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Development and Performance Improvement of an Automated Washing System for a Specified Modulator in the Scale of Industrial Automation

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ABSTRACT

Automation is a solution to improve things in industrial world. The automation itself makes the system able to work automatically and decrease the use of man power. Modulator is a part of conditioner system that was being produced without using automation. The process to produce the modulator consists of a number of steps: loading, cutting, washing, drying, and finishing. In order to wash and to dry the modulator automatically, several industrial components are used as the actuators to execute the process. The industrial components such as water pump, solenoid valve, proximity sensor, and pneumatic cylinder are controlled by a Programmable Logic Controller (PLC). The PLC uses ladder programming language to decide the behavior of the system. A feedback system is applied to the system to get a better performance in terms of process lead time. The performance of the process is better after using the feedback system. The system without feedback has an average lead time of 15.4 s and the system with feedback has an average lead time of 14.7 s.

Keywords: ***automation, modulator, PLC, ladder programming language, feedback, lead time.***

I. INTRODUCTION

A. Background

In industrial world, profit is the thing that is wanted to be increased. The profit itself is positive difference between the income and the production cost. There are two things that can be improved in order to decrease the production cost. They are lead time efficiency and standard production procedure to do the production process. Here, lead time is the time required to do the production process for one unit of product. The standard procedure, as the name said, is the prescribed flow activity to do the production process.

Automation is the solution to improve the process lead time efficiency and standard production procedure. The best process lead time can be achieved by using automation and the application of feedback control system analysis to the process we want to improve. Also, the standard production procedure can surely be achieved since the machines will do the job automatically.

B. Problem Statement

Modulator is a part of air conditioner system. It is made from aluminum. Figure 1 shows us the picture of modulator and its dimension. The process of producing a modulator consists of: load the material, cutting and washing, drying, finishing. This device is doing the automation on washing and drying parts using PLC to control the system. Not only realize the automation on washing and drying, this device is improves the time needed to produce one modulator becomes faster using feedback control system. The illustration of the automation device is shown on the Fig 2 below.

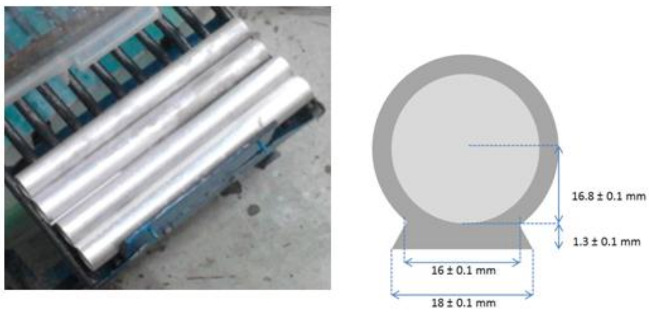

Fig.1. Modulator and its Dimension

Fig.2. Automated Modulator Washing Device

This automated modulator washing system is a development from an existing modulator washing system.

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The existing system is a conventional one where the washing and drying processes of modulator's production obligating a direct human's intervention or necessity of man power to perform the washing and drying processes.

Therefore, we believe that by introducing the automated modulator washing system, a necessity of man power in the process of washing and drying modulator as a process in manufacturing modulator can be avoided. Indeed, we are able to design an automated washing system controlled by a Programmable Logic Controller (PLC). We also propose a new technique involving concept of feedback control system applied to improve the system's performance.

II. LITERATURE REVIEW

A. Ladder Programming Language

Ladder programming language is a programming language for programming a programmable logic controller. The language visualization is looks like a ladder hence the name is ladder programming language. To have a quick understandable about the language, we can see Fig 3. This programming language is used to program the hardware aspect of the automated modulator washing device's controller.

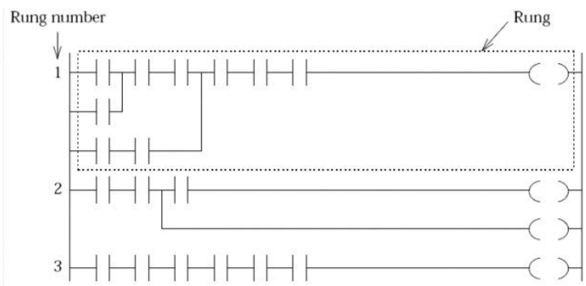

Fig.3. Ladder Programming Language

To operate the controller, we may assume that the automated modulator washing system is a process block shown in Fig. 4. A process block will require aspect of input and aspect of output. In the ladder programming language, an input means a signal input which will be processed by a controller in order to obtain certain characteristics of result generated by the automated modulator washing system.

