Academic Journal of Nawroz University (AJNU), Vol.13, No.1, 2024
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https://doi.org/10.25007/ajnu.v13n1a1766

Designing a PLC-based Bottle Filling Machine with Conveyor System and Reduced Filling Time Using Ladder Logic

Rafid Salih[1], Shelan Kamal[2], Emad Adil[3] and Mohammed Ameen[4]

1 Electrical and Computer Department, College of Engineering, University of Duhok, Duhok, KRG - Iraq
2 Energy Engineering, Duhok Polytechnic University, Iraq
3 Information Security Department, IT Directorate, University of Duhok, Duhok, KRG – Iraq
4 Electrical and Computer Department, College of Engineering, University of Duhok, Duhok, KRG - Iraq

Abstract

The objective for this scientific paper is to build and design a bottle filling machine by using Allen Bradley Programmable Logic Controller (PLC) with Pro-face Human Machine Interface (HMI). In this research, the PLC with HMI is used to introduce a cup filling machine.

The PLC based controller in automation industry. The primary concept for the study is to design and fabricate a filling system by utilizing PLC. The cup is moved via a belt conveyor by using DC Stepper Motor. When the cup reaches the sensor, it will stop and the sensor will give instructions to the valve that controls the flow of the water. The position of the bottle is identified through the use of laser sensors so that the pump can operate when it is needed. The PLC used in this framework could be the Micrologic 1400 which makes the framework more adaptable and simpler to operate. When the bottle is beneath the tank, the pump starts, filling it with water. This filling device is inexpensive and can be utilized in bottle filling systems for small businesses like tea shops, milk industries, and any other liquid manufactures. In this work, only three sensors are required, and no additional pumps are needed. The pulse is created in the flow sensor by a time-based controller, and the filling process is completed as a result. It used in a variety of factories to less human effort. So, the results of this work are more reliable. And the most important aim in this research is save the time compare to others needs more components and more time.

Keywords: PLC, Automation, Bottle Filling Machine, conveyor, HMI software and Water Filling.

1. Introduction

Since we live in a continuously fast growing technological world, we need new ways to use the technology to make our lives easier and Programmable Logic Controller (PLC) is a great method to do so as it makes everything automatic which is a great help to humans' daily life.

The term "Automation" refers to using technology to convert a specific process to automatic process which in turns decreases the intervention and support of human work in raising the production.

The only method to create productive factories can be achieved by making them adapt to the development of technology in the world's markets. Based on that, utilizing PLC in the processes and automated machines for different factories will take a step to a new era of manufacturing (Dakre et al, 2015). It has a very necessary and significant effect in the main function in the automation field which resorts to minimizing the complexity, enhance safety and cost performance (AbuSaeed et al, 2012). The procedure of filling is based on the user who defines the size of the liquid by which the user can select the size of the liquid to be filled. The sensor, which is designed in the conveyor, is utilized to sense the bottle that is located under the tank and thus the corresponding tank gets switched on in order to fill the bottle (Savita & Lokeshwar, 2014). In these days, there are plenty of applications in the field of industry, a conveyor system is utilized to transfer products from one place to another in an efficient method to decrease the loss of time, stress as well as being very beneficial in packaging operation.

A conveyor system has many shapes. The research of (Saleh et al, 2017) applied a Flat belt type utilized to transfer the bottles. Conveyors are particularly important in applications that include the transmission of heavy or large materials. The dimension of a flat belt conveyor is about (120*70*30) cm and it is made from flexible material (Saleh et al, 2017). applied one application of PLC to arrange bottles in beer filling production in an automatic line and efficient reference. (Zhang et al, 2012).

In this paper, PLC has also been used as a based control system in an automatic bottle filling station, but we tried to reduce the time which takes to fill the bottles by using ladder language and ladder logic to control the process. Compared to the preceding studies which take more time to fill the bottles, our study focuses on reducing the time of filling process since the reduction of time is very important for the industry to make the productive service quick and efficient at the same time. The other sections of the research are organized as follows: Section II is a description of our proposed device, Section III explains the ladder logic by using ladder language, Section V presents the selection of PLC, System specification is given in section VI. Furthermore, the results have been discussed in section VII and lastly, the conclusion is given in section VIII.

