International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

AUTOMATIC BOTTLE FILLING MACHINE

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Abstract - *The world is increasing moving towards Automation, i.e., the process of performing various tasks without or with minimum human intervention. It increases the overall efficiency and output of a process. It involves establishing control loops using microcontrollers like Arduino or PLCs, which control the working of the entire plant. Filling is an operation in which a predetermined amount of liquid needs to be precisely filled in the bottle. It is used by soft drinks industry, packaged water industry and various pharmaceuticals. The operation was earlier carried out by humans and involved placing one bottle at a time on the conveyor belt and filling it. The process then was slow, involved spilling of liquid and unequal quantities of liquid in bottles. The process is now carried out by PLCs in large manufacturing units now. PLC machines are very expensive. Due to their high costs, filling is still carried out manually in small manufacturing units. This results in shortcomings in the operation and at drives up labour costs. This problem compels us to design a system with reduced costs. This can be achieved by using Arduino as a microcontroller. The proposed project will reduce cost for small scale industries and help them in setting up automated plants. In this project, we aim to study the industrial process as carried out by a PLC, comparison between PLC and Arduino and then design a bottle filling system using Arduino UNO as microcontroller.*

Key Words: **PLC, Arduino, Ladder Logic, Filling, IDE, Microcontroller.**

1. INTRODUCTION

The world is moving towards Automation, i.e., completion of processes without or with minimum human intervention. Automation involves remotely controlling processes and creating control loops, so that the operation can be carried out electronically with minimum human intervention. The whole process is controlled by microcontrollers, which act as the brain of the system. Microcontrollers are very compact integrated circuits with three main components, viz. processor, I/O peripherals and memory unit. These microcontrollers are generally used in embedded systems and are connected to other heavy components which carry out the actual work in the process. Examples of Microcontrollers include 8051, AVR microcontrollers, ATmega328 etc.

In large industries PLCs or Programmable Logic Controllers are used to automate the process. PLCs are large scale digital computers which are adapted to withstand rough industries conditions, which include humidity, dust, heat, vibrations and large number of I/O operations per unit time. They use Ladder logic, which has been used by engineers and technicians for a very long time. They are reliable and sturdy. The initial cost of a PLC is very high.

Filling operation involves filling a predetermined amount of liquid precisely in a bottle. This operation was earlier carried out by humans and involved placing one bottle at a time on the conveyor belt and filling it. The process then was slow, involved spilling of liquid and resulted in unequal quantities of liquid in bottles. In large scale industries like soft drinks and pharmaceuticals, filling is carried out by PLCs. But the very high initial cost of a PLC machine discourages small scale industries to automate. They still work manually which drives up their labour costs, increases wastages and decreases their overall efficiency. Therefore, these small scale units should also be provided a cheap option for them to automate their units and save time, money and resources. This problem can be solved by using Arduino as a microprocessor. Arduino is a much cheaper option as compared to PLCs. It is a microcontroller board which has many I/O pins through which it can interact with outside elements. It also has a memory unit (flash memory, SRAM and EEPROM) and a processor. It is easily available and can be coded using an Arduino IDE (Integrated Development Environment). This project aims to design an automatic bottle filling system which uses Arduino Nano as base. This will reduce labour and operation costs in small scale industries.

In order to understand the basics of such a design, an extensive study of the following research papers was carried out. **Bipin Mashilkar, Pallavi Khaire and Girish Dalve** [1] in their paper explain in detail have worked on an **Automatic bottle filling machine**. Their project aims to reduce the complexity and price of a bottle filling system. It uses Arduino as the microcontroller and details the design parameters of a system.

Sagar Dadhe, Rohit Maske, Rohit Kalukhe and Meghana Vare [2] in their research paper, expounds in detail the design process of an **IoT Based Smart Energy Meter**. Their project aims at reducing electricity theft in the country by giving electricity boards the power to remotely control energy meters. A small change is made to the existing meters

converting them into smart meters. Their project uses **IoT** or **Internet of things** to actualise the process. The microcontroller used is **Arduino** which communicates continuously with the server using an **ESP 3266 module**. Arduino is used as it is energy-efficient and is fast in processing data.

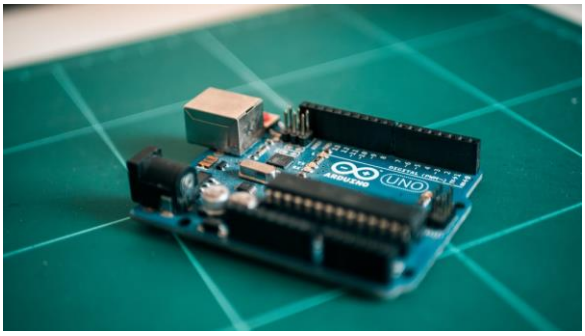

Fig -1: Arduino UNO.