In this ladder programming language, we can state the input as many as we want, but for the output it can only be one on the right side. We cannot state another same output on other line since the controller cannot understand it, but we can use the output as an input too by utilize the memory function. Based on the reality, an input can resemble the output of a certain sensor. A signal from a sensor can be used by the automated system as an input to generate a certain signal as an output by processing the input by the system's controller.

B. Feedback Control System

Control system is interaction between components which form a system that will produce a system response. Cause-effect relationship of the components can be used to analyze the control system. A component of the system that wants to be controlled can be represented by a block, as shown in Fig 4.

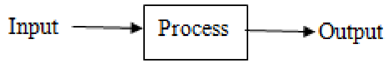

Fig.4. Process Block [RCD08]

The cause-effect relationship is represented by the input-output relationship of the process, meaning the input signal is processed to produce an output signal variable. An open-loop control system has controller and actuator to obtain the desired output or response, as shown in Fig 5. An open-loop system is a system without feedback.

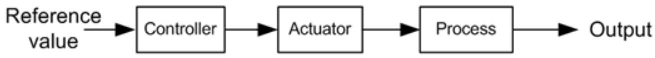

Fig.5. Open Loop Control System [RCD08]

Beside the open-loop system, there is also a contrast system to open-loop system, called closed-loop system. The closed-loop system utilizes an additional measure of the actual output to compare the actual output with the desired output. The measure of this actual output is what we called feedback signal. Simple closed-loop feedback control system is shown in Fig 6.

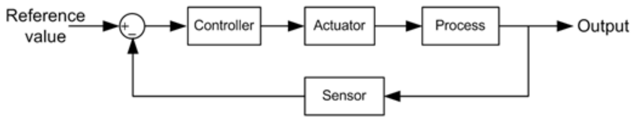

Fig.6. Closed Loop Control System [RCD08]

A feedback control system is a control system that tends to maintain the output approach the desired input by using the difference between the output and the desired input as a means of control. To get a good approximation of the actual output of the system, an accurate sensor is a must. In this project, the system is open loop for the general process, but to produce the lead time the system used is the non-linear closed loop system.

We implemented the concept of open loop control system shown in Fig 5 to the automated modulator washing system. Moreover, we proposed another technique which has been applied to enhance the performance of our automated modulator washing system from the aspect of time needed to wash and dry a modulator. This technique, implementing the concept of closed loop control system, will occupy a certain sensor as shown in Fig 6 in order to feed the output signal back to the controller.

C. Programmable Logic Controller

Programmable Logic Controller (PLC) activates its output terminals in order to switch devices on or off. The decision to activate an output is based on the status of the system's feed-back sensors and these are connected to the input terminals of the PLC. The decisions are based on logic programs stored in the RAM and/or ROM memory. They have a central processing unit (CPU), data bus and address bus. A typical unitary PLC is shown on Fig 7 [DJD14].

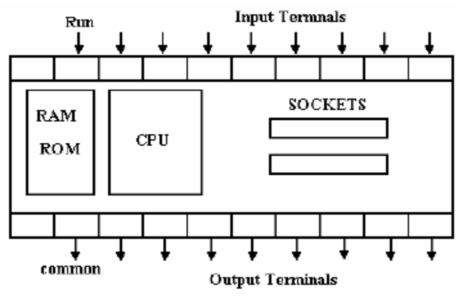

Fig 7. PLC Diagram [DJD14].

The Fig 8 shows a very oversimplified diagram of the structure. The Central processing Unit controls everything according to program stored in the memory (RAM or ROM). Everything is interconnected by two buses, the address bus and the data bus (shown as a single red line). The system must be able to communicate with external devices such as programmers, display monitors and Analogue/Digital converters [DJD14].

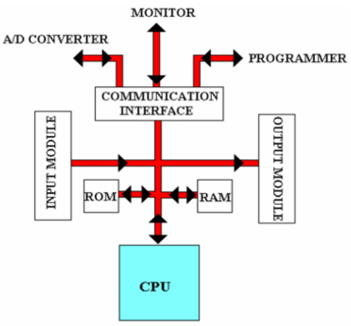

Fig.8. Oversimplified PLC Diagram [DJD14]

Ladder programming language used in this work for configuring the PLC-based controller, shall be uploaded to the PLC using a certain unit of programmer as depicted in Fig 8. The program which function to run a certain task, will be stored in a certain memory of PLC, and normally ROM is used for storing the program. Later, CPU of PLC will update status of input based on the configuration written to the ROM, execute process, and generate output. The organization of PLC's peripherals can be also seen from Fig 8.