Description of our Proposed device. It is based on PLC automation, which consists of many types of components that are divided into two main parts:

1. Hardware Components of Filling Machine Part

Major components used in this research are MicroLogix 1400 Programmable Logic Controller (PLC), 30V 5A Adjustable, DC Power Supply, Capacitive Proximity Sensor, Belt Conveyor, DC Stepper Motor, NEMA-Tb6600-4A-9-42V-Stepper-Motor-Driver-CNC-Controller, one inch 220V-240V AC Brass Electric Solenoid Valve NPT , Tank, HMI (Human Machine Interface) Screen, Relay, ON/ OFF Push Buttons and LEDs.

In this research, the inputs and outputs are controlled through the use of MicroLogix 1400 PLC. A DC Power Supply is provided an input supply to the PLC. The rating of the Power Supply is 30V DC 5Amps Adjustable. The PLC utilized in this study might be a compact PLC that has settled number of inputs and outputs. In this type of PLC show, the CPU consists of 20 computerized inputs and 12 digital outputs. One diffused Capacitive proximity sensor has been utilized for the situating of the bottles. The belt conveyor is operated by using a DC Stepper Motor engine. The ratings of the DC engine are 12V and 50 RPM speed with a tall beginning torque of 70 Kg-cm (at no stack). Flip switches are utilized to serve as the reason for a few inputs to the PLC.

For the system to be completed and operate efficiently the following components must be included:

- 30V 5a Adjustable DC Power Supply
- The MicroLogix 1400 Programmable Logic Controller (PLC)
- Capacitive Proximity Sensor
- Belt Conveyor
- DC Stepper Motor
- NEMA-Tb6600-4A-9-42V-Stepper-Motor-Driver-CNC-Controller
- 1 inch 220V-240V AC Brass Electric Solenoid Valve NPT
- Tank
- HMI (Human Machine Interface) Screen
- Push Buttons and Leds
- Relay 24V dc

These are the basic components for connecting the system and operating it properly, how each component is presented in detail as follows.

1.1 30V 5a Adjustable DC Power Supply

Figure 1. DC power Supply

This is the power supply used to apply direct current to the system. The output varies between (0-30) V. Set it to 24V here because the whole system works with 24V input. From its functions, it provides constant voltage and constant voltage linear adjustment, voltage, current coarse and fine adjustment, overcurrent protection, overvoltage protection also overheating protection intelligent fan.

The specifications of DC power supply are:

Constant voltage operation
Line regulation: ≤0.05%+1Mv
Load regulation: ≤0.1%+5Mv
Ripple & Noise: ≤10mVrms
Constant current operation
Line regulation: ≤0.05%+10Ma
Load regulation: ≤0.1%+10Ma
Ripple & Noise: ≤20mArms

1.2 The Micro Logix 1400 (PLC)

Figure 2. PLC

A programmable logic controller (PLC) is a digital computer utilized for automation. This is the interface between the program and the input.(Zar and Tin, 2019) [6]. PLC is a Programmable software. For example, a real-time application is used to control various devices. As shown in Table 1, Micro Logix 1400 programmable logic controllers include power supplies, input/output circuitry, processors (CPUs), and various communication ports. Supports 32 discrete I/O points (20 digital inputs, 12 discrete outputs) and 6 analog I/O points (4 analog for inputs and 2 analogs for outputs). As an I/O unit, it represents an interface between the PLC and the real-time system. Additionally, The CPU is responsible for performing all logic and control operations, manipulation work and data transfer, and. Moreover, the automation of the entire process of filling is performed by entering the required conditions into the PLC utilizing ladder logic, which the latter is a method of programming PLCs. consequently, based on the developed logic, different operations are performed and the filling of the cup is carried out. This research uses PLC , This is because it is more convenient. Also, using a PLC allows more flexible and reliable operation. Program changes in PLC ladder logic can be changed very easily as required.