Dr. A.S.C.S. Sastry, K.N.H. Srinivas, V S R G Krishna, Ch. Sesha Kiran Kumar [3] in their research paper go into detail to design and realise a temperature and volume based liquid mixing system. Three low cost AT89S51 microcontrollers are used to develop electronic sub systems for controlling the system. The objective of the project is to mix different liquids in required ratios and different temperatures. The sensing of temperature is carried out by two LM35 sensors. The mechanical sub system through which the liquid is allowed in required ratios is powered by two geared DC motors.

Eka Cahva Primaa, Siti Sarah Munifahab, Robby Salamb, Muhammad Haidzar Azizb, Agustin Tia Survanic [4] designs an Automatic water tank filling system in their research paper. Their project is meant to be used in homes in Indonesia where groundwater is pumped up to fill a water tank. They aim to reduce wasteful electricity consumption and spilling of water which occurs in case of non-automated systems. For fulfilling this objective, they design an Arduino based sensor which detects water levels in the tank and cuts the circuit when the tank is filled.

Rahul Ambare, Swapnil R Lende, Prashant R Arote, Onkar B Pokharkar, Ganesh R Waykar [5] in their research paper design and implement a Programmable logic controller based Automatic bottle filling machine. It uses a Delta PLC (DVP 14 SS) as field controller. The system sequence of operation is designed by ladder diagram and programming of the project is done using programming software. Sensors are used as input signal transmitters for the PLC.

Pravin Kalubarme, Sushil Kumar Madane, Abhijeet Malve, Reshma Bagal, Shivaji Kamble [6] design an automatic bottle filling and counting unit. The unit fills and counts bottles without human intervention. The project counts bottles using IR sensors. Arduino is the microcontroller used in the project.

Table -1: Difference between PLC and Arduino.

S. No.	PLC	Arduino
1.	Digital Computer ruggedised to withstand industrial conditions.	Microcontroller board designed for light use.
2.	Large number of inputs and outputs.	Less numbers of inputs and outputs than PLC.
3.	Programmed using Ladder logic.	Programmed using C language in an Arduino IDE.
4.	Widely used in industries.	Not currently being used in industries.
5.	Can withstand vibrations, noise, humidity, dust and other industrial conditions.	Delicate electronic instrument not made to withstand such conditions.
6.	Understood and known by engineers and technicians all over the world.	New technology used by specialised engineers.
7.	Can perform large number of operations at the same time.	Cannot perform large number of operations at once.
8.	Plug and play type of device.	Not a plug and play type of device.
9.	Very reliable device in industrial conditions.	Less reliable than a PLC.
10.	Very high initial and maintenance cost.	Very easily available and cheap.

2. WORKING METHODOLOGY

The main objective of an Automatic Bottle Filling System is to complete the process of filling without human intervention. For achieving this, the machine follows a methodology depicted in the flow chart shown below.

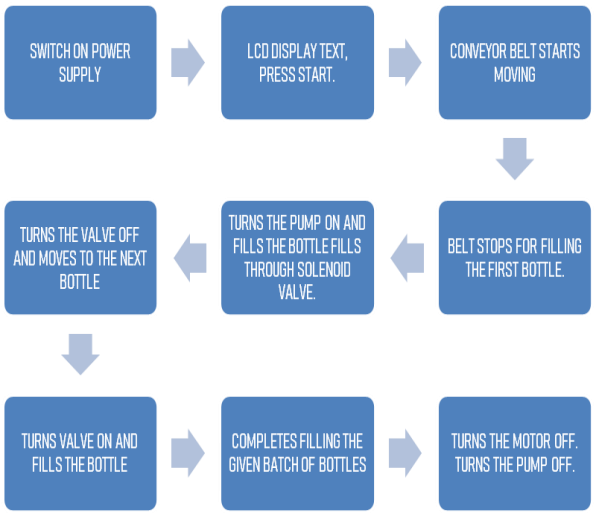

Fig – 2: Working of Automatic Bottle Filling System

When the power supply is switched on, the LCD starts displaying, "PRESS START". After pressing the start button, the conveyor belt starts moving, powered by a stepper motor. The belt moves to and stops at its pre-determined position. The LCD displays, "START FILLING". The water pump starts at this point filling the bottle kept under it through the solenoid valve. After filling the user feed quantity of water in the bottle, the pump is stopped. The belt moves to its new position and the next bottle comes under the pipe. The pump is again started and the second bottle is filled. The pump is stopped and the belt moves ahead after the bottle is filled. The process is subsequently repeated until every bottle of the batch has been filled. The stepper motor powering the conveyor belt is then turned off. The water pump is turned off. LCD displays, "JOB DONE".