A. Design of the Device

Automatic modulator washing devices consists of several parts. They are: entrance (A), washing area (B), rear area (C), and exit Area (D). The part's illustration of the devices is shown in Figure 9.

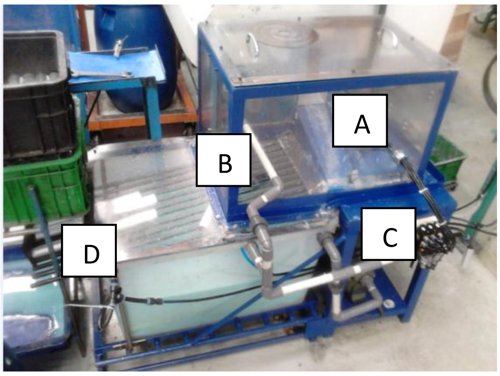

Fig. 9. Parts of the devices

There are 3 unique parts available in the device:

- Water and Wind Output (located at washing area)

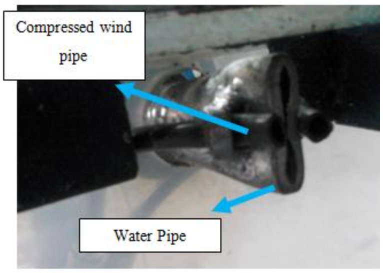

Fig.10. Water and Wind Output

- Pusher (located at the entrance)

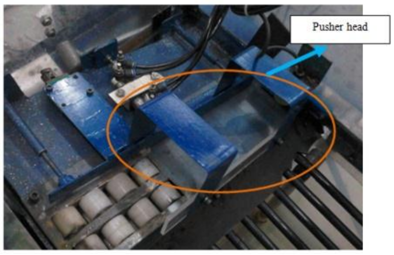

Fig.11. Pusher

- Stopper (located at the washing area)

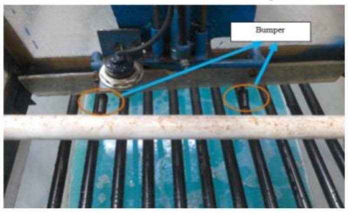

Fig.12. Stopper

- Conveyor and the entrance

(a) (b)

Fig.13. (a) entrance; (b) conveyor

B. Circuit Diagram

Fig. 14 shows us the circuit diagram used in the design. The design uses relay for the water pump and wind solenoid valve since the input for both of them are 220 VAC.

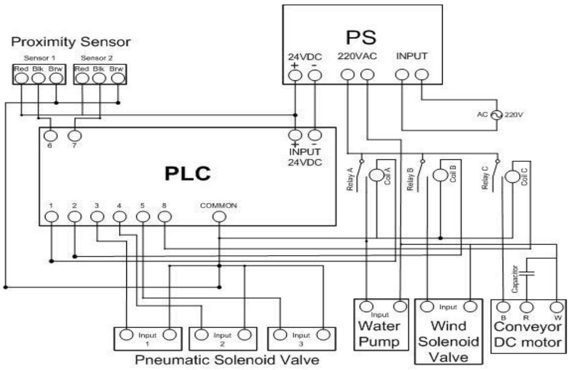

Fig.14. Circuit Diagram

For safety reason, the pneumatic solenoid valve should use relay also, but since the input is 24 VDC the relay is not too necessary also for saving the cost. It is clearly shown in Fig 15, for the pneumatic solenoid valve the connection consists of two pins: one to the common of the PLC and one to the pin which assigned at the PLC.

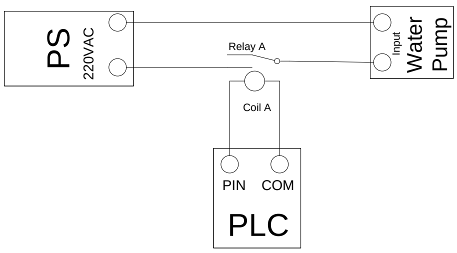

Fig.15. AC Component Circuit Diagram

The connection for the induction motor of the conveyor is slightly different with the other component which uses AC power by the present of capacitor. The capacitor is needed to make the current at the stator of the induction motor stay at the same direction. It is shown in Fig 16.