1.3 Capacitive proximity sensor

Figure 3. Capacitive Proximity Sensor

Capacitive nearness sensors work by noticing an alter within the capacitance perused by the sensor, it is utilized to sense the nearness of objects or materials. It depends on the capacity of objects to hold an electrical charge indeed when the question is non-conductive. The alter in capacitance that happens when a question (ordinarily called the "target") approaches the sensor. they can tune out non-metallic holders and can be tuned or set to identify distinctive levels of fluids or strong materials. In our venture the sort NPN nearness sensors are utilized it gives a dynamic Moo yield. This implies that when a protest enters the identifying run of the sensor. The sensor output is associated with the ground. This type of sensor is additionally known as 'sinking' sensor.

Features:

- Output Type: PNP (normally open) 3 Wire
- Detected object material: metal, nonmetal.
- Sensing distance Sn adjustable 0 – 7 mm
- Voltage supply range + Vs 6… 36 VDC
- output current < 200 Ma.

1.4 Conveyor system

Figure 4 Belt Conveyor

Belt Conveyor is a kind of flexible belt that moves objects located on it from one side to another to implement the errand. This belt works by stepper motor.

- Dimensions of conveyor belt
  Length = 140cm
  Width = 21cm

- 3. Dimension of structure
  Length = 140cm
  Width =21cm
  Height =127

1.5 DC Stepper Motor

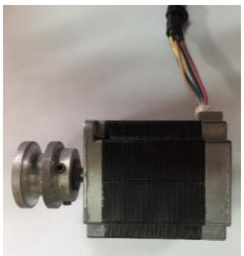

Figure 5 DC Stepper Motor

The DC motor utilities is a DC stepper motor type, and the shaft is connected to the axis of the roller. The input voltage is 24V~48V for this motor and the rated current is 3A. The reason for choosing this motor is the different speeds it produces to rotate the belt. The maximum holding torque is 13kg, providing plenty of torque for your load. The speed of each stepper motor depends on the specifications of the included controller. A typical maximum speed for a stepper motor is 1000 rpm. A stepper motor is a brushless electric motor that can divide one revolution into many steps. A precise control for the rotation of motor can be made without using a feedback mechanism. This is a fixed power device and the increment of torque for the motor is raised as the RPM increases. The stepper driver is used in this project to control this effect, as it vibrates more than the other types of motors that cause noise.

1.6 NEMA-Tb6600-4A-9-42V-Stepper-Motor-Driver-CNC-Controller

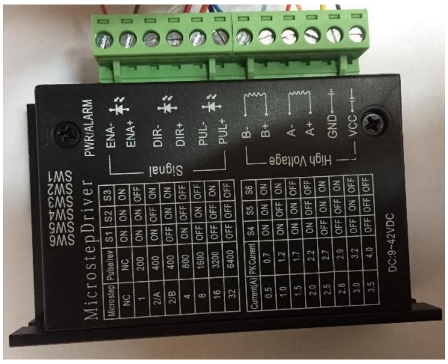

Figure 6 Stepper-Motor-Driver-CNC-Controller

The TB6600 stepper motor driver is a single axis drive and a low-cost micro stepping drive. This is a professional driver which has 2 phases stepper motor driver, supports stepper motor speed and direction control. Microstep and output current can be adjusted with 6 DIP switches.

Input current 0-5A

- Power (max): 160W
- Operating voltage: 9-42V DC
- Output Current: 0.5-4.0A
- Pulse input frequency up to 20kHz
- Micro steps: 1, 2/A, 2/B, 4, 8, 16, 32
- 5V levels input signal
- 200-6400 pulse per revolution
- Suitable for 2 and 4 phase motors
- Over current and over heat protection

1.7 1 inch 220V-240V AC Brass Electric Solenoid Valve NPT

Figure 7 Solenoid Valve (One inch)

Solenoid Valve is an electromagnetic valve, in which through automated opening and closing system, that is used to control various kinds of liquids making it a multitasking device due to the presence of a ferromagnetic core (plunger) which creates a magnetic field exerting an upward force on the plunger to open and close the valve. In this research 1inch valve is chosen for the flow of the liquid to be faster.

