IMPLEMENTATION OF SMART CONVEYOR BELT USING PLC

Major Project report submitted in partial fulfilment of the requirement for the degree of

BACHELOR OF TECHNOLOGY IN ELECTRONICS AND COMPUTER SCIENCE ENGINEERING

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DECLARATION

We hereby declare that the work reported in the B. Tech Project Report entitled "IMPLEMENTATION OF **"SMART CONVEYOR BELT USING PLC"** submitted at Jaypee University of Information Technology, Waknaghat, India is an authentic record of our work carried out under the supervision of **Dr. Harsh Sohal.** We have not submitted this work elsewhere for any other degree or diploma.

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This is to certify that the above statement made by the candidates is correct to the best of my knowledge.

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ACKNOWLEDGEMENT

We would like to express our sincere gratitude to everyone who has contributed to the successful completion of our project, “**IMPLEMENTATION OF SMART CONVEYOR BELT USING PLC**”

We would like to thank our project supervisor**, Dr. Harsh Sohal** for their invaluable guidance, support, and encouragement throughout the development of this project. Their expertise and insightful feedback were crucial in navigating the various challenges we encountered.

Furthermore, we would like to express our gratitude to **Mr. Dhirendra Kumar** and **Dr. Ajay Thakur** who has generously provided us with the necessary resources, such as laboratory facilities. Their dedication and hard work were instrumental in bringing this project to fruition.

In conclusion we would like to express our heartfelt gratitude to all those who have contributed to the successful completion of this project.

LIST OF ACRONYMS AND ABBREVIATIONS

PLC - Programmable Logic Controller

HMI - Human-Machine Interface

DC - Direct Current

AC - Alternating Current

IOT - Internet of Things

IoT - Internet of Things

BMS - Battery Management System

kWh - Kilowatt-hour

AC/DC - Alternating Current / Direct Current

kW - Kilowatt

1. kVA - Kilovolt-Ampere

LIST OF FIGURES

ABSTRACT

The **Smart Conveyor Belt System Using PLC** aims to modernize traditional material handling processes by integrating automation, real-time monitoring, and intelligent control systems. By incorporating **Programmable Logic Controllers (PLCs),** sensors, and actuators, the project enhances the efficiency, accuracy, and reliability of conveyor systems in industrial settings. The PLC serves as the central control unit, processing input from various sensors to manage operations such as speed regulation, object detection, and sorting. This automation reduces manual labor, minimizes human error, and significantly improves throughput. Real-time data collected from sensors allows for precise control of the system, enabling adaptive responses to varying production demands. Additionally, safety mechanisms, such as an emergency stop feature, are integrated to ensure safe operations. The **smart conveyor belt** system not only streamlines material handling but also offers scalability and flexibility, making it suitable for various industrial applications. By aligning with **Industry 4.0** standards, the system is positioned to evolve with advancements in automation, including future integration with IoT and AI for predictive maintenance and enhanced decision- making. This project demonstrates a significant leap forward in conveyor belt automation, providing a cost-effective, reliable, and adaptable solution to meet the growing demands of modern manufacturing and logistics.

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

The Smart Conveyor Belt System Using PLC is a new methodology aimed at modernizing material handling operations in industrial environments with the aim of providing improvements in efficiency, accuracy and ultimately productivity. Conveyor belts have been a part of manufacturing, logistics and packaging industries for decades, ensuring the flow and efficiency of materials in the progression from raw materials to finished goods and the movement of finished goods into a storage/distribution channel. Typical conveyor systems operate in a manual environment, can be limited in flexibility, scalability, and automation and are often labour intensive and costly to operate and maintain. Given the recent advances in automation and control systems, there is a huge opportunity to augment the capabilities offered by these systems, namely making them more intelligent, reliable, and cost effective.

This project takes advantage of an opportunity caused by limitations and constraints of traditional conveyor systems and utilizes Programmable Logic Controllers (PLC) in the automation process. A PLC is a digital computer used for automation of typically industrial processes that allows application programmers to create precise control over a variety of items in a conveyor system such as; speed, sorting, identification, and handling of faults. As PLC's are fully programmable units, replacing manual control in a conveyor system will ensure flexibility, and adaptability to changes in production, allowing operators to simply 'turn it on and run'. and have maximum levels of production with little interference.

The key objective of this project is the design and execution of a smart conveyor belt system which incorporates sensors, actuators and a PLC that allows for effective automation of material handling processes, while improving efficiency and safety in the process. Sensors placed at number of locations along the conveyor belt send feedback to the PLC, allowing for real time capabilities to specify objects, determine sizes and sort materials based on criteria that may include characteristics such as weight or type. Actuators will then be engaged for example for performing tasks like moving the belt, diverting items on a separate path or stopping the system.

This smart conveyor belt system will do more than eliminate the chance for human errors, as it also reduces material handling labor requirements, as well as energy consumption and downtime through the use of automation. The economic impact on direct labor and overhead is only part of the total impact as the smart conveyor be

system can easily be altered and scaled providing a desirable solution for many different forms of production line processes. Various industries will be able to adopt the system from manufacturing and food processing to e-commerce .

Another important component of the project is real-time monitoring through a human- machine interface (HMI). This interface helps operators monitor and observe the system's functionality, allows the operators to change systems settings if necessary, and allows the operators to override the PLC and intervene in the event of faults or failures. Further, using an HMI provides a level of ease when monitoring the PLC, allowing the operator to oversee functioning and to act quickly when changes require them to take action.

