PLC Based Automatic Racking System

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Abstract

Automatic racking system is used in the bakery industry for baking purpose and also for storage and retrieval of the products. The proposed work describes the design of PLC (Programmable logic controller) based automatic racking system. The system consists of two workstations, one station fills the empty pallets and in the other station these pallets are arranged in an order. The system is motorized where DC motors are used to drive the system. Sensors are used to identify the presence of the pallets, and in this system PLC's are used for the control of the system. The language used to program the PLC is ladder diagram. This principle can be used to fill the pallets and shift them to a rack in a synchronized manner and can make ordinary systems automatic and smart. The system replaces the existing manually operated racking system to allow plants to increase productivity, minimize repetitive work, reduce injuries and lower the cost of labors.

1. Introduction

The tremendous advance in today's technology requires innovative solutions in each and every industry. One such industry is bakery industry. Bakery industry in India today has an important place in the industrial map of the country. The bakery industry is very much consumer lead with a constant requirement for new varieties of Products, bakeries compete to gain shelf space and customer brand loyalty.

Recent market trends have seen the rise of convenience foods and 'healthy options'. Being in synchronization with the trends and fashions for new product can gain market share and increase profit margins. Demands at the bakery production level need to reflect changing consumer requirements. Bakery equipment and processes need to be flexible enough to cope with a variety of modes of operation that match a continually changing marketplace, whilst balancing variables such as cost of raw ingredients, energy, minimizing waste and conforming to the appropriate regulatory requirements. As the industry is in the verge of growth, wide variety of automation solutions are to meet the varying demands from a modern bakery business. All-encompassing product solutions are backed up by service, support, and most importantly industry know how to provide bakeries with the resource needed to produce consistently high quality products on time every time.

1.1 Problem Statement

The racking systems used in bakery industry are not completely automated, the trays or the pallets are moved to the racks using manual operations, AGV's, forklifts, gantry robots, shuttle robots, stacker cranes etc., this lead to long time consumption, large floor space utilization and requirement of human operators.

1.2 Proposed system

The aim of the project is to design and develop workstation where the pallets are filled and then moved on to the racks automatically which is controlled using Programmable Logic Controller.

This work is controlled using Programmable Logic Controller (PLC). It is used to control the movements needed to store and retrieve the parts from the racks. A program needs to be created for the PLC using ladder diagram. The system requires Direct current (DC) motors to move the pallets. An inductive sensor is used to detect the metal pallets and thus gives signal for further operation. A limit switch and sensors are used to make the system to stop at particular position. The whole setupis interfaced with the PLC, as per the program the racking system operates.

1.3 Objective of the project

The main objective of the project is to design and develop an automatic racking system with PLC integration. Programming of the system is done using PLC ladder logic/diagram. To develop a system where the pallets/trays are filled with products and with an automatic motion system, the pallets are moved to the racks by the operation of DC motors connected within the system.

2. Hardware Description

A brief description of the hardware components used in this project is given in this chapter.

The hardware components used in the system is as follows

1. PLC
2. DC Motor
3. Sensor
4. Relay
5. Limit Switch

2.1 Programmable Logic Control (PLC)

Programmable logical controller is a device that is capable of being programmed to perform a controlling function. The PLC was designed to provide flexibility in control based programming and executing logic instruction. PLC allowed for shorter installation time and faster commissioning through programming rather than wiring. The PLC has in recent years experienced an unprecedented growth as universal element in industrial automation. It can be effectively used in applications ranging from simple control like replacing a small number of relays to complex automation problems. Today the PLCs are used for control and automation job in a single machine and increases up to full automation of manufacturing / testing process in a factory.

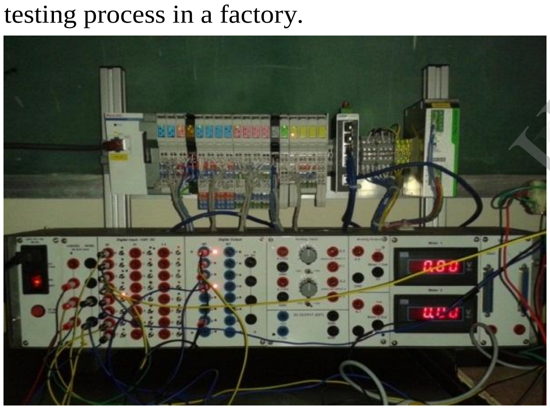

Figure 2.1: shows the L10 PLC used in the system.

The PLC used in the project is as shown in Fig 2.1 is a BOSCH Rexroth's L10 PLC. The PLC is used to control the motion of the system. It consists of 16 input ports and 16 output ports. The PLC logic is not a mechanical part of the controller. The PLC logic is a software program, which runs on the processor in the PLC. This program has to be created with a special programming tool on a PC. After downloading the program into the PLC, the control automatically starts the program.

2.2 DC Motor

DC motor use a rotating permanent magnet in the rotor and stationary electrical magnets on the motor housing. A motor controller converts DC to AC. A DC motor has a two wire connection. All drive power is supplied over these two wires think light bulb. When you turn on a DC motor, it just starts sinning round and round. Most DC motors are pretty fast, about 5000rpm.