3. COMPONENTS OF THE SYSTEM

The following components are used to construct the project:

3.1 Arduino Nano

Arduino Nano is a small, compact, breadboard-friendly board based on microchip ATmega328P. It is programmed using the Arduino IDE. The program is uploaded to the board using type B USB cable.

3.2 Display

The system uses a 2-line, 16-character LCD display. It uses a 4-bit interface. The characters showing the process occurring are send to the screen to display.

3.3 Stepper motor

Stepper motor is a brushless DC electric motor that can divide a full-rotation into a number of equal parts, the motor being able to hold its position in any part. They are important electronic equipment and are used in printers, floppy discs, 3D printers etc.

3.4 Stepper Motor Driver

A stepper motor driver is a circuit used to run a stepper motor. It needs to be connected to the Arduino board for the program to run a stepper motor.

3.5 Solenoid valve

Solenoid valve is an electromechanically operated valve. They are generally used in places where fluid flow needs to be controlled automatically.

3.6 Buzzer

The buzzer is an audio signaling device which will alert us about the various steps occurring in the model.

3.7 Base

The Base will be a wooden board upon which all components, electrical or mechanical, of the project will be mounted. It is made by using 12mm thick plywood.

3.8 Water Pump

It is standard submersible water used in desert coolers. It will pump water from the reservoir to the filling station.

3.9 Voltage Regulator

Voltage regulators are safety devices which do not allow excess current to flow in the circuit. This protects delicate electronic instruments used in the circuit. 7805 and 7812 are the two transistors used in this project.

3.10 Conveyor Belt

Conveyor belt is used to transport the bottles in the production line. It is made of a rubber belt and is run on three rollers. It is powered by a stepper motor.

4. DESIGN OF THE SYSTEM

The design of the system can be categorised in two parts:

4.1 Electrical/Electronic Design

The circuit and PCB are designed using EasyEDA designer. An electrical circuit or Schematic is designed as shown in figure 3. This maps the connections between all the components of our design. The electrical circuit file or schematic is then converted to a PCB file using the software. Placement is carried out wherein components are arranged in on a virtual board. Once, we have arranged the components as we desire, a process known as routing is carried out.

After obtaining the PCB, all the components are soldered onto the surface of the PCB. The components are placed in their right positions, soldered with the help of soldering iron and the extra terminals cut off from the surface.

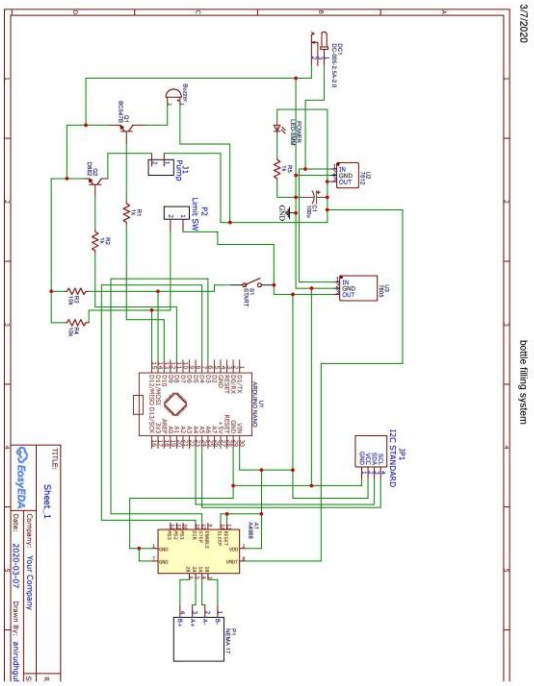

Fig – 3: Electrical Circuit of the System

4.2 Mechanical Design

The mechanical design of the Automatic Bottle Filling Machine is carried out using AutoCAD software.

The mechanical part of the design will support the above mentioned components and carry out the intended task. The drafts and 3D model are shown in figure 4 and 5 respectively.

