. The stepper motor is used to run the cable-pulling mechanic, which will pull according to the size stated on the HMI. This system can cut AWG20 and AWG16 cables in various lengths from 50 mm to 3000 mm with the number or number of wires that can be set from 1 cut to 10 cuts for each size.
Keywords: Cable, PLC, Omron CP1E, Automatic, Cutter

1. Introduction

Automation technology has developed over the centuries, especially since cam and governor components were invented. Since the advent of the microprocessor in 1973, automation technology has been overgrown, and since then, automation technology has penetrated all areas of human activity. In the development of the industrial world, control systems play an essential role in increasing precision, accuracy, and speed, improving quality, and reducing production costs. Proper control design will reduce energy losses and production costs for the industry, and control system design also reduces the role of humans in production (Junaidi, 2015; Anaam et al., 2022).

This research aims to design and build an automatic cable-cutting control system that can be used to reduce cable manufacturing time so that human resources owned by a company do not need to carry out the cable-cutting process manually so they can be diverted to other work. This cable-cutting machine uses PLC, HMI, and a Stepper motor, this system can cut cables in several sizes for one process with the number of cables and cable sizes that will be input into the HMI.

According to Rahmi Berlianti and Nasrul, using HMI as monitoring and input and the OMRON CP1E PLC can work well on automatic cable-cutting machines. Tests were carried out with 2.5 mm NYA cables of 50 cm, 100 cm, 150 cm, and 200 cm with a DC motor actuator producing factor. The error is 9.5%, which is also influenced by the gap between the cable winders, which are not the same (Berlianti, 2020). According to Budi Cahyo Wibowo and Fajar Nugraha in their journal, stepper motors are a type of actuator that is very popular and widely used in the industrial world, especially in the manufacturing and electromechanical industries. Stepper motor control using the start-stop method is a method that produces output pulses according to the target frequency that has been set so that the stepper motor will rotate at a speed according to the target frequency. By using the start-stop method, the stepper motor is capable of rotating at speeds between 30 rpm – and 240 rpm and the rotation angle that can be operated on the motor is from 2°-360°(Wibowo & Nugraha, 2021).

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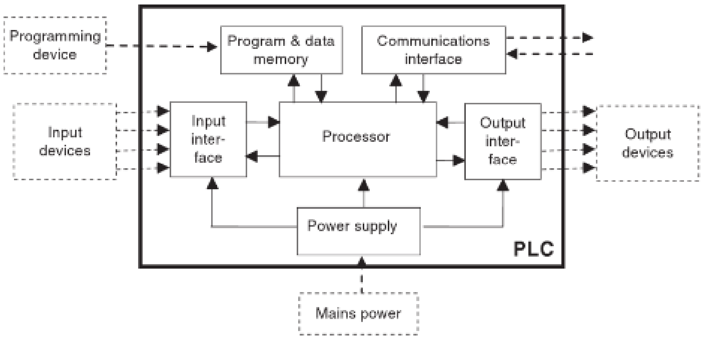
Programmable logic control

A Programmable Logic Controller (PLC) is a computer specifically designed to control a process or machine. This controlled process can take the form of continuous variable regulation such as in servo systems or only involve control of two states (On/Off) but is carried out repeatedly as we commonly encounter in drilling machines, conveyor systems, and so on.

Figure 1
System in PLC



Usually, a PLC system has basic functional components, namely a CPU (processor unit), memory, power supply unit, input/output interface, communication interface, and programming devices. Figure 1 shows the basic arrangement (Bolton, 2015) and (Setiawan, 2006).

CP1E N30DTD is a compact type PLC made by OMRON which is designed for easy application. The CP1E includes a basic model CPU unit for standard control operations, using basic instructions, movement, arithmetic, and comparison that supports connection to programmable terminals, inverters, and servo drivers.