Four motors have been used in the project. Two DC motors of geared type 12 volts DC motor and speed of 100rpm and two DC motors of geared type 12 volts DC motor with a speed of 3.5rpm.

2.2.1 Design Constrains

The design constrains considered while selecting motor is as below:

2.2.1.1 Design of motor1

The design considerations for motor 1 are as given below.

Weight = 2kg

Distance travelled = 215.9 mm

Time taken = 5 sec

$Torque = F \times D$ …..(2.1)

Where

F = Force

D = Distance travelled

Here, $F = m \times a$ ………. (2.2)

Where

m = mass

a = acceleration

Here,A=changeinvelocities/timetaken (2.3)

Velocity = displacement/time taken …..(2.4)

$V = 215.9 \times 10^{-3}/5$

$= 0.04318$ m/s

Substituting the value of velocity in equation (2.3), we get

$A = 0.04318/5$

$= 8.638 \times 10^{-3}$ m/s^2

Substituting the value of acceleration in equations (2.2), we get

$F = 2 \times 8.638 \times 10^{-3}$

$= 0.01727$ N

Now, substituting the value of force and distance travelled in equations (2.1), we get

$T = F \times D$

$= 0.01727 \times 215.9 \times 10^{-3}$

$T = 3.729 \times 10^{-3}$ Nm

Torque required for 200 rpm can be obtained by $P = \frac{2\pi NT}{60}$….. (2.5)

The torque obtained from the above design considerations is 3.729×10^{-3} Nm; whereas a motor with 200 rpm requires a torque of 17.53 kg-cm. hence a 200 rpm DC motor has been opted for the system.

2.1.1.2 Design of motor2

The design considerations for motor 2 are as given below.

Weight = 0.3kg

Distance travelled = 215.9 mm

Time taken = 25 sec

$V = 215.9 \times 10^{-3}/25$

$= 8.635 \times 10^{-3}$ m/s

Substituting the value of velocity in equation (2.3), we get

$A = 8.635 \times 10^{-3} /25$

$= 3.45 \times 10^{-4}$ m/s^2

Substituting the value of acceleration in equations (2.2), we get

$F = 0.3 \times 3.45 \times 10^{-4}$

$= 1.035 \times 10^{-4}$ N

Now, substituting the value of force and distance travelled in equations (2.1), we get

$T = F \times D$

$= 1.035 \times 10^{-4} \times 215.9 \times 10^{-3}$

$T = 2.234 \times 10^{-5}$ Nm

The torque obtained from the above design considerations is 2.2778×10^{-4} kg-cm; whereas a motor with 200 rpm requires a torque of 17.53 kg-cm. Hence a 200 rpm DC motor has been opted for the system.

2.1.1.3 Design of motor3

The design considerations for motor 3 are as given below.

Weight = 3kg

Time taken = 25 sec

As the rack is attached to a belt, the distance travelled is equal to the belt length.

The length of the belt can be calculated by using the equation below,

$$L = 2C + \frac{\pi}{2}(d_1+d_2) + \frac{(d1+d2)2}{4C} \quad \text{...…. (2.5)}$$

Where

L = length of the belt

C = center distance between the pulley

= 0.07v = 0.245

d_1 = pulley diameter 1

d_2 = pulley diameter 2

Therefore, L = 1695.97 mm

$V = 1695.97 \times 10^{-3}/3$

$= 0.56$ m/s

Substituting the value of velocity in equation (2.3), we get

$A = 000.56 /3$

$= 0.1884$ m/s^2

Substituting the value of acceleration in equations (2.2), we get

$F = 3 \times 0.1884$

$= 0.565$ N

Now, substituting the value of force and distance travelled in equations (2.1), we get

$T = F \times D$

$= 0.565 \times 1.69597$

$T = 0.958$ Nm

The torque obtained s within the range of the torque required for a 3.5 rpm DC motor. Hence a 3.5 rpm DC motor s used in the system.

2.3 Relay

A relay shown in Fig 2.3 is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

Figure 2.3: Shows a relay

2.4 Limit Switch

A limit switch is a switch, usually mechanical, that is actuated by a moving part of some machine. Its operation is much like any other switch in that there are contacts that move when a plunger or lever on the outside of the switch is pushed. Internally there is an over center spring mechanism that snaps the switch open or shut in response to a gradual motion of the plunger or lever.

Many limit switches have three terminals. One is the normally closed contact, another the normally open contact and the third is the common that switches between these two as the mechanism is moved.

Figure 2.4: Industrial Relay

The limit switches used in this project are of leaf type. There are four limit switches used in the system. The Fig 2.4 shows a limit system. Limit switch is operated by the motion of a machine part or presence of an object. They are used for control of a machine, as safety interlocks, or to count objects passing a point.