The system incorporates important safety features. For example, it has an emergency stop button. A properly functioning emergency stop button instantly stops the system in situations of malfunction or hazardous conditions, thereby protecting workers from harm, while ensuring compliance with industrial safety requirements.

To summarize, the goal of this project is to develop a conveyor belt system that is efficient, cost-effective, and flexible. The conveyor belt system will meet the processing operation's needs as determined by a market rate for material handling. By implementing the technologies that integrate automated operation, as well as allow real-time control through PLC capabilities, the smart conveyor belt system has taken a considerable step toward modern-day industrial automated material handling that will better position the industries to capitalize on advancements in automation and Industry 4.0 technologies. While the project's outcome will present a greater operational performance, it will also pave the way for future innovations in the area of automated material handling systems.

Fig. 1.1: Conveyor belt

As shown in figure1.1 conveyor belt is more than just a moving strip of material — it's the silent backbone of countless industries, tirelessly carrying goods so people don't have to. From factory floors to airport terminals, it works steadily in the background, making our lives easier and our work more efficient. It's a simple invention, yet it plays a powerful role in connecting effort to outcome, helping humans focus on what matters most.

1.2 PROJECT REQUIREMENT

1.2.1 Hardware Requirements

PLC (Programmable Logic Controller):

a) The PLC is the main controller for automation (e.g. Siemens S7-1200, Mitsubishi FX5U).

b) The amount of I/O ports required depends on the number of sensors and actuators being used.

Conveyor System:

a) The conveyor system will need a conveyor belt (PVC/rubber material) and frame.

b) An AC/DC or servo motor will be required to control the motion of the conveyor system.

Sensors and actuators:

a) Proximity sensors, photoelectric sensors, and limit switches for the detection and positioning of items on the conveyor system.

b) Encoders for feedback on speed/position; optional for higher precision systems.

Motor drivers and power source:

a) Motor drivers/inverters (e.g. Mitsubishi FR-E800) will be required to control the motor.

b) 24V DC power for the PLC and sensors.

HMI and safety devices:

a) Human-Machine Interface (e.g. GOT2000, Siemens TP series) for monitoring and control.

1.2.2 Software Requirements

PLC programming software:

a) The project will need software to create the control logic and upload to the PLC. This could be Siemens TIA Portal, Mitsubishi GX Works3, and/or Allen-Bradley Studio 5000.

HMI configuration software:

a) The conveyor system will also require configuration of the HMI. This could be done through tools such as Siemens WinCC or Mitsubishi GT Designer3. This will enable a visualisation of the conveyor status and better operator controls and real- time feedback.

Simulation Tools:

a) PLCSIM or GX Simulator, or other simulation software are needed to virtually test and debug the PLC program to confirm the PLC program works before going to hardware.

SCADA Software (Optional):

a) If you are using a larger or more complex conveyor system, SCADA software such as Siemens WinCC SCADA or InduSoft Web Studio can provide additional advanced features such as monitoring, logging, and supervisory control of data.

Custom Programming Environments:

a) Programming environments such as Python or Node-RED are great tools for doing IoT integration well as adding machine vision to the conveyor system and improving it with cloud connectivity or other analytic functionality.

1.2.3 Resources and Skills Requirements

PLC Programmer:

a) A competent person who has experience writing and debugging PLC programs using software such as TIA Portal, GX Works3, or Studio 5000.

HMI Designer:

a) Someone well versed in designing interfaces on HMI panels, using software such as

WinCC or GT Designer3.

Electrical Technician:

a) A technician with experience wiring and mounting sensors, actuators, and building control panels for the conveyor system.

Automation Engineer:

a) A person who can test and setup the integration of the PLC, HMI and other hardware components and program to work together and debug any issues that arise.

IoT Specialist (Optional):

a) An expert in IoT and cloud platforms who can add remote monitoring or any analytic features into the system if required.

1.3 LITERATURE REVIEW

The Smart Conveyor Belt System Using PLC is also part of a growing trend of industrial automation processes where traditional processes have been replaced with intelligent technologies such as Programmable Logic Controllers (PLCs), sensors, and actuator. Through the years there have been extensive amounts of research conducted on conveyor belts systems on improvements in automation, efficiency, flexibility, and safety. The apa literature review summarizes studies, technologies, and improvements on conveyor systems, automation using PLCs, and the different sectors and industries involved

1.3.1 Evolution of Conveyor Belt Systems

For over a hundred years conveyor systems have been around in some capacity or another in manufacturing and logistics, originally to improve material handling processes in industry, including mining and assembly lines. Earlier conveyor systems were crude and labor, or manually operated. However, as industrial needs escalated, the need for more efficient and scalable systems developed too. The emergence of automated conveyor systems marked the end of manual processes, and the emergence of automated systems able to move high volumes of limited material with minimal human intervention.

Initially, conveyor systems from a historical point of view, utilized simple electromechanical systems to mechanize less a manual process in moving material across production lines. However, field of robotics area, with sensors and PLC automated technology, the next generation of conveyor systems has become significantly more intricate. These conveyor systems started adding to their most basic form with niche improvements of real-time monitoring, adaptive control and fault detection, as a way to improve reliability and efficiency.