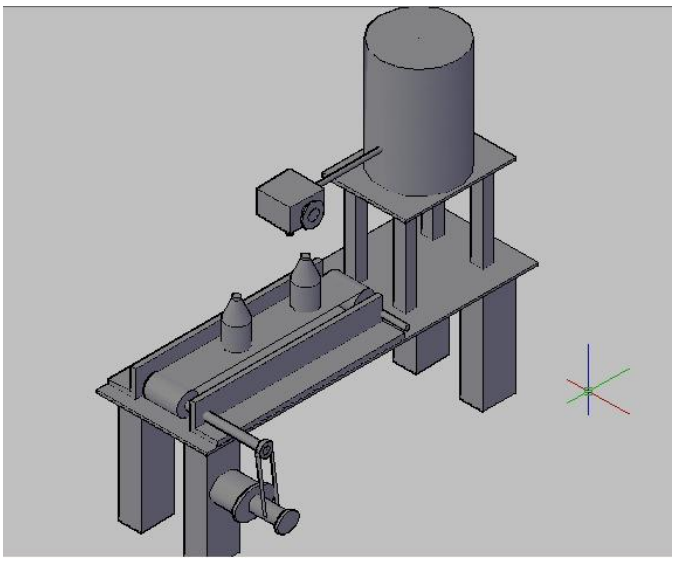

Fig - 4: 3D model of the system

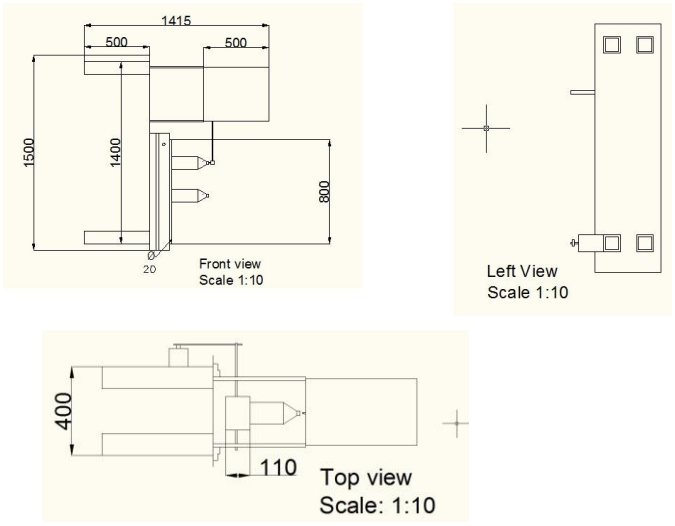

Fig – 5: 2D Draft of the System

4. NUMERICAL ANALYSIS

- **Diameter of roller**s,
  d = 150mm or 0.15m.
- **RPM of motor,**
  N = 60.
- **Belt Speed,**
  V = (π×d×N)/60 = (π×0.15×60)/60 = 0.4712 m/s or 471.2 mm/s

- **Sectional Area,**
  A = L×H = 0.150×0.005 = 7.5×10^{-4} m^2.
- **Material Density,**
  ρ = 1522 kg/m^3.
- **Belt Capacity,**
  B.C. = 3.6×A× ρ ×V = $3.6\times7.5\times10^{-4}\times1522\times0.4712$ = 1.937 kg/s.

- **The mass of Material M_m (live load) per metre loaded on a belt conveyor is given by,**
  M_m = BC/ (3.6×V) = 1.937/ (3.6×0.4712) = 1.1419 kg/m.

- **Length of the Belt,**
  L = (πd) + (2×centre distance)
  = (π×0.15) + (2×0.8)
  = 2.0712 m.

- **Discharge through the solenoid valve (in m^3/s),**
  Assume Q = 2 lit/s = 3.33×10^{-5} m^3/s
- **Area of solenoid valve,**
  A = (π/4) × d^2 = (π/4) × 12.5 × 10^{-3} = 1.22×10^{-4} m^2.
- **Velocity of fluid through solenoid valve,**
  V_1 = Q/A = (3.33×10^{-5})/ (1.22×10^{-4}) = 0.2713 m/s = 271 mm/s.

- **Time required to fill a One Litre bottle,**
  In one second discharge is 0.03333 lit/s.

For filling a 1L bottle, time required = bottle capacity (in litres)/ discharge in 1 sec (in lit/s)
Time required = 1 / 0.03333
Time required = 30 seconds.

6. RESULTS AND DISCUSSION

The results from numerical analysis show that the time required to fill a one litre bottle moving on the conveyor belt is **30 seconds**.

This is applicable when the conveyor belt is moving at a speed of 471 mm/s. The length of the belt is 2.0712 m. The discharge or volume of water which comes out of the valve per unit time is assumed to be 2 litres/second. Thus, the velocity of the water flowing through the solenoid valve becomes 271 mm/s.

The time required to fill a single bottle, i.e., 30 seconds feed into the Arduino code as time-delay of the motor. This is the time for the motor driving the conveyor belt stops for the bottle to fill.