3. Modeling

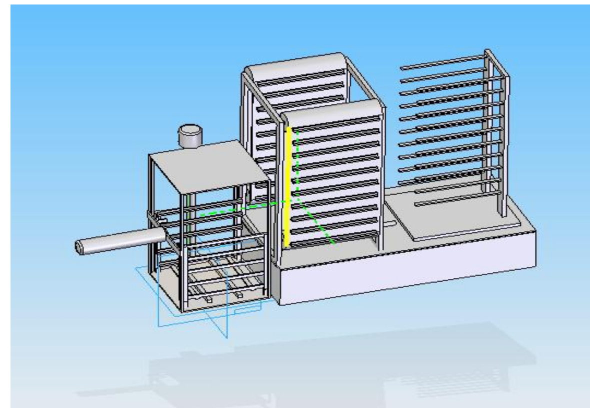

Figure 3.1: Represents the 3d model of the system developed with solid edge V18.

The model is shown in the Fig 3.1 is designed using solid edge software. Solid Edge is a 3D CADparametric featuresolid modeling software. It runs on Microsoft Windows and provides solid modeling, assembly modeling and drafting functionality for mechanical engineers, designers and drafters.

The complete model of the racking system is developed using the software solid edge V18, and the fabrication is done according to the dimensions from the developed design.

Inputs and outputs are connected to the PLC. Switches, sensors and limit switches are taken as inputs and motors are considered as outputs.

4. Experimental Setup

The Fig 4.1 shows the experimental setup of the system and also the hardware components used in the system.

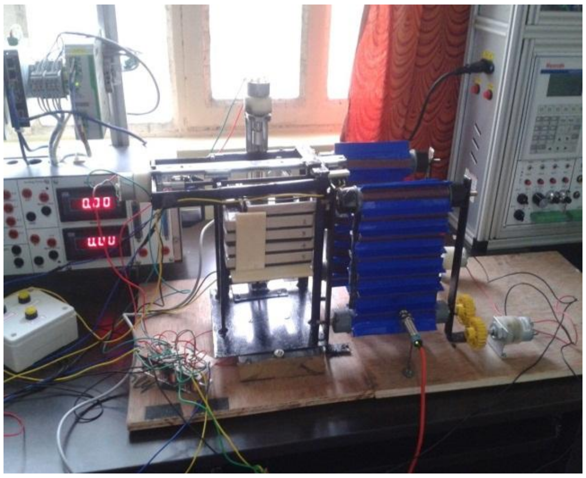

Figure 4.1: shows the experimental setup of the system

Hardware components of the system

1. DC Motor 1
2. DC Motor 2
3. DC Motor 3
4. Sensor 1 (Inductive Sensor)
5. Sensor 2 (Inductive Sensor)
6. PLC kit
7. Relay circuit
8. Rack
9. Tray holder

The PLC based automatic racking system consists of two units. The first unit contains the trays or the pallets. The second unit is a rack where these trays are placed for further operation of baking. Complete system is controlled using a PLC.

4.1 Working Principle of the System

The system consists of three DC motors M1, M2 and M3 respectively. M1 is used to lift the tray holder which has a forward and reverse motion with the help of a lead screw. M2 is similar to M1 with forward and reverse motion with a lead screw and is used to push the tray to the rack and M3 is used for the motion of the rack.

The system also consists of two inductive sensors and four limit switches. Inductive sensors are used to sense the metals which are named as S1 and S2 in the system. Inductive sensors are used to sense the presence of the trays. Also four limit switches also called mechanical switches which are named as LS1, LS2, LS3 and LS4. Bosch Rexroth Indralogic software is used for programming the system. The figure shows the hardware setup of the system.

The power to the system is supplied by a push button. Once the system starts trays which are aligned are lifted by a tray lifter, which is controlled using a motor (M1). The figure shows the lifting of the trays.

As the trays are lifted, at certain position sensor (S1) senses the presence of the tray. M1 stops its operation as S1 is sensed. At the same time the first tray starts moving in linear direction. The linear movement is controlled by second motor (M2).

The tray travelling in linear direction moves with a stop for a small interval. At this interval the tray is filled with the products which are to be racked (dough, cookies etc. for baking purpose) are dropped on to the tray. The tray is pushed to the rack with the help of a rod which is connected to a lead screw controlled by M2The rod retracts back to its home position when it comes in contact with limit switch (LS2).

At home position, it contacts with limit switch (LS1). The rack moves such that it makes way for the next tray to position on it. At the same time the tray lifter also lifts for the next cycle. And thus the cycle repeats for every tray.

Once when all the trays are filled in the rack, they are moved on for further baking operation. The tray lifter also moves to its home position with the signals from limit switches LS3 and LS4.

5. Conclusion

Demands at the bakery production level need to reflect changing consumer requirements. Bakery equipment and processes need to be flexible enough to cope with a variety of modes of operation that match a continually changing marketplace, whilst balancing variables such as cost of raw ingredients, energy, minimizing waste and conforming to the appropriate regulatory requirements.

Hence an automatic racking system meets the need of a bakery industry by reduces travel time, material handling with high access frequency, easy to modify, suit a wide range of applications, prevention of work place accidents due to better ergonomics, improve inventory accuracy, reduce labor and product damage, can save energy and make processes more efficient.

6. References

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