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DESIGN AND SIMULATION OF PLC AND HMI -BASED CONTROL AND MONITORING SYSTEM OF COMPRESSED AIR APPLICATION IN A PINEAPPLE CANNERY INDUSTRY

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ABSTRACT

Energy Conservation or ENERCON is the main concern of every industry today. With the advent of new technology installed in the process line, the need to address the conservation of applied energy such as steam, water, electricity, and compressed air are still the core to run an industrial plant. The use of compressed air as a blower is widely used now a day for several benefit compared to running the blowing system with the motor. The system presented in this study is used to automatically switch off the compressed air that serves as a can top blower before printing whenever there are no can detected in the conveyors in a pineapple cannery industry. The cutting off of the compressed air used will result in significant saving in the plant-wide drive on conserving energy. The hardware composition, control system design, software application and simulation of the Programmable Logic Controller (PLC) and Human Machine Interface (HMI) - based monitoring and control system of compressed air are present in this work. The system's main components are PLC, HMI, Inductive sensors and Directional valves. This paper focuses on the application for a pineapple manufacturing plant but not limited to the compressed air application but for all the industrial utilities mention above.

Keywords: programmable logic controller (PLC), human-machine interface (HMI), energy conservation (ENERCON), motion sequence diagram (MSD).

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1. INTRODUCTION

The compressed air system is one of the most widespread applications of energy use in the industry nowadays due to various factors such as good transportability, safety, purity, cleanness, storability and easy use [1]. However, a compressed air system is one of the most expensive forms of energy. It is estimated that only 10-30% of the input energy reaches the point of end-use [2]. Energy is lost as heat, leaks, drop pressure, inadequate uses, amongst others [3]. The most common cause of energy loss is the inadequate usage of compressed air in an industry. In industry, there is an existing misconception that compressed air is inexpensive, encouraging its inappropriate use and causing a decrease in efficiency between 2% and 3% [4]. Some examples of such uses are, open blowing, atomizing, padding, dilute-phase transport, dense phase transport, vacuum generation, personnel cooling, cabinet cooling, vacuum venturis, among others [5] The compressed air should only be used if it results in significant improvement in terms of safety, productivity, labor reduction, enhancements or other factors [6]. Blow-off applications using compressed air are common [7], and the compressed air used for them is costly. With this scenario, many plant practitioners and experts are studying ways to be able to save energy on this area. Many of these systems have used less compressed air using high-efficiency nozzles or blowers. High efficiency nozzles are typically easy and inexpensive to implement by adding a nozzle where there is presently a standard nozzle or an open tube, and the savings can be significant, however, the issue of continuous blowing is still present, hence, contributing to energy wastage. Further, the compressed air use can be eliminated entirely in some cases by using a blower that is motor-operated. This offers greater savings than compressed air nozzles and preserves system capacity; however, it requires effort and expense to implement.

One typical industry that relies heavily on compressed air application in its operations is the pineapple cannery industry. In Figure-1, the complete process flow of the pineapple cannery operation situated in Northern Mindanao, Philippines is shown. This company is one of the country's leading manufacturers of pineapple canned products catering to both the local and foreign markets.

This study focuses on the filled can air blowing before printing as indicated by the dashed (blue)- box in the figure.

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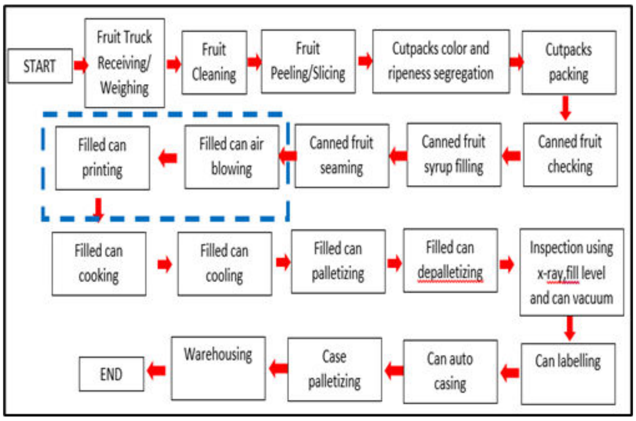

Figure-1. Pineapple cannery process flow (dashed box: the focus of the present study).