The normal operating mode of the solenoid valve is (normally closed). This research is typically utilized to automatically control the flow of water that fills a water cup. When the proximity sensor detects the water cup placed on the first moving belt conveyor, the belt conveyor stops working and simultaneously the electromagnetic valve is energized for a specific duration of time (based on the required time, the timer can be set by PLC programming). After the time elapses, the solenoid valve becomes inactive and juice or liquid no longer flows through the valve. The valve remains off until the conveyor starts moving again and the sensor detects the cups again.

- Operation Type 2-way 2-position direct lift diaphragm
- Operation Mode: Normally closed
- Pipe Size 1" NPT female (11-1/2 TPI) Orifice
- Working Medium: liquid
- Flow Rate Cv = 12
- Diameter: 25 mm
- Flow Direction: Unidirectional (follow the arrow on valve body)
- Media: Water, air, natural gas, propane, butane, petroleum oil, mineral oils, diesel, low viscosity fluid, etc
- Operating Pressure Differential: 0-145 psi (0-1 MPa, gravity-feed capable)
  Electrical:
- Current: 0.1 Amp
- Voltage: 220-240 VAC

1.8 Tank

The purpose of the tank is to conserve and save the water, which in turn fills the plastic cups by solenoid valves on demand.

1.9 HMI (Human Machine Interface) screen

Figure 8 HMI Display Screen

The method that enables the operator to interact with the system is accomplished by using the human-machine interface. HMI is the control panel of controller. Based on that, the present state of the system can be seen and monitored by the operator via the HMI panel. The user can also turn various features on or off from the user interface, view the number of empty and filled cups, and motor speed. Moreover, the operator or user can see and monitor the information concerning the state of processes through the use of application software known as HMI, which the latter also provide the operator with many control commands known as GP-prox.V4.9. Input Voltage is DC 24 V.

- Rated Voltage DC from 19.2 to 28.8 V
- Power Consumption 26 W (max.)
- 2 Serial interfaces (COM1) & (COM2).
- USB Host Interface (USB)
- Ethernet Interface (LAN)
- Power Connector (Socket)

1.10Relay

Figure 9 24VDC OMRON RELAY

The main advantage of relays is that relatively little current is required to operate the relay coil, but the relay itself can be used to control the operation of AC valves.

Type of relay electromagnetic
Switched voltage max. 250 V AC
Switched voltage max. 125 V DC
Contact resistance 100 Mω
Body dimensions 27.94x21.59x36.06 mm
Contact current max. 5 A
AC load rating @R* 5A / 220V AC
DC load rating @R** 5A / 24V DC
Operating temperature -55…70°C

1.11 Push Buttons

Figure 10. Control Panel of Push Buttons

A control panel has many push-button (PB). it has some switches that are used to control the start of the system, its stop, and its direction. These switches work to open and close by pressing and releasing a push button on the switch. The type used in this paper is the (NO) normally open push button which also has alternate operations. When the push button is pressed first, it is held in the same position by an internal locking mechanism. A second press releases the lock and returns the push button to its original position. In this research, there are 6 PBs, each of them having different operations in different modes within the system. The table below shows each push button according to its control action. The system also uses three 24V DC LEDs to indicate the status of whether the system is in manual or automatic mode and to let you know how the system functions in case of an emergency. Pushbuttons LEDs, and selector switches.