Figure 2
Omron CP1E N20DTD PLC

Human Machine Interface

HMI (Human Machine Interface) is a system that can bring humans together with machine technology. HMI is in the form of a controller and shows status, either done manually or presented with real time computer visualization. HMI can also be referred to as a user interface and control system for manufacturing. The task of the HMI or Human Machine Interface itself is to create visualizations of a technology or system in real time (Haryanto & Hidayat, 2016). OP series operation panel can control PLC via buttons, text, lights. Its characteristics are as follows:

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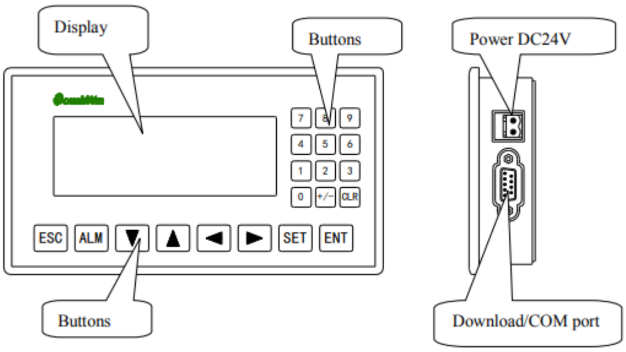
a. Edit the program in OP320 series software, can download the program via PC serial port,
b. Can communicate with various PLCs. Such as Mitsubishi FX series, Omron C series, Siemens S7 series and so on,
c. Password function
d. Built-in RTC
e. OP can display dynamic text
f. Alarm function
g. All buttons can be defined as multifunctional
h. STN LCD with backlight
i. Protection level IP65
j. Supports BMP image display

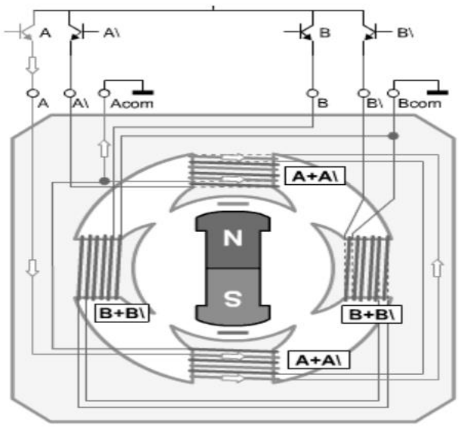
Figure 3
Xinje OP320 HMI configuration



Stepper motors

A stepper motor is an electric motor that is controlled by digital pulses, not by providing a continuous voltage. The series of pulses is translated into shaft rotation, where each rotation requires a specified number of pulses. One pulse produces one increment of rotation or step, which is part of one complete rotation. Therefore, a calculation of the number of pulses can be applied to obtain the desired number of revolutions. Pulse calculation automatically shows the number of revolutions that have been made, without requiring feedback (Kalatiku & Joefrie, 2019; Silaban et al., 2020).

Figure 4
Stepper Motor Configuration



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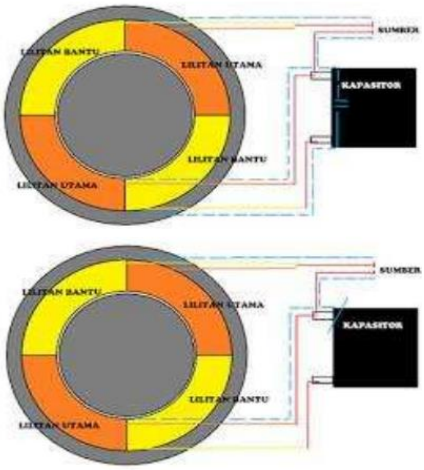
1 Phase AC Electric Motor

A 1 phase capacitor electric motor is a type of 1 phase electric motor that has two coils, namely the main coil and the auxiliary coil. The main coil usually has a larger size than the auxiliary coil which has a smaller size but in greater numbers. A single phase capacitor electric motor is equipped with a capacitor as an assistant (King & Kapo, 2017).