As depicted in the figure, after seaming the can, it will pass to a printing machine to have it printed with the designated day mark and variety code. With the current situation and operation of the cannery on the steam usage, relative humidity, and condensation during operation, there are some particles such as water and moisture that will go to the top portion of the can were the printing operation is happening. As a result of this, the printing operation is directly affected because ink jet printing is a very precise droplet of ink going to the top portion of the can and when this goes with the moisture and water present on that area, it will cause poor print quality, or worst, will result to blurred printing. Though this issue might not affect the quality of the product inside the can, however, it will surely affect the exact identification of the product through variety code. In addition, it will also affect the monitoring of the expiry date of the product through the day mark.

Moreover, such an issue on printing will become very critical if the product is exported overseas, considering that recipient countries such as Japan and European countries are very strict in terms of can day marks. Once there are significant issues observed from their ends, these will become grounds for them to return all the products purchased from the pineapple canning company. This is presently addressed by the company by providing a pneumatic hose 8mm in diameter with 4 to 5 bars of pressure. The hose will continuously blow air to the top portion of the can, hence, ensuring that all the particles, moisture and water are blown out before printing, thus avoiding any issues on printing. With this existing practice, possible printing issues and concerns might be eliminated; however, the continuous blowing of compressed air to the can will surely pose related concerns to the company. Continuous blowing of compressed air from the compressor even if there are no can present is surely an issue to the company. Such a situation is not a good setting as far as energy efficiency and energy conservation of the company are concerned. This is both true to electricity usage in operating the compressor and the cubic foot per minute cost of compressed air produced.

The current setting of installing a pneumatic hose above the conveyor of the seamed can before printing continuously introduces compressed air to the can, resulting to air waste production. Moreover, such a present setting results to continuous operation of the compressor which may lead to electricity waste production as well as issues on wear and tear of compressor parts due to non-stop operation of the compressor's motor. Aiming to address the issues mentioned related to energy conservation and efficiency, the present study designed and simulated a Programmable Logic Controller (PLC) and Human Machine Interface (HMI) - based system that is capable of automatic control and monitor in of compressed air application during printing of cans. With this control and monitoring system of compressed air, air will be supplied once cans are detected in the conveyor. If no cans are detected, the system will automatically shut off the supply of compressed air.

Figures 2 and 3 show the present status of air blowing system and the proposed PLC and HMI–based control and monitoring system of compressed air, respectively. With the present air-blowing system, compressed air is continuously supplied even if there are no cans present in the conveyor. This situation of NO can occur during break times (typically, at two hours per day) as well as during scheduled and unscheduled breakdowns in the production line. On the other hand, with the PLC-based control system, it can automatically detect the presence of can in the conveyor, thus, supplying a compressed air and once no can is detected, the system will automatically shut off the supply of compressed air. Such an initiative of providing a smart and state-of-the-art control system that can control and monitor the usage of compressed air will surely contribute to the energy conservation effort which is a priority program of the company.

2. METHODOLOGY

2.1 System Designing

System designing covers and addresses the gap between the main problem and the solution system in a manageable way. This part of the designing addresses the question of how to implement solutions and what are the needed operation in the process.

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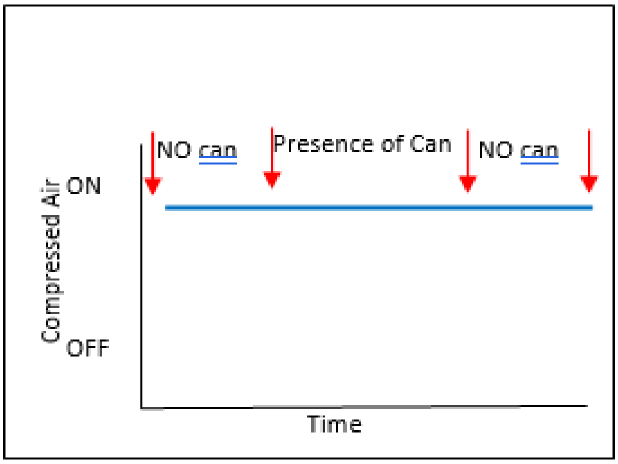

Figure-2. Present compressed air blowing.