- Dimension of control panel

Width =63cm
Length =62cm
Height =62cm

Table 1 push buttons

Push Button Symbol	The Controlled Operation	Operation Mode	Normal Mode
START PB	Motor rotates the belt in clockwise direction	Automatic	NO
STOP PB	Motor stops Rotating the belt	Automatic	NC
⟹ PB	Motor rotates the belt in clockwise direction	Manual	NO

⇐ PB	Motor rotates the belt in anti-clockwise direction	Manual	NO
VLV PB	To open the valve for discharging the tank	Manual	NO
RST PB	To reset the counting of the cups	Manual, Automatic	NO
EMG-STOP PB	To shut down the system in case of fault or	Manual, Automatic	NC

2. Software Part

The programs and the used logics are discussed in the software part. For controlling the systems, there are some programming languages that are used to accomplish this objective:
Block diagram (BD)
Ladder diagram (LD)

In the proposed device, the Ladder Diagram is utilities to interface the ON/OFF button and programing logic. Despite of the presence of various software, using ladder logic in the proposed device was preferable and feasible due to making the programing flexible and intelligible.

III. Ladder Logic

Ladder logic, which is based on mimic relay logic, is the main programing tool used in PLC. This is due to the arduous and complexity of the relay logic and for this reason the relay used in the modern control systems is not used as a logic diagram. Therefore, relay in the latter case is exclusively used as a device implementing magnetic fields to control electrical switches. Relay is used to control the solenoid valve, when PLC DO passes 24V DC to Relay coil, it closes NO contacts, which AC 220V connected through these contacts to the Solenoid valve coil.

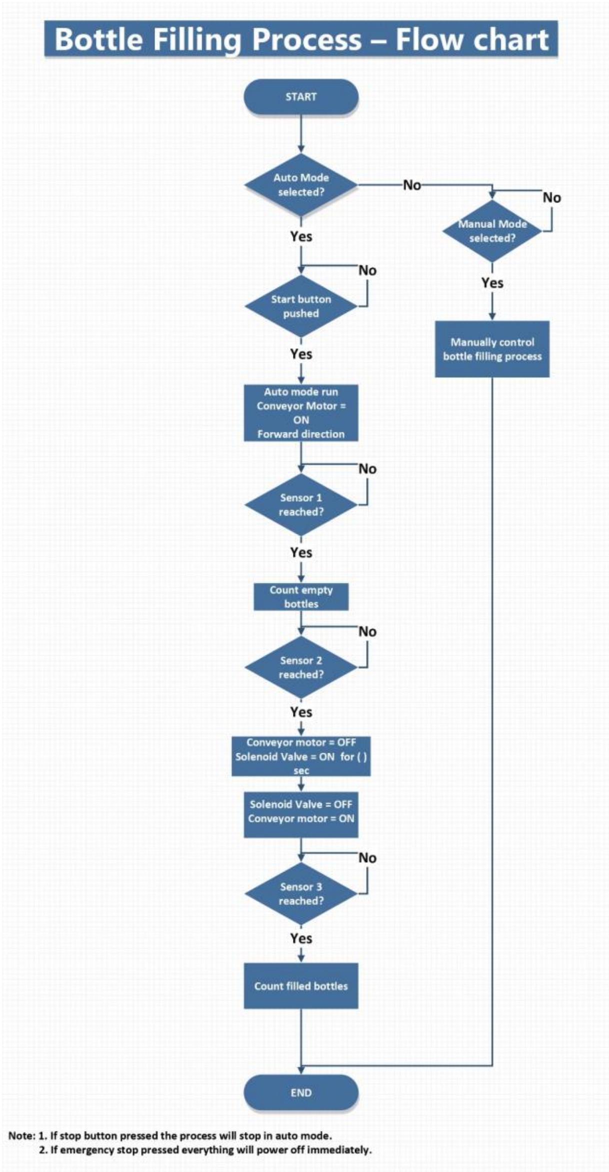

Figure (11) Bottle Filling Process- Flow Char

3. Flow Chart

Pushing the start button ignites the motor enabling the conveyor belt to move. When the start button is pushed the motor starts, hence the conveyor belt starts moving. Having the bottle to be filled under the valve immobilize the motor due to the presence of a sensor which eventually makes the conveyor belt stop. At that moment the bottle is completely filled with water and the valve closes leading to turning on the motor again and mobilizing the belt which in turn carries the bottle away from the valve. The process starts over once another bottle is sensed and whenever the stop button is pressed the entire process stops

IV. Selection of PLC

There are several important factors when choosing a PLC for any application.