Figure 5
AC 220V Electric Motor



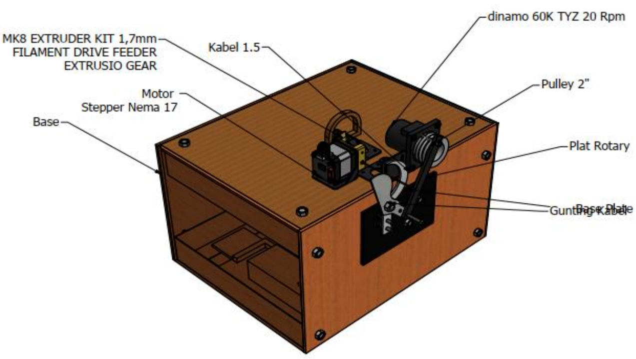
Electric current enters and creates magnetism in the main coil. Because the main coil has balanced power on both sides of the coil, there is a balanced attraction, so there will be no rotation. Therefore, an auxiliary coil is created which will create traction and make the motor rotate. When the main coil and electric motor are working normally (usually after the speed is 70% stable) the capacitor will cut off the current supply to the auxiliary coil and make only the main coil work (King & Kapo, 2017).

2. Methods

Mechanical design

Mechanical design is the process of creating an automatic cable cutting tool and Also mechanical design aims to determine the location of the components used in the manufacture of automatic cable cutting tools.

Figure 6
2D image of the machine



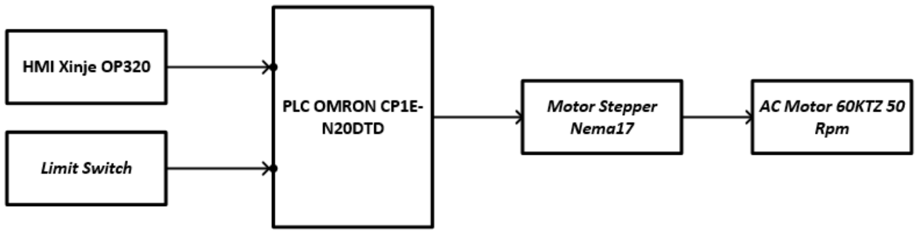
In the mechanical design of the automatic cable cutter, the mechanical specifications are as follows:

a) Base; Consists of boards and acrylic shaped like a box which will also be used as a panel.
b) Cable pulling roller; Consists of a stepper motor and mechanics that will be used to run the MK8 extruder
c) Cutter; Consisting of an AC motor that will move the pulley and then connected to a plate that moves the cable cutting scissors.

Machine control design

Figure 7

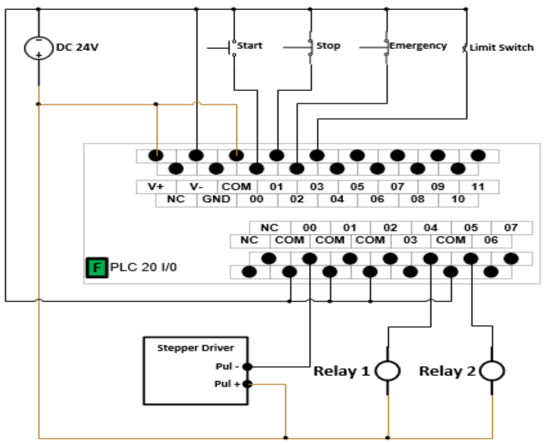
Machine installation block diagram



HMI is used as input to fill in the value of the cable length and number of cables to be cut (Haryanto & Hidayat, 2016), the value entered can vary with a minimum value of 50mm to 3000mm. The Limit Switch is used to read the position of the cable cutting scissors and reverse the direction of rotation of the scissor driving motor. After that, the value entered from the HMI will be sent to the PLC using an RS232 communication cable and entered into the PLC's internal memory to be processed in the PLC and converted into an output in the form of a pulse which will be used to drive the stepper via the PLC output with address 100.00. The stepper driver will move the stepper motor according to the pulse value sent by the PLC, when the pulse value has been reached the PLC will activate the relay to drive the AC motor which is used to run the cable cutting scissors, after the cutting process is complete the limit switch will read the position of the scissors and the counter inside The PLC program will calculate the number of cables to be cut.

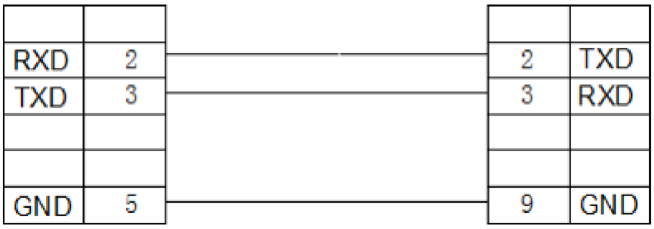
Figure 8

Installation of actuator components to the PLC



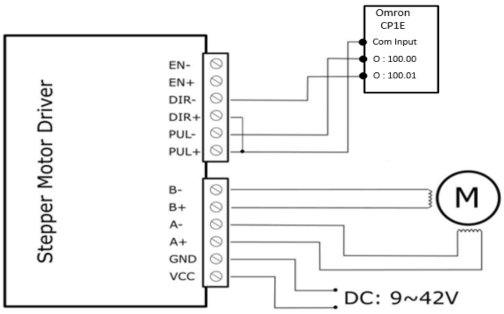
The Omron CP1E PLC uses 24VDC voltage as its input voltage, the components used as input are connected to the PLC input terminal after which the data will be processed by the processor to regulate the state of the actuator (Hurulean & Setyawan, 2020), for the stepper driver, use a terminal with address 100.00 which can provide signals in the form of pulses.

Figure 9
DB9 connector configuration



For RS232 connections, pin number 2 (RXD) of the DB9 (Male) connector on the HMI OP320 is connected to pin number 2 (TXD) on the DB9 (Female) connector of the PLC, then pin number 3 (TXD) of the HMI is connected to pin number 3 (RXD) of the PLC and pin number 5 of the HMI is connected to pin number 5 on the PLC as GND.

Figure 10
Stepper motor drive circuit installation



There are three total input signals: pulse signals PUL +, PUL -; direction signals DIR+, DIR; offline signals EN+, EN-. The driver supports both common-cathode and common-anode circuits. This control circuit uses two inputs, namely a pulse signal input which is connected to the PLC output at address terminal 100.00 and a direction signal which is connected to the PLC output 100.01 with a common-anode circuit (Setiawan, 2006) and (Hurulean & Setyawan, 2020).

Stepper drive program design

The design of the stepper drive program is made in the CX-Programmer software, the program will convert the cable length value set from the HMI with the formula: number of pulses = length value (1600/50) where the value 1600 is the pulse value needed for one motor rotation stepper, and the value 50 is the circumference of the MK8 Extruder cable pickup roller. After that the results of the calculation will be processed by the PULS instruction to run the stepper motor.

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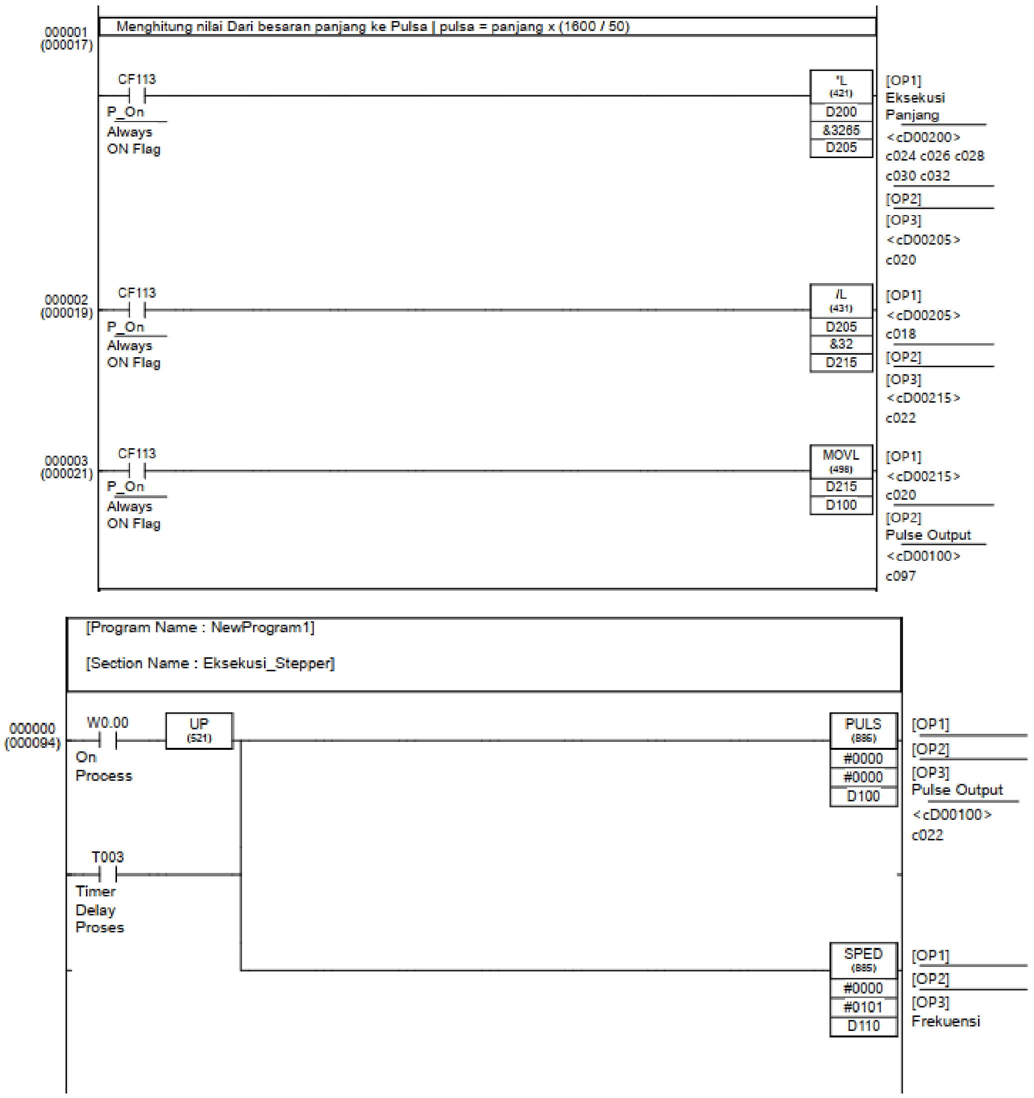
Figure 11
Program to convert length quantities into pulse quantities



3. Results and Discussion

Testing the resulting pulse value

In this test, the desired cable length value will be entered into the HMI, then it will be observed what pulse value is produced in the PULS instruction on the PLC and when the length value is changed whether the value in the PULS instruction will also change.

Table 1
Conversion program test results

PLC Address	Mark	D100/PULS Credit Value
D2	100mm	10203
D3	155mm	15814
D4	223mm	22752
D5	331mm	33772
D6	502mm	51219

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In the table it can be seen that if a length value is given in the HMI and then the value is changed, the value in the PULS instruction will also change. For a cable length of 100mm, the pulse value generated in the PULS instruction is 10203 pulses and if calculated using the formula number of credits = 100 (3265/32) then the result obtained is 10203,125 credits. For a cable length of 155mm, the pulse value generated in the PULS instruction is 15814 pulses and if calculated using the formula number of credits = 155 (3265/32) then the result obtained is 15814.84375 credits. For a cable length of 223mm, the pulse value generated in the PULS instruction is 22752 pulses and if calculated using the formula number of credits = 223 (3265/32) then the result obtained is 22752.96875 credits. For a cable length of 331mm, the pulse value generated in the PULS instruction is 33772 pulses and if calculated using the formula number of credits = 331 (3265/32) then the result obtained is 33772.34375 credits. For a cable length of 502mm, the pulse value generated in the PULS instruction is 51219 pulses and if calculated using the formula number of credits = 502 (3265/32) then the result obtained is 51219.6875 credits

Test the output results of the tool when running

This test aims to find out whether the results of cutting the cable from the tool are in accordance with the set points entered in the HMI. Then the error factor for each fruit will be measured. The error factor is calculated based on the formula, error factor = (Tp – Hp)/Tp X 100%. Where TP is the cutting target and HP is the cutting result (Raharja & Suhilman, 2017).