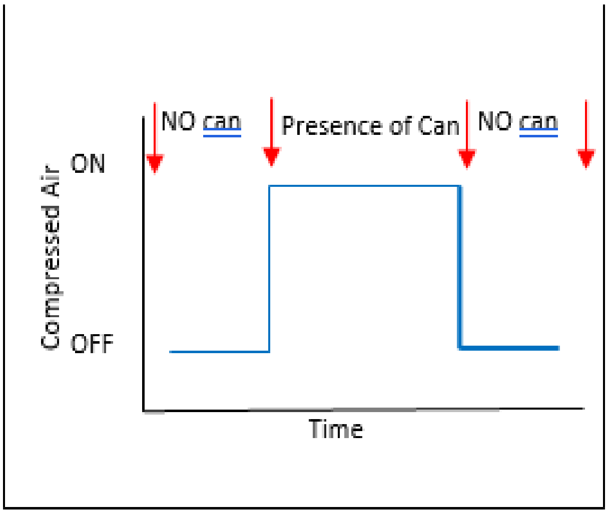

Figure-3. Simulated PLC and HMI - based control and monitoring system of compressed air.

The complex activity of the system development is represented by different processes through the box representation and results to a process flow. Each box created represents input, output, controller (processor) and display, which is now called the PLC and HMI-controlled Automatic Air Blower process flow. Likewise, the process flow representation is converted to Schematic diagramming to help understand the system in technical aspect. The Schematic diagram in this procedure is a graphical representation of the entire system taken from the standard symbols of Piping and Instrumentation Diagrams or P&ID.

2.2 Hardware and Software Design and Simulation

2.3 Motion Sequence Diagram (MSD) Design

MSD is one of the most important parts in designing the program of the entire system. This is the first step to undergo in programming since it symbolizes a timeline that activates starting from the top and going down to mark the sequence of interactions. This is the visual layout of the movement of the system converted to the software application. This MSD design provides the overview by using letters and symbols which represent the flow and series of the system.

2.4 Programmable Logic Controller (PLC) Hardware and Software Design and Simulation

A PLC is an industrial computer consisting mainly of hardware and software that is used to control a machine or a process [8]. The PLC is the core of the system and is responsible of the following tasks: (i) Receive signal from the field instruments which is the inductive sensor and will analyze these data to be able to decide if the system will provide output as compressed air; (ii) provide output signal 24vdc to the solenoid coil to be able to allow the flow of compressed air which will result in can air blowing; and, (iii) provide data to be displayed in the Human Machine Interface(HMI) in terms of time which is likewise computed in total compressed air usage, equivalent to monetary value in terms of Peso.

2.5 Human Machine Interface (HMI) Hardware and Software Design and Simulation

A Human Machine Interface (HMI) is a user interface or dashboard that connects a person to a machine, system, or device [9]. Designing and simulation for the Human Machine Interface (HMI) is also done in both hardware and software, as with the PLC. The design of HMI hardware is based on the estimated number of components to be displayed on the screen. This means that the higher the number of design lines to be displayed, the larger the size of the screen display is needed. The hardware simulation for HMI is connected to the identified software used. The hardware and software of HMI is connected to the communication link in which interchanging of data simulation takes place.

2.6 Sensor Design and Simulation

Sensor design covers the needed sensors parameters such as sensing coverage, PNP/NPN type, sensor type, face diameter, diagram connection based on PLC module use and the power supply rating requirement to activate. On the other hand, simulation of the functionality of the sensor refers to the signal received in PLC during triggering action. This step also explains the schematic diagram of the sensor used and how it is connected to the PLC input module.