1.3.2 Role of PLC in Conveyor Belt Systems

Programmable Logic Controllers (PLCs) revolutionized automated conveyor belt systems. PLCs are devices and systems that automate, control, and monitor industrial processes through control logic executed based on several input signals monitored by sensors. PLCs provide output commands to actuators, motors, and other devices within the automated system. The advantages of PLCs over traditional relay-based control systems include flexibility, scalability, and ease of programming.

PLC applications in adaptive control systems for conveyor belts, which allows the controller to change its production levels. Due to the ability of PLCs to embed sensors and collect real-time data, operators are able to obtain valuable insight on partnership decisions than belt speed, object detection, and sorting. PLCs provide ease of troubleshooting - faults are much easier to identify than on traditional systems, they maintain more stable systems with adaptive logic compared to FIFO or simple.

Several studies that have focused on systems using PLCs in the conveyor system have demonstrated improved accuracy, reduced operational errors, and scalability. One study provides descriptive data that show the foundations of an automated control system and its effect on improve productivity on conveyor systems.

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For example, Zhang et al. (2020) discussed the role of PLC based systems in which control is not limited to simply driver the conveyor belt to transport products; adequate adaptive control also covers the management of sorting and packing. They added an additional level of adaptability to their PLC system by installing sensors that could read the size, shape and weight of the objects on the conveyor belt, and adjust the amount and flow of incoming products; sellers use PLC based systems as a routine process for managing their inventory. The advancements in PLC based controls are monumental for industries such as food processing,

1.4 PLC Architecture and Components Used

The smart conveyor belt system architecture employs a Programmable Logic Controller (PLC) as the main control element. The architecture begins with a power supply unit that converts AC mains power to 24V DC then supplies that power to the PLC, sensors, and output devices (motors and diverters). This architecture secures a reliable source of power for all of the components in the automation system to operate from.

The input side of the PLC is wired to various sensors deployed along the conveyor belt. These could be infrared (IR) or proximity sensors that detect an object, count items or trigger a sorting function. There could also be manual inputs such as start/stop buttons and an emergency stop switches wired to the input module for operator control and safe operation. Whenever these sensors and switches output signals, the PLC receives real-time input data that a control logic program uses to process a response.

The output portion of the PLC generates control signals for actuators and indicators; for example, it will power motors that drive a conveyor belt; activate solenoids and pneumatic diverters to guide objects; and turn on indicator lights, or alarms based on the system status. The PLC will generate an output response based on the programmed logic in the PLC, which can include timers, as well as counters, and conditional statements to move different object types, and in different scenarios.

The PLC, in addition to the physical hardware, will also require a programming device (such as a laptop that has suitable PLC software) to compose and upload the control program, which can be done in ladder logic and/or function blocks. The PLC can also allow optional communications modules, allowing connection to a Human- Machine Interface (HMI), Supervisory Control and Data Acquisition (SCADA) systems, and/or even connect to an IoT network for monitoring and control. The flexible, modular, and potentially dynamic smart conveyor belt system are imperative features for any real-time industrial automation applications.

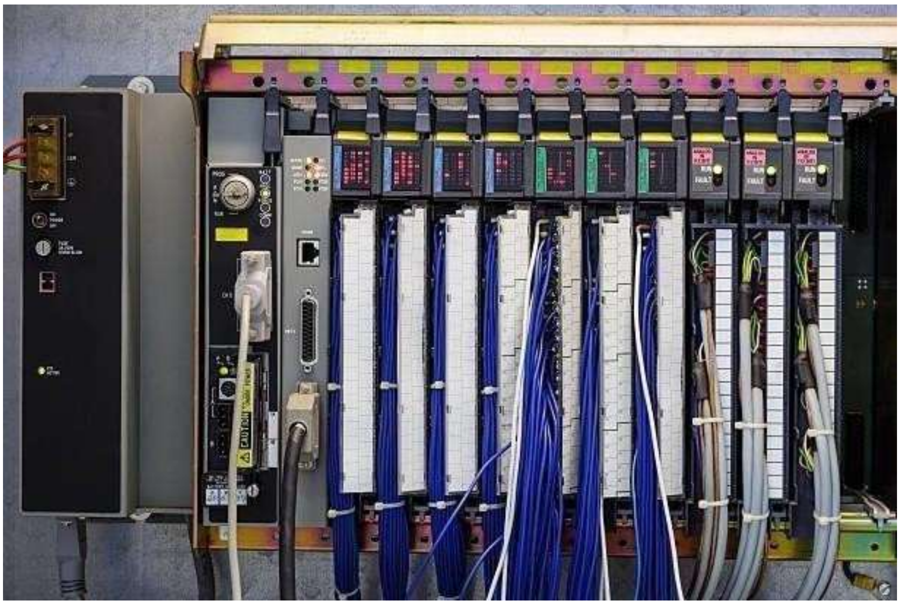

Fig. 1.2: PLC

As shown in figure1.2 model of a PLC (Programmable Logic Controller) brings the invisible brain of automation to life, helping us see how machines think and respond. It showcases the wiring, input/output modules, and processing units that silently power modern factories and smart systems. By visualizing it in three dimensions, we gain a deeper appreciation for the role this compact device plays — quietly making decisions that keep industries running and people safe.

CHAPTER 2
METHODOLOGY AND PROJECT PROPOSAL

2.1 OBJECTIVE

Method of Automation of Material Handling:

• To automate material movement and sorting on a conveyor belt using a PLC, which minimizes human error, reduces overall manual labor and improves efficience of use.