- Memory size
- Input and output
- Compatibility to HMI
- System speed
- Easily communicable

Distinctive PLCs have distinctive numbers of I/O ports. In certain instances, adding external I/O cards can increment the number of I/O ports. The current proposed device uses DELTA DVPt-16. Sp which possess 8 inputs and 4 relay outputs. A full program sampling time of 4ms and the memory space is sufficient for automatic bottle filling.

VI. System Specification

- Capacity:4 BPM
- Input: 220 V AC
- Maximum bottle diameter: 4.6′′
- Maximum bottle height: 6.6′′
- Maximum pressure: 200 pascals
- Automatic shut off when bottle is full
- 2 filling Nozzle
- Best liquid will be Water

VII**. Results**

Unlike other researches our machine can fill a bottle in 9 seconds, while theirs fill a bottle in 30 seconds as is referred to the research of (Guha et al, 2020). Also, our filling process is faster than the research of (Saleh et al, 2017) which states that "The water filling machine in this paper can fill up to 5 or more bottles in one minute depend on the size of bottle.". As a result, more than six bottles can be filled within a duration of one minute. Compare to their research that fills 5 bottles in a minute. In this research, only three sensors are required, and no additional pumps are needed. The pulse is created in the flow sensor by a time-based controller, and the filling process is completed as a result. It may be used in a variety of coffee shops, juice bars, and other drink stores professionally to lessen human effort. Therefore, the results of the practical research are quite positive. Understanding the need for PLC in industrial automation and being able to see the value of studying it are additional benefits.

VIII. **Conclusion**

Using automated machines, like the sample mentioned in this study, to increase productivity in developing countries is very important since the requirements of such machines are available and affordable. Furthermore, operating such tool require simple and cheap training of workers to run it productively. Increasing productivity using automated machines play important role in developing economic status of countries because of the mass production system. In the current study PLC is used to control the whole automation system to significantly reduce the cost of the system through efficiently using the device for a long period of time despite the expensive installation fee. Applying PLC based control system on the automated liquid filling station increased the reliability of the system and decreased the period required to produce specific amount of the product. This means the proposed device is more trustworthy and time saver compared to other devices that were used previously.

References

1. Dakre. A., Sayed. G.J., Thorat. E.A. & Chaudhary. A. (2015). " Implementation of Bottle Filling and Capping using PLC with SCADA" International Research Journal of Engineering and Technology, (2)9,2588-2592
2. Abu Saeed, A. U., Al-Mamun, M. & ZadidulKarim. A.H.M. (2012). Industrial Application of PLCs In Bangaladesh. International Journal of Scientific & Engineering Research, (3)6.
3. S & L. (2012). Implementation and performance analysis of bottle filling plant using ladder language. International Journal of Science and Research, (3)7, 1803-1806.
4. Saleh, A. L., Naeem. L. F. & Mohammed, M. J. (2017). PLC Based Automatic Liquid Filling System for Different Sized Bottles. International Research Journal of Engineering and Technology (IRJET), (4)12, 57-61.
5. Zhang, T., Dong, F. & Yuan, H. (2012). Application of PLC for arranging bottle in Beer filling production line. 2012 24th Chinese Control and Decision Conference (CCDC), 2012, pp. 1215-1220.
6. Win, Z. K. & Nwe, T. T. (2019). PLC Based Automatic Bottle Filling and Capping System. International Journal of Trend in Scientific Research and Development, (3)6, 389-392.
7. Viraktamath, S. V., Umarfarooq, A. S., Yallappagoudar, V. & Hasankar, A. P. (2020). Implementation of Automated Bottle Filling System Using PLC. Inventive Communication and Communication Technologies, 33-41.
8. Guha, A., Ganveer, A., Kumari, M., & Rajput, A. (2010). Automatic Bottle FillingMachine. International Research Journal of Engineering Technology, 7(6), 1010-1015.