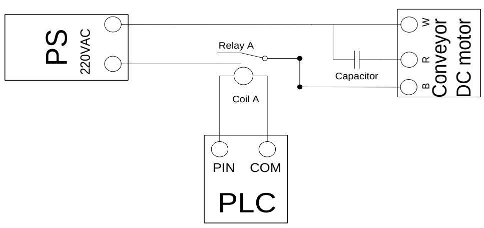

Fig.16. Induction Motor Circuit Diagram [RCN14]

The proximity sensor consists of three pins: red for 24VDC+, brown for common of the PLC, and black for input pin. The circuit diagram is shown in Fig 17.

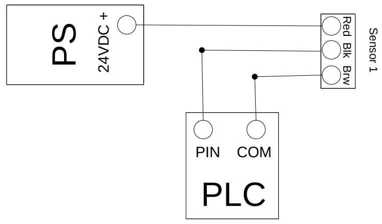

Fig.17. Sensor Circuit Diagram [AUTO]

C. Flowchart of the system

The system has been developed using ladder programming by implementing the flowchart of the system. The following is the legend for the flowchart:

S1 = Sensor 1	Tp = Timer process
S2 = Sensor 2	Pn1 = Pneumatic 1
C = Counter	Pn2 = Pneumatic 2
Twr = Timer Water	Pn3 = Pneumatic 3
Tw = Timer Wind	Cv = Conveyor
D = Constant	

The flowchart itself is shown in Fig 18 below.

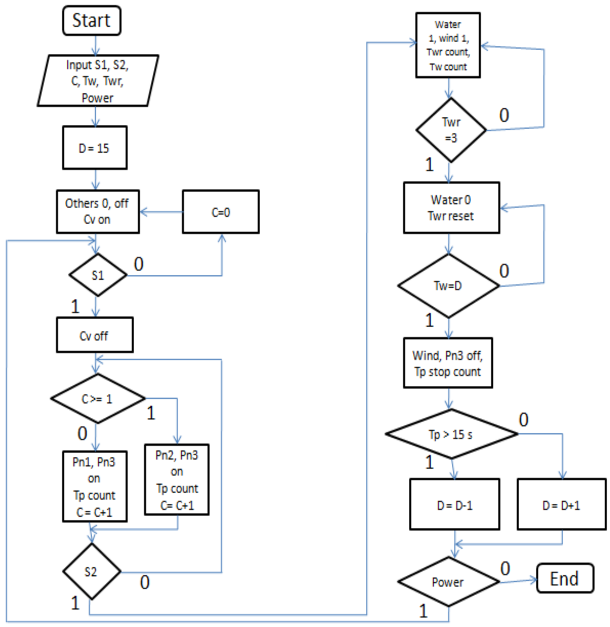

Fig.18. Flowchart Diagram [AS13]

The flowchart can be stated based on these steps:

1. The Input is sensor 1, sensor 2, counter, and timer. The output is pneumatic 1, 2, and 3, the water, the wind, and the motor.
2. At the start process all of the input is set to value zero and the output is on off mode. The time for the wind is set to be 15 seconds.
3. The conveyor will be on to deliver the modulator towards the entrance.
4. If sensor 1 read the material then the pneumatic 1, 2, and 3 will push according to the value of the counter. While pushing the process timer will be on to

measure the time consume for one modulator. The conveyor also will stop.

5. If the value of the counter is equal to zero, only pneumatic 1 and 3 will be on. If the value of the counter is equal to one, only pneumatic 2 and 3 will be on.
6. If the pneumatic 3 is on, the counter value is added by one and the water will be on.
7. When there is a reading on sensor 2. The water and wind will be on.
8. If the count of the water timer reaches 3 s, the timer will reset, the water will off, but the wind still on.
9. If the count of the wind timer reaches 15 after it is reset, the wind will be off and pneumatic 3 will be off too.
10. The time from process timer will be taken and processed to determine the wind timer.
11. If there is no read in sensor 1, the counter will be set to zero value, and then all of the input and the output will be set to 0 values or off mode.

III. DATA RESULTS

A. Feedback Analysis

A controller has the ability to get feedback from the environment due to the existence of a sensor. In the design, the feedback is the lead time or the time to process one piece of modulator.

Here, the definition of the lead time is the time measured from the modulator entering the end of the entrance until it leaves the washing and drying area. The controller has to pursue 15 s for this process. Since there are areas which the time is uncontrollable, the design cannot pursue the 15 s using open loop system. Controllable time and uncontrollable time is shown on Fig 19.

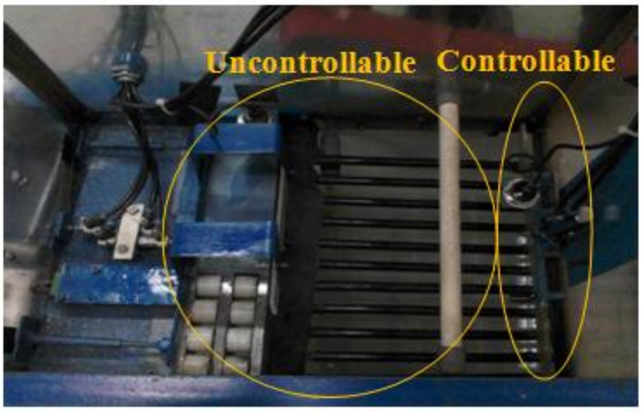

Fig.19. Controllable Time and Uncontrollable Time

$$T_p = T_f + T_x T_p = T_f + T_x \qquad (1)$$

$$T_f = \begin{cases} T_f = T_f - 1, T_p > 15\ s \\ T_f = T_f + 1, T_p < 15\ s \\ T_f = T_f, T_p = 15\ s \end{cases} \qquad (2)$$

Let T_f equals to controlled time, T_x equals to uncontrolled time, and T_p equals to lead time. The relation of this variable is shown on the equations below.

The initial value for the compressed wind is set to be 15 s. The controller will measure the time for the design to process one modulator. Based on (1) and (2), T_p will be compared with the standard time 15 s. If it is less than 15 s, the T_f will be increase by 1 s. If it is greater than 15 s, the T_f will be decrease by 1. This process will run continually until it reaches a steady state.

B. Feedback Data Result

The data in Fig 20 is taken for 27 samples of producing the modulator using the timer inside the controller monitored via the ladder language program for LG.

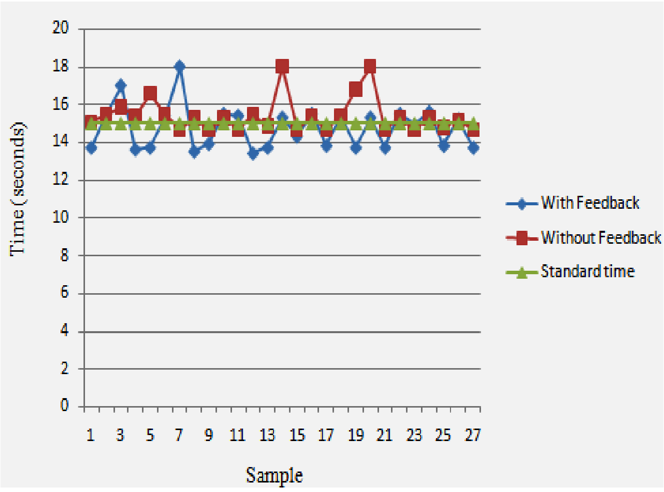

Fig.20. Graphics of lead time result

The system with feedback is tends to go up and down more than the system without feedback. It occurred because the system with feedback always repairs its data due to the feedback received by the system. For example, the data number 5 is 180 and the data number 6 is below 140. Clearly, because the data taken is 180, the next process will decrease the time and reached the number below 140. But, it takes sometimes to reaches the stability than the system without feedback.

Table 1. Lead Time Data

Data	Feed Back (s)	Without Feedback (s)	Standard time (s)
1	13.7	15.1	15
2	15.5	15.5	15
3	17	15.9	15
4	13.6	15.4	15
5	13.7	16.6	15
6	15.4	15.5	15
7	18	14.7	15
8	13.5	15.3	15
9	13.9	14.7	15
10	15.5	15.3	15
11	15.4	14.7	15

12	13.4	15.5	15
13	13.7	14.9	15
14	15.3	18	15
15	14.3	14.7	15
16	15.5	15.4	15
17	13.8	14.7	15
18	15.4	15.4	15
19	13.7	16.8	15
20	15.3	18	15
21	13.7	14.7	15
22	15.5	15.3	15
23	14.9	14.7	15
24	15.6	15.3	15
25	13.8	14.8	15
26	15.2	15.2	15
27	13.7	14.7	15
Average	14.740741	15.43703704	15

Although there are stability factor on system with feedback, it produces a better performance at average. From the 27 samples in Table 1, the average time in for system with feedback is 14.74 ms, meanwhile, the average time for the system without feedback is 15.44 ms. The system with feedback gives a better performance at average although it has some instability.

IV. Conclusion

The automation for the washing and drying process of modulator can be done by utilizing industrial components and PLC to control it. Also, There is improvement on the system when feedback control system being applied compare to system without feedback. The improvement is the average lead time is faster for the system with feedback controller.

Acknowledgement

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