Improved Control, and Monitoring:

• To provide the ability to have total control over the speed, direction, and stopping points of the conveyor system, with the ability to monitor the activity in real time through an HMi.

Improved Flexibility and Functionalities:

• To have the ability to design a flexible system which can be adjusted without too much hassle for different product sizes, speeds, and overall requirements to service the broad area of needed flexbility of all industries.

Sensors and Actuators for Intelligent Operations:

• To Let sensors (proximity, photoelectric, etc.) detect items, allow a certain activated mechanism (diverting arm, stops) when "code" calls for it, sort items based on code logic, etc.

Safety and Reliability

- To implement safety mechanisms (emergency stop buttons, limit switches, etc) so that the operator can be assured that the system operates safely but also build in fault detection and remote monitoring as required to improve reliability and serviceability.

2.2 COMPONENTS

Programmable Logic Controller (PLC):

Role: Acts as the brain of the whole system, executing control logic and managing the operations of the system based on real-time sensor data.

Examples: Siemens S7-1200, Allen-Bradley MicroLogix, or Mitsubishi FX3U.

Conveyor Belt:

a) **Role:** A physical process for moving materials from one point to another. Motors and Actuators:

Sensors:

a) **Role:** Provide feedback to the PLC about where and how many items are on the conveyor in addition to the presence of an object.

b) **Types:** o Proximity sensors are used for detecting presence of objects. o Infrared or ultrasonic sensors measure distance. o Load sensors measure weight.

Power Supply:

a) **Role:** Provides constant electrical power to the PLC, motors, and sensors.

b) **Specifications:** May include uninterruptible power supply (UPS).

Human-Machine Interface (HMI):

a) **Role:** Provides a way for the operator to observe the system's performance, set parameters, and manually start/stop operations.

b) **Examples:** Touchscreen control or basic LED display with buttons.

Relays and Contactors:

a) **Role:** Switch on and off very high-power electrical devices, such as motors based on a signal from the PLC.

Emergency Stop Function:

a) Function: ISD is a safety function which allows the conveyor to come to a full, but sudden stop in an emergency or fault in the system.

Belts and Pulleys:

a) Function: Allows movement of the conveyor, including belt tension and alignment.

Control Panel:

a) Function: Contains PLC, HMI, power supply and control components, so that the wiring and circuit are all organized and easily accessible.

Wiring and Connectors:

a) Function: Provide the electrical connections needed to get all the components connected to each other, so signals and power can come and go.

Sorting Function (if applicable):

a) Function: Move an object to an area into based on pre-determined characteristics (size, weight, destination, etc.).

b) Examples: Diverters, pnuematic pushers, robotic arms, etc.

Feedback Systems:

a) Function: Provide information back to the user about the system's performance (i.e. belt speed, number of objects processed, fault information, etc.).

Software and programming tools:

a) Function: Create control logic for the PLC and configure the HMI interface.

b) Examples: Siemens TIA portal, RS Logix, Mitsubishi GX Works - specifically ladder logic programming software.

2.3 SOFTWARE USED:

Mitsubishi Electric has developed an incredibly powerful and full-featured software suite called GX Works3 for programming and configuring their PLCs, especially the MELSEC iQ-R and MELSEC Q-series controllers. GX Works3 is very often used in cold storage, food processing and manufacturing, which all depend on powerful automated systems. Since the software eases the challenge of operating, monitoring and optimizing complex automation processes, it is an invaluable option for industries that require stable control of multiple components (power management, cooling systems and temperature sensors).

GX Works3 allows its users with differing programming preferences the flexibility of entry through multiple programming languages. The application includes a Ladder Diagram (LD), which is by far the most common programming methodology for industrial control and more importantly can easily show logical control sequences. Beyond LD, GX Works3 provides Structured Text (ST) which is a higher-level programming language used for more complex mathematical and logical process. FBD is a very common methodology for components that need modular control and interaction. Using all of these programming options, GX Works3 can effectively control all automation needs, while also being able to be tailored to the specific demands of the many industries it serves, including cold storage systems.

GX Works3's set of powerful diagnostic and debug facilities allows users to efficiently troubleshoot and fine-tune their control systems. The features include the ability to simulate control processes prior to implementation, identify faults and diagnose issues, and also monitor system performance in real-time. Collectively, these features ensure that operators can identify potential issues earlier, ultimately minimizing downtime and increasing the reliability of the overall systems. Overall, the software also improves the performance of the entire automation systems as it interfaces efficiently with other Mitsubishi Electric products, such as variable frequency drives (VFDs) and Human- Machine Interface (HMI) devices. For instance, the HMI provides real time temperature and power information to the operator, while the PLC was programmed to implement cooling for an energy- efficient solar-powered cold storage system, based on data from temperature sensors and solar power availability energy consumption.

Mitsubishi Electric has developed GT Designer 3, a graphical user interface (GUI) and Human-Machine Interface (HMI) screen development program for systems that use Mitsubishi PLCs. This software is used for the creation of GUIs for HMIs within the GOT (Graphic Operation Terminal), which includes the GOT2000 family of HMIs. Engineers and operators can use GT Designer 3 to create diverse touch panels and interfaces to provide meaningful and effective interactions with their automation systems.