7. PROGRAM CODE OF THE SYSTEM

The program running the system is written below. The code has been written in Arduino IDE and is uploaded to the Arduino board using a type B USB cable.

```
#include <Servo.h>
#include <LiquidCrystal.h>

Servo servo;
LiquidCrystal lcd(1,2,4,5,6,7);
int pos = 180;
int irPin = 13;
int aPin = 8;
int bPin = 9;
int cPin = 10;
int dPin = 11;

void setup()
{
        servo.attach(12);
        lcd.begin(16,2);
        pinMode(irPin, INPUT);
        pinMode(aPin, OUTPUT);
        pinMode(bPin, OUTPUT);
        pinMode(cPin, OUTPUT);
        pinMode(dPin, OUTPUT);
}

void loop()
{
        lcd.clear();
        servo.write(pos);
        lcd.print("Conveyor is ON");
        while(1)
        {
                if(digitalRead(irPin)== HIGH)
                        {
                        break;
                        }
                digitalWrite(dPin,HIGH);
                delay(2);
                digitalWrite(dPin, LOW);
                digitalWrite(cPin, HIGH);
                delay(2);
                digitalWrite(cPin, LOW);
                digitalWrite(bPin, HIGH);
                delay(2);
                digitalWrite(bPin, LOW);
                digitalWrite(aPin, HIGH);
                delay(2);
                digitalWrite(aPin, LOW);
        }
        lcd.clear();
        lcd.print("Conveyor is OFF");
        delay(2000);

        for(pos = 180; pos>=155; pos = pos-1)
        {
                servo.write(pos);
                delay(10);
        }
        lcd.setCursor(0,1);
        lcd.print("Valve is OPEN");
        delay(5000);

        for(pos = 155; pos<=180; pos = pos+1)
        {
                servo.write(pos);
                delay(10);
        }
        lcd.clear();
        lcd.print("Conveyor is OFF");
        lcd.setCursor(0,1);
        lcd.print("Valve is CLOSE");
        delay(2000);
}
```

8. FUTURE SCOPE

The world is increasingly moving towards automation. Small Scale industries place a particular disadvantage from the start in this field. They are discouraged to automate due to the high initial cost of automation. This design has the potential to be used at a large scale by Medium and Small Scale Industries (MSMEs). Its main advantage is the substantial reduction in setting up units and operating it. It can be used by various industries such as pharmaceuticals, paint industry, packaged water industry, soft drink industry, cooking oil industry etc. with particular modifications. The modifications can be industry-specific and according to the challenges typical to particular industries. The system can also be used as an auxiliary unit in large scale production plants. It can

complement production along with PLCs. Production can be carried out on this system, when the PLC is out of order or under maintenance. It can also assist production when the PLC is overloaded. Capping operation can also be carried out using piston arrangement. The system can also be modify to count the number of bottles per unit time and place caps on them after filling operation is completed.

9. CONCLUSION

With the world increasingly moving towards Automation due to its various benefits, efforts should be made to make this technology more accessible to various small and medium scale industries. It can eventually help them in diversifying the fruits of the endeavour to the general public and contribute to the overall growth of the country's economy. Filling is an important operation carried out in various stage of the process in many industries. This process is carried out by PLC machine in large scale industries. While PLCs are efficient, adapted to industrial conditions and easy to use, their initial costs and maintenance costs are very high. Thus, many small scale industries continue to work manually as they cannot afford a PLC. This project attempts to solve that problem by using an Arduino board as the microcontroller in the system. An Arduino is efficient, robust and widely available microcontroller. An interface circuit has to be constructed to facilitate the operation using an Arduino board. This substantially reduces the cost of the machine. Overall, our Automatic Bottle Filling Machine is efficient, economically friendly and accurate.

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BIOGRAPHIES

I, **Aniruddh Guha**, was born and brought up in Indore. I am currently a final year student pursuing a Bachelor of Engineering in Mechanical Engineering from Madhav Institute of Technology and Science, Gwalior. I have completed certification courses in designing software AutoCAD 2D and 3D. My areas of interest include thermal engineering, thermodynamics and heat transfer.

I, **Adarsh Ganveer** was born and brought up in Balaghat. I am currently a final year student pursuing a Bachelor of Engineering in Mechanical Engineering from Madhav Institute of Technology and Science, Gwalior. I aim to pursue a Master in Production Technology. My areas of interest are Power Plant Engineering, Manufacturing Processes and Automobile Engineering.

I, **Manjari Kumari** was born in Punjab and brought up in different places all over India. I am currently a final year student pursuing a Bachelor of Engineering in Mechanical Engineering from Madhav Institute of Technology and Science, Gwalior. My areas of interest include Strength of Materials and Machine Design.