2.7 PLC and HMI Program Simulation

After designing and simulating the programs of PLC and HMI, the need to simulate the connection link, input, and output of the two areas must be confirmed and validated. With the input and output already integrated to the PLC, the system can be simulated using triggering materials. In this study, any inductive materials such as tin cans or metals can be used to check the functionality of its operation.

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3. RESULTS AND DISCUSSIONS

3.1 Design of the System

Figure-4 shows the entire process for system Controlled Automatic Air Blower. The idea eliminates the compressed air waste during break time of the line including unscheduled downtime where no can is passing to the conveyor going to printer. The presence of can is sensed in the line and then switch ON the valve for can blowing but if there are no can passing it shut off the valve, thus eliminating the compressed air wastage. Figure-5 shows the Schematic Diagram from PLC, HMI, Sensors (input) and Directional valve going to Air Knife. The 30mm inductive sensor is installed in the guide of conveyor open to the detection of can passing to the conveyor. The signal coming from this sensor serves as the input to the Programmable Logic Controller. Then the 3/2-way directional valve operated by the solenoid coil is installed near the printer with the 6mmX1/4 NPT fittings with pneumatic hose installed just above the can passing to the conveyor to blow the particles or water and moisture accumulation. On the other hand, the PLC and HMI are installed in centralized panels away from the area to ensure isolated control and free from water penetration. The centralized panel has an input signal coming from the line going to the solenoid coil of the directional control valve.

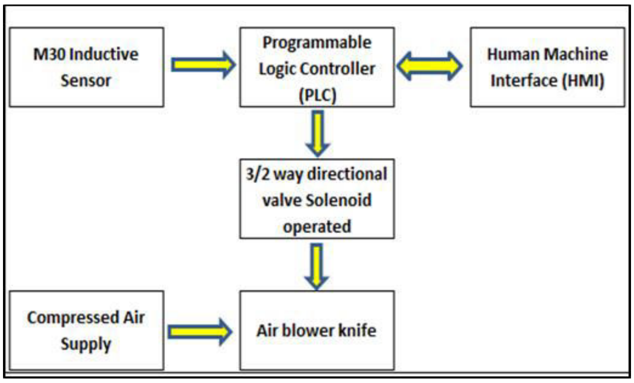

Figure-4. Process flow for the PLC and HMI - controlled automatic air blowing system.

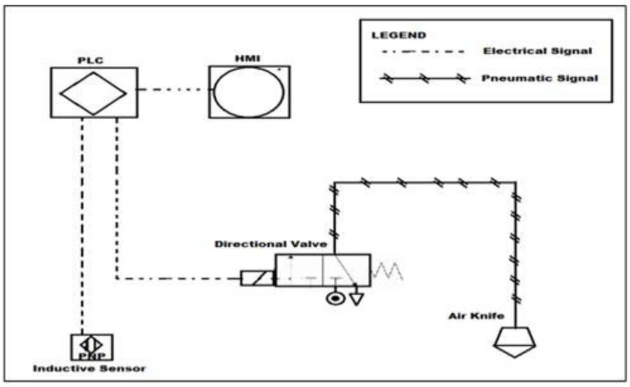

Figure-5. Schematic diagram of PLC-based automatic air blowing system.

The triggering of the sensor means that there is can pass and thus, will energize the coil. Once the sensor is not triggered, it will de-energize the coil thus shutting down the valve. Such ON/OFF status of the valve are recorded in PLC and are displayed in the HMI. The interface includes the status of the valve, the OFF time of the valve, the accumulated time the valve is shut off and the volume of compressed air saved converted in monetary value (in Philippine Peso).

The needed materials and devices for these systems are as follows: directional valve 3/2 way solenoid operated, 6mm pneumatic hose; 6mm X ¼ NPT fittings; 24Vdc solenoid coil; Belden cable; Programmable Logic Controller (PLC); Human Machine interface (HMI); Inductive Sensor 30mm face diameter; and, Air filter regulator.

3.2 Hardware and Software of the System

3.3 Motion Sequence Diagram (MSD)

The Motion Sequence Diagram is used to design the ladder program via the Programmable Logic Controller. The sequence and triggering of the operation are the corresponding outputs of the design, making the programming easier to build. Figure 6 shows the design and simulated sequence through Motion Sequence Diagram. In this design and simulation, "A" represents the solenoid coil for the directional valve and "B" the signal to start data logging. Here, A+ means that the valve is activated, thus allowing the flow of compressed air while A-, on the other hand, means that the valve is switched off. Moreover, B- means that the data logging of conserved compressed air is not activated, since the valve is switched ON and blowing. On the other hand, B+ signifies that the data monitoring on air blowing is activated since the valve is switched OFF.

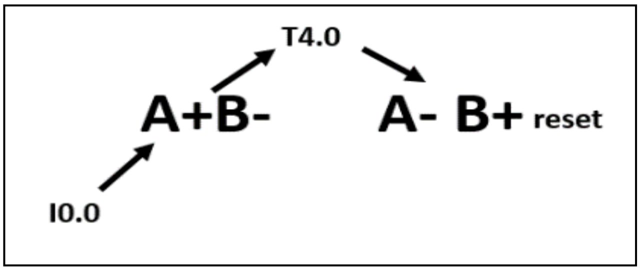

Figure-6. Motion sequence diagram.

3.4 Programmable Logic Controller (PLC) Hardware and Software

The designing and simulation of the PLC are divided into software and hardware domains. In the design and simulation of the hardware, the study prioritizes the availability of the hardware components such as central processing unit, I/O modules, and power supply. After designing the PLC, simulations for both hardware and software are paralleled to each other, wherein, the hardware arrangement is simulated with the software

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application. This also includes simulations of the input and output modules using the identified software.

In this study, an Allen *Bradley SLC500 PLC* is used which is configured in *RSLogix 500* software in building up codes in ladder programming style. Table-1 shows the hardware specifications used in the system. In Figures 7 and 8, the hardware and software images are shown. The designing of the PLC program in this system included the use of different instructions such as Examine If Closed (EIC), Examine if Open (EIO), Timers, Move and Computation to be able to come up with the desired sequence of operation.

3.5 Human Machine Interface (HMI) Hardware and Software

In this study, the *PanelView Plus* device for HMI is used and the programming codes are initiated in *Factory Talk View* application. Both the PLC and HMI are connected to RS link communication via internet cable. Monitoring and operator intervention to control are accessible through HMI. Instruction buttons, tagging and codes are used to design a user-friendly screen for easy access to the system. The designing of HMI is composed of an integrated and interactive development environment that primarily develops graphical user interfaces and to connect them to Programmable Logic Controller for clear access to real-time activity inside the controller. Multiple buttons, displays and output monitoring have been conceptualized to the screen of the HMI. The *Panel View Plus 2711-PRP8A* with 12 inches screen display is used including touch and keypad application for more effective monitoring and screen transition. Figure-9 shows the actual image of the Human Machine interface including the *FactoryTalk View* software use in the designing and simulation.

Table-1. PLC specification and catalog number.

Type	Description	Catalog number
Processor	SLC5/05 Processor Unit	1747-L552
Input Module	SLC 500 Input Module DC-Sink	1746 - IB16
Output Module	SLC 500 Output Module DC-Source	1746-OB16
Power Supply	SLC 500 Power Supply Module	1746-P3

Figure-7. Hardware Designing of Allen – Bradley Programmable Logic Controller.

Figure-8. Software designing of Allen - Bradley programmable logic controller.

3.6 Input Sensor

The designing of the sensor used in the system have three (3) main categories. The first category is the signal type. Since the 1746-IB16 input module of the Allen- Bradley PLC is used, the 3 -wire PNP type of sensor is likewise utilized. PNP sensors produce a positive output to our industrial control input [10]. A simple operation for PNP type is that the negative voltage must be applied to the base pin to allow current to flow from emitter to the collector lead. The load being controlled is wired between the collector and the ground thus allowing flow of positive supply to the PLC module during activation or triggering.

Figure-9. Hardware and Software of Allen - Bradley Human Machine Interface (HMI).