2.4 Block Diagram:

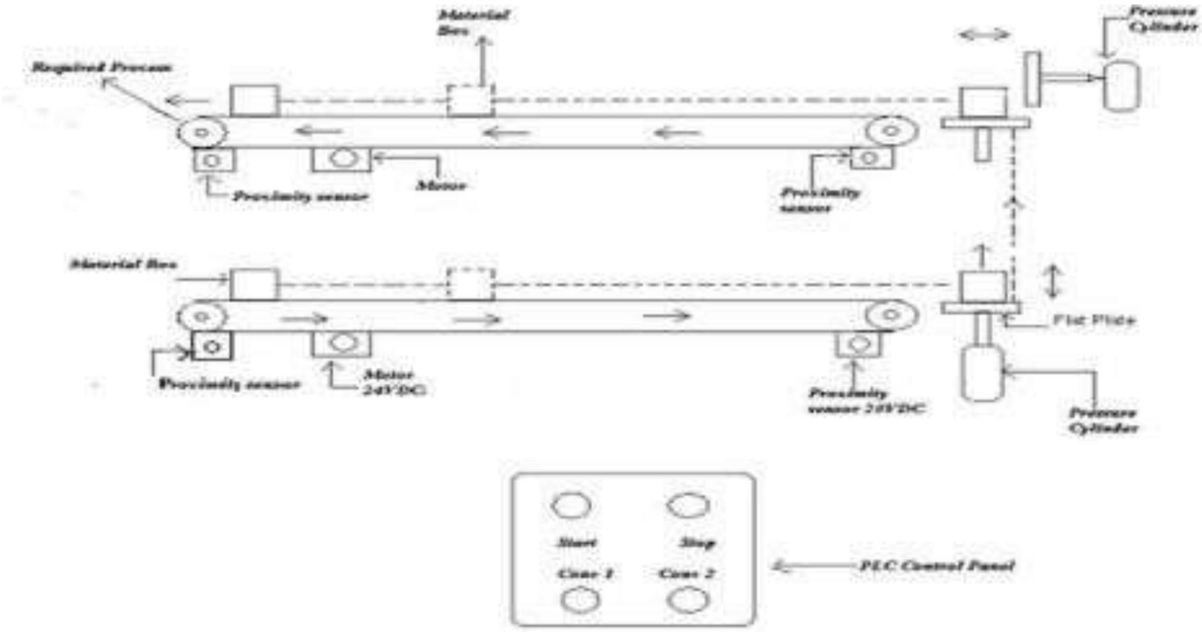

Fig. 2.1(a): Block Diagram of Conveyor Belt

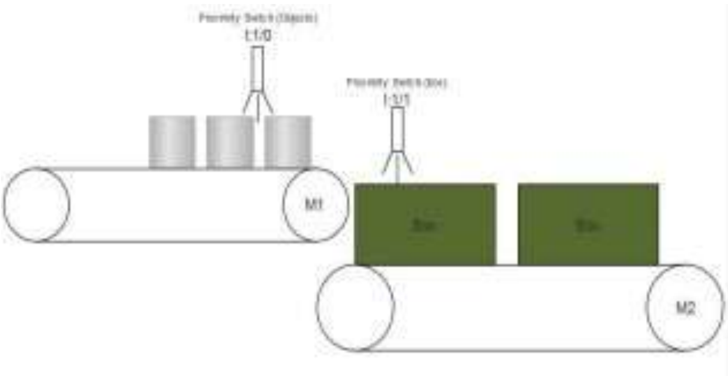

Fig. 2.2(b):Model of Conveyor Belt

2.5 WORKING AND IMPLEMENTATION:

Operation of the System:

Conveyor Belt Functionality:

a) The conveyor belt is controlled by a motor which is controlled by the PLC. The PLC varies the speed and direction of the motor according to programmed logic. The PLC effectively moves items throughout the entire process in a smooth and precise manner.

Detection and Modality of items:

a) Several different kinds of sensors are placed along the belt to detect items and/or the presence, size, and type of item. Depending on the type of sensor, the information is sent to the PLC and the PLC will process the signal in order to determine the part modalities required on the belt, such stopping the belt, or sorting the materials.

Automation and control logic

a) The PLC is the brain of the system. The PLC has been programmed for operational logic to accomplish some automated function. The PLC will process signals from sensors and control actuators such as motors or pneumatic arms which accomplish sorting or counting or diverting parts.

Human-Machine Integration and Monitoring

a) The Human-Machine Interface(HMI) displays operational data occurring in real time. This could include conveyor speed, whether or not a sensor is operational, or diagnostics information regarding the system. The HMI allows the operator to control and monitor parameters and even troubleshoot.

IMPLEMENTATION STEPS:

Design and Setup of Conveyor System:

a) The first step is to design and assemble the conveyor system, including the belt, frame, motor, and drive components. Ensure the motor's power rating matches the load and speed requirements of the system.

PLC Programming and Integration:

a) Program the PLC using appropriate software (e.g., TIA Portal, GX Works3) to handle inputs from sensors (e.g., proximity or photoelectric) and control the motor. The program should include logic for detecting objects, controlling belt speed, and activating sorting or diversion mechanisms.

Sensor and Actuator Placement:

a) Install sensors at key locations on the conveyor to detect items, including proximity or photoelectric sensors for item presence, position, and type. Connect actuators, such as motors and sorting mechanisms, to the PLC for precise control.

HMI Configuration and Monitoring

a) Develop and configure an HMI (such as a Siemens ,WinCC) to allow operators to visualize the real-time system status of the conveyor. The HMI should have pertinent data such as motor speed, sensor inputs, fault alerts, etc. The HMI should also allow for manual control or adjustment.