Table 2

Comparison of cable cutting results with set points

PLC Address	Mark	D100 Credit Value	Machine Output (mm)	Error Factor
D2	100mm	10203	99mm	1%
D3	155mm	15841	155mm	0%
D4	223mm	22752	222mm	0.45%
D5	331mm	33772	329mm	0.6%
D6	502mm	51219	502mm	0%

It can be seen from table 2 that the results of the actual length of the cable cut do not differ much from the set points given

Testing and analysis of tools for production

This test was carried out at the Mahameru packaging manufacturing company, and was used to prepare cables that would be used to assemble the packaging machine control panel; therefore, the cable length values were adjusted to the needs of the panel, from a total of 141 types of cable lengths the author took 5 length data samples in sequence. random. The author also took tool speed data and compared it with cutting the cable manually.

Table 3

Comparison of cutting processes with tools and manually

Long	Number of Pieces	Average Cutting Time		Percentage comparison
		Tool	Manuals	
1069mm	10 pcs	66s	131s	49.6%
330mm	10 pcs	29s	101s	59.7%
405mm	10 pcs	48s	105s	54.2%
180mm	10 pcs	16s	77s	71.2%
780mm	10 pcs	54s	134s	79.2%

The results of the comparison of the time for the task of cutting cables with tools and manually show a very significant reduction in time. For the comparison itself, at most, up to

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79.2% faster and at least 49.6% faster. This is also influenced by the focus of the human resources in charge of carrying out the process.

Table 4

Cable cutting table with a length of 1069mm

2nd piece	Machine Output (mm)	Difference (mm)	Error Factor
1	1064	4	0.4%
2	1060	9	0.8%
3	1061	8	0.7%
4	1061	8	0.7%
5	1065	4	0.3%
6	1067	2	0.1%
7	1059	10	0.9%
8	1060	9	0.8%
9	1061	8	0.7%
10	1065	4	0.3%
Average	1062.3	6.7	0.6%

Table 5

Cable cutting table with a length of 330mm

2nd piece	Machine Output (mm)	Difference (mm)	Error Factor
1	329	1	0.3%
2	325	5	1.5%
3	328	2	0.6%
4	325	5	1.5%
5	328	2	0.6%
6	327	3	0.9%
7	326	4	1.2%
8	326	4	1.2%
9	328	2	0.6%
10	324	6	1.8%
Average	326.6	3.4	1%

Table 6

Cable cutting table with a length of 405mm

2nd piece	Machine Output (mm)	Difference (mm)	Error Factor
1	402	3	0.7%
2	400	5	1.2%
3	403	2	0.4%
4	403	2	0.4%
5	402	3	0.7%
6	400	5	1.2%
7	405	0	0%
8	403	2	0.4%
9	403	2	0.4%
10	404	1	0.2%
Average	402.5	2.5	0.6%

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Table 7
180mm long cable cutting table

2nd piece	Machine Output (mm)	Difference (mm)	Error Factor
1	179	1	0.5%
2	180	0	0%
3	178	2	1.1%
4	178	2	1.1%
5	177	3	1.6%
6	179	1	0.5%
7	178	2	1.1%
8	179	1	0.5%
9	178	2	1.1%
10	179	1	0.5%
Average	178.5	1.5	0.8%

Table 8
Cable cutting table with a length of 780mm

2nd piece	Machine Output (mm)	Difference (mm)	Error Factor
1	772	8	1%
2	775	5	0.6%
3	777	3	0.3%
4	777	3	0.3%
5	772	8	1%
6	772	8	1%
7	775	5	0.6%
8	778	2	0.2%
9	777	3	0.3%
10	772	8	1%
Average	774.7	5.3	0.6%

From the test data results above, the smallest error factor is 0% and the largest error factor is 1.8%, and the average results of the smallest error factor are 0.6% and the largest error factor is 1%. This can happen because different cable positions have different stretches and different cable pulling weights vary.

4. Conclusion

Based on the results of testing, measurement and analysis of the tool system, it can be concluded as follows: (1) the PLC program and circuit work according to the system and control the stepper motor properly and RS232 communication from the PLC to the HMI runs normally. (2) the program for converting length to pulse value to run the stepper on the PLC runs well with an error factor of 0 to 1.8% which is also influenced by cable stretch. (3) the counter program for counting cut cables runs well according to the set points in the HMI. (4) the HMI sends input data regarding the length value and the number of cables to be cut to the PLC accurately. (5) the average speed of the machine can cut a cable with a length of 1000mm every 5 seconds.

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