The second category is the range of detection. Since the system is designed to detect#10 or Galloon can size, a M30 (30mm) face diameter sensor is used to ensure wide coverage of can side detection during operation. The sensor is designed in such a way that the wider the face diameter the wider is the range of detection. The last category is the triggering application. Since a tin can running in a conveyor will be detected, the sensor used is an inductive type that detects all metal in the line. In Figures 10 and 11, the diagram and image of an M30 inductive sensor are shown, respectively.

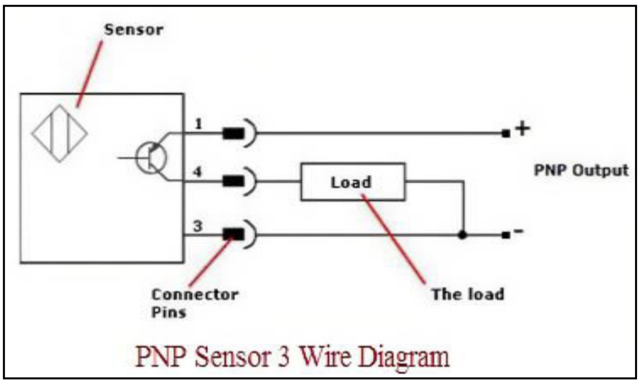

Figure-10. M30 Inductive sensor diagram.

Figure-11. M30 Inductive Sensor actual image.

3.7 Simulation of Program of PLC and HMI

To successfully install the system to the production line, simulation both the program of Programmable Logic Controller (PLC) and Human Machine Interface (HMI) have been conducted. Since an M30 inductive sensor is used as input signal to start the sequence, this can be simulated by triggering the sensor with any metals. Indicators that the system is already starting are the control output signal for the solenoid coil of directional valve which open and close the supply of compressed air and other indicators of the accumulated time of compressed air supply savings which can be seen in the Human Machine Interface. Table-2 shows the step-by-step result of the PLC and HMI program simulation.

Table-2. PLC and HMI program simulation results.

Triggering Metal (in actual run this will represent the cans passing)	Time (in minutes)	Control Output (Solenoid coil for the Directional valve)	Accumulated Time (savings displayed in HMI in minutes)
(STEP 1) Can presence	5	Energized	0
(STEP 2) NO Can	5	Not Energized	5
(STEP 3) Metal is Present	5	Energized	5
(STEP 4) NO Metal	10	Not Energized	15
(STEP 5) Metal is Present	10	Energized	15
(STEP 6) NO Metal	5	Not Energize	20
(STEP 7) Metal is Present	10	Energized	20
(STEP 8) NO Metal	10	Not Energized	30
TOTAL TIME	60 mins	TOTAL SAVED TIME	30 mins

4. CONCLUSIONS AND FUTURE STUDY

This work describes the design and simulation of an automatic Energy conservation (ENERCON) initiative that aims to contribute to the goal of every organization in energy management. The system is basically operated and controlled by the Programmable Logic Controller (PLC) and can be monitored using Human Machine Interface (HMI). Through this simple yet effective initiative, the compressed air discharge as blower can be controlled by switching the valve only if needed. In addition, this system offers the following advantages if implemented in real life: (a) save energy and cost by means of switching of the compressed air supply in the can blower when not needed or if there are no cans passing in the conveying system; (b) can accurately read the save time when the valve is switched off thus the savings monitoring is real time and exact; (c) can also save energy through the switching ON and OFF of the compressor unit, which is very critical because the cutting IN of the compressor unit during continuous usage of compresses air is very important, the equivalent current use for motor start-up have also equivalent monetary value which can also be saved through this system; (d) can also save runtime in hour for the compressor unit; and, (e) can ensure accurate blowing of cans before printing through the automatic system installed.

For future works, this system can be applied to other utilities as this is not just limited to controlling and monitoring savings for compressed air. It can be incorporated to other utilities used in the organization such as steam, water and heaters. Moreover, it can be integrated in much wide data storage for further evaluation of data. The integration of the data to the cloud is also possible in the future study.

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