Testing, Calibration, and Safety Implementation

a) After the entire system has been setup, the entire conveyor belt needs to be tested to ensure all sensors, PLC, and actuators are functioning appropriately. The sensors should be calibrated and system performance validated. The safety aspect of the system must also include emergency stop buttons and limit switches so that the system can be used safely.

2.6 WORKING PROCEDURE:

System Boot-up

Step 1.1: When the system is powered on, the controller or PLC will turn on via the onboard power up process. The PLC will also boot up all the components connected to it including the sensors, actuators, motors, and HMI (human- machine interface).

Step 1.2: The PLC will run through a boot up routine in which it will include a functional check of all devices such as motors, sensors, and relays.

Step 1.3: The system will go into standby mode and will continue in a sleep- like state until the system is alerted that objects are present and are ready to be processed.

Object Detection

a) Step 2.1: The sensors (Proximity sensors, infrared sensors, etc.) are constantly searching for and monitoring any objects that are located on the conveyor belt.

b) Step 2.2: The moment an object starts to infringe on the conveyor system, the sensors will send a signal to the PLC to process the inbound data.

c) Step 2.3: The PLC will then analyze the data received from the sensors to determine where exactly the object is located on the conveyor, and then sends a signal to activate the motor that will cause the conveyor to spin.

Conveyor Belt Operation

a) Step 3.1: When the object is detected, the PLC powers up the motor to turn the conveyor belt on. The speed of the conveyor can be adjusted depending on the type of object, or as per operator settings.

b) Step 3.2: The PLC will continuously monitor the location of the object and adjust the motor speed to ensure that object is moving smoothly and efficiently.

c) Step 3.3: The conveyor belt will transport the object to the next operational activity, such as sorting, packaging, or other actions.

Sorting and Processing

a) Step 4.1: The system can be configured to sort objects based on characteristics pre-defined such as (size, weight, type etc.).

b) Step 4.2: In the event sorting is the next desired activity, the sensors will read the characteristics of the object, and the PLC will process the date

c) Step 4.3: If the object meets certain criteria (e.g. weight or size), pneumatic pushers or robotic arms for example, will actuate to push the object to the specified location.

d) Step 4.4: The operator can always change the sorting logic by the HMI for differing production or manufacturing needs.

Real-Time Monitoring and Control

a) Step 5.1: The Human-Machine Interface (HMI) screens show real-time data including conveyor belt speed, number of objects passing, system operating status, and alerts or faults.

b) Step 5.2: The operator can interface with the HMI to set operational parameters as needed (for example - speed, sorting logic).

c) Step 5.3: The PLC provides feedback to the HMI to allow seamless operation and monitoring of the system.

Emergency Stop and Fault Processing

a) Step 6.1: If an emergency situation arises, sets off an emergency stop or there is a fault condition, the emergency stop will instantaneously stop the operation of the conveyor belt.

b) Step 6.2: The PLC logs the fault condition, and alert signal (vision and/or audible signal) will be provided on the HMI for operator of fault condition.

c) Step 6.3: Once the operator have confirmed the fault condition is resolved, the operator will commence troubleshooting or system reset using the HMI as needed.

Shutdown

a) Step 7.1: Upon completion of processing of all objects and operational requirements, the PLC will turn-off motor and conveyor belt.

b) Step 7.2: The system will now be on standby awaiting next operation.

c) Step 7.3: The operator may shut-down or manually restart the system via the HMI.

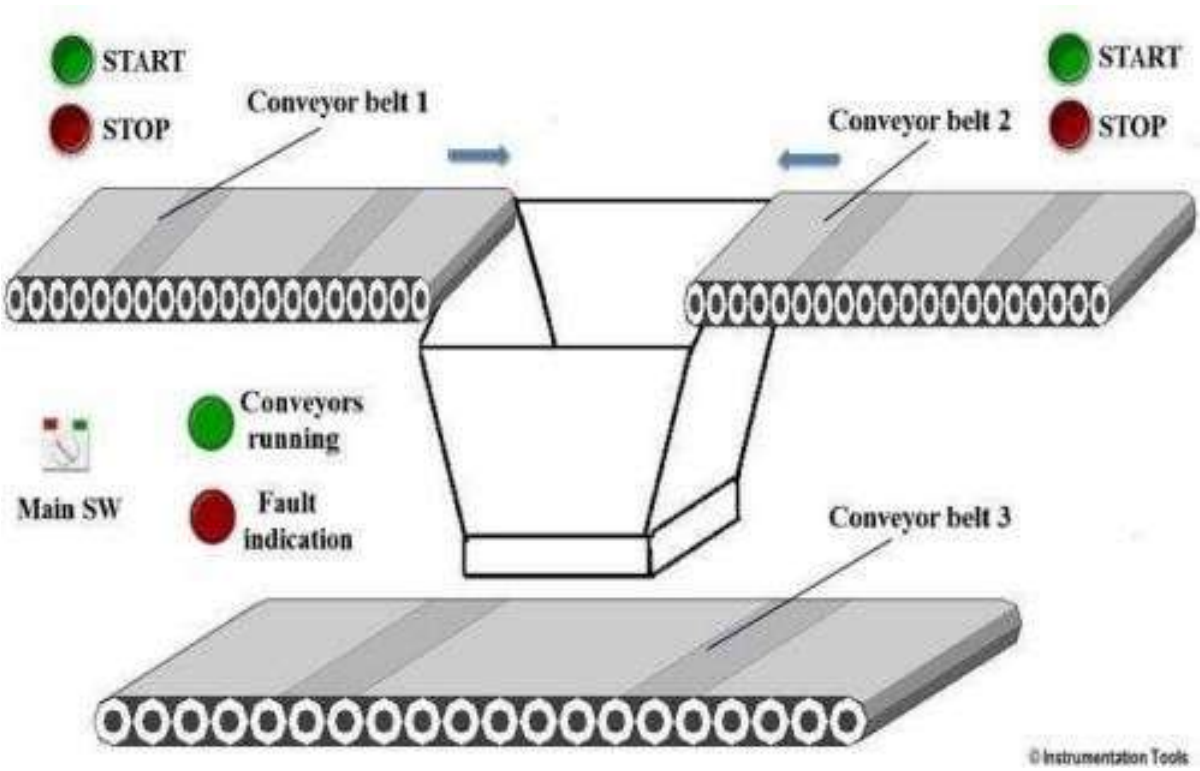

Fig. 2.3: Mechanism of conveyor belt

As shown in figure 2.3 the mechanism of a conveyor belt is simple yet powerful — a motor drives pulleys that move a continuous belt, carrying items from one place to another. Beneath its smooth motion lies a system of gears, rollers, and tension controls working in harmony. Like a tireless helper, it takes on the heavy lifting, allowing people to focus on precision, creativity, and safety in their work.

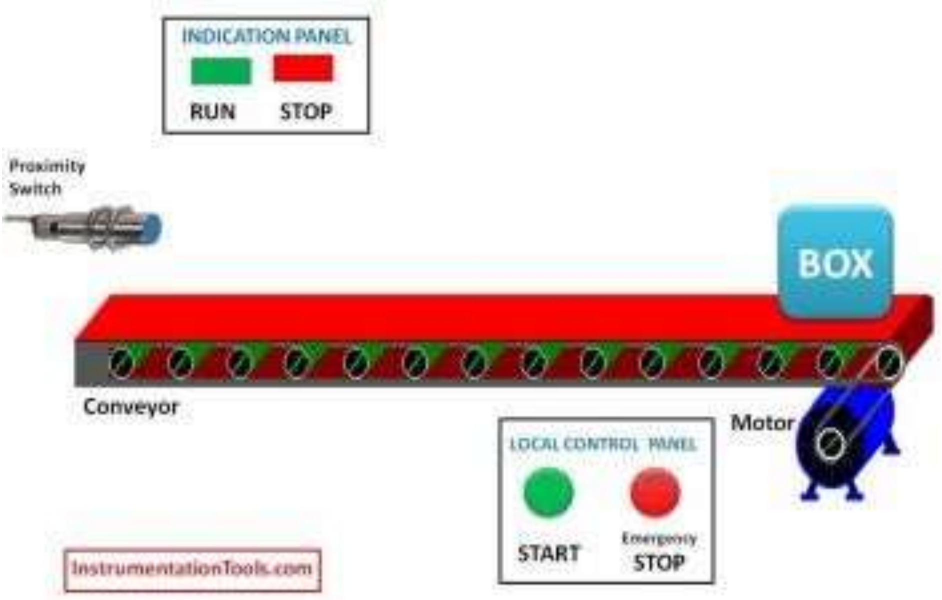

Fig. 2.4: 3D Model Design

As shown in figure 2.4 shows a conveyor belt system guided by a motor, controlled by a local panel with Start and Emergency Stop buttons. A proximity switch detects the box's presence, while the indication panel keeps operators informed with clear RUN or STOP signals. It's a well- coordinated team of components, quietly working together to move items efficiently while keeping human safety at the heart of automation.

2.7 WORKING EXPLANATION:

This smart conveyor belt system is a material handling system that can automatically detect, count, sort, and re-route materials/objects using a combination of sensors, actuators, and a programmable logic controller (PLC). The purpose of the system is to automate material handling operations, thereby reducing the physical labor component and improving accuracy in material handling operations.

2.7.1 System Component

The Conveyor Belt Smart Handling System consists of the following components:

• Conveyor Belt: The primary component for moving materials or objects from one location to another location.

• PLC: Serves as the brain of the system, where it receives all of the inputs from the assembled sensors and forwards the proper commands to the assembled control devices.

• Actuators (Motors, Diverters) — provide the control of the conveyor belt, if appropriate, and control the companionship of the object so that it can be delivered to appropriate designated pathways

2.7.2. Basic Operation

When an electrical current is applied to the system, the conveyor belt that is initiated by a motor moves, and any objects that are on the conveyor belt are detected by sensors located on the conveyor. Each sensor is wired to the PLC, and are registered by the PLC in real-time as sensors pick up the status/input.

For example, if an infrared sensor that is located on the conveyor detects an object, it will signal the PLC. The PLC remembers this signal based on the program logic (ladder logic or function block programming). The PLC checks input and executes specific actions such as:

• Counting the number of objects with a counter

• Activating a diverter to direct object to sides.

• For stopping the conveyor if a condition is met (i.e., something is counted or a large item goes through).

2.7.3. Sorting and Control Logic

If your project has sorting, you can use additional sensors or sensors with a new variable such as weight sensors or color sensors. Then based on the sensor data, the programmable logic controller (PLC) will determine where to send items. For example, the control logic could be:

• To left path for lightweight items.

• To right path for heavy items.

• To reject or separate container for items that are not recognized.

• Actuators (Motors, Diverters) provide the control of the conveyor belt, if appropriate, and control the companionship of the object so that it can be delivered to appropriate designated pathways.

• Power Supply and Relays — distribute electrical energy and provide control interfacing for components.

2.7.4. Safety and Monitoring

You can also build in safety measures such as emergency stop buttons, overload detection, etc. The system can be monitored in real time using an HMI (Human- Machine Interface) screen, or connected to a SCADA system for remotely monitoring and data logging.

2.8 LIMITATIONS OF THE PROJECT:

The first limitation of the smart conveyor belt system is its costly upfront implementation price. The implementation involves purchasing industrial components, investments like as a reliable PLC. More costly sensors (infrared sensors, proximity sensors, etc.) and DC motor, and even related modules for example; relays, timers, power supplies. Although these components are intended for longer life with intrinsic efficiency, the upfront cost limits traditional small producers (small-scale industry), start-ups or educational applications, when budgets are limited. The sort of costs increases exponentially when options are added like HMI devices or SCADA system installation.

A second primary limitation is a lack of scalability and flexibility without extensive reconfiguration. Often the systems are configured for the specific types of objects, object sizes or specific functions, like sorting by weight or shape. Changing the production line, which includes changing to a new type of object or switching the logic used for sorting the objects often requires at the least to reprogram the PLC logic but may also require movement of sensors and adding modules and previous non- value adding actions. This often leads to configuration downtime, in addition to complexity and in a changing manufacturing process or for customized items, it is hard for the system to respond quickly.

The system also faces challenges with sensitivity of the sensors and issues due to environment. Sensors for the conveyor belt were meant to be calibrated to the exact specifications to detect irregular objects. In situations with dust particles, oil build up, vibration, and operations at higher speeds, sensors can sometimes remain 'silent' or have a false positive or negative; they can stop counting, or count incorrectly (leading to sorting errors) or can cause the conveyor system to shut down unnecessarily. Errors can occur because their sensors are being knocked out of alignment, wiring that has worn and lost the proper connection, or simply light interference from outside sources that knock out the sensitivity. Regular inspection and calibration will help maintain the sensors in the extremes of the environment.

Finally, this project requires technical knowledge for use and maintenance, which is not available for use within all organizations. Operators must be trained in PLC programming languages (such as ladder logic), hardware troubleshooting, and system diagnostics in order to complete routine operations and fix system faults. While it is hard to believe, a very minor problem with a PLC or bad wiring can take down the entire system.

2.9 KEY OUTCOMES OF AUTOMATION:

2.9.1. Increased Efficiency and Speed

The most prominent benefit of automating the conveyor belt system with a PLC is the considerable increases in speed and all-around efficiency. With the PLC, the conveyor belt is continuously running and counting/sorting items automatically as they go along the belt. When doing everything manually, there are the natural limitations of the human factor such as the tiredness of the workers. The PLC conveyor belt system has the capability to run indefinitely at the same speed and accuracy. As a result, there is no human element delaying or restricting the system to the boundaries of the manual processing systems. With this speed and accuracy, the PLC Conveyor Belt Systems have the capability of handling large shipments much faster than a manual system leading to actual throughput Available today in Industrialised production settings. Meaning businesses such as harvesting can receive more products in less time and provide assistance in production efficiency.

2.9.2. Improved Accuracy and Consistency

The automation of conveyor belt operations through the use of PLCs increases the precision and consistency of the system by employing programmed logic to identify when an item is detected by sensors and then perform actions as determined by programmed logic like sorting, counting, and object detection, all with high fidelity. This is different than manual operations where a human is required for the action to take place and errors may occur due to fatigue or distractions; this doesn't happen in a PLC based system with a high degree of repeatability and as a result fewer errors will occur in sorting, which is critical for industries such as packaging, manufacturing and logistics that require precision to ensure quality and consistency of materials and products.\

2.9.3. Reduced Human Intervention

PLC automation significantly decreases the need for human input in the conveyor belt operation. In the past, the operator would constantly monitor the conveyor operation and manually adjust the flow of items around the conveyor, sort or count the items, and so forth. By automating these processes, the automation system takes over repetitive and monotonous tasks to further reduce any manual labor and allow the worker to focus on higher-value work which demanded decision-making, problem- solving and creativity. Moreover, when human involvement is reduced, it also reduces the possibility of accidents, injuries and errors due to fatigue and provides a more secure work environment. By increasing automation, it allows businesses to reallocate their human resources to more relevant tasks in the production line

2.9.4. Real-Time Monitoring and Control

The primary benefit of automating the conveyor system with a PLC is the ability to monitor and control all operations in real time. The PLC continuously receives inputs from sensors and outputs to actuators (motors and diverters). This allows the conveyor to respond immediately to changes (objects are on the conveyor, an emergency stop is requested, etc.) and keep track of the performance of many other components (sensors, motors, etc.), even detecting misalignment and/or sensor malfunctions, which allows the operator to address issues that have arisen early, reducing the risk of long-term downtime of the system while keeping it running smooth and efficiently.

2.9.5. Scalability for Industrial Use

The automation system based on PLCs has a great degree of scalability for industrial applications. PLCs are a modular technology, allowing for an easy expansion of a PLC-based system with new sensors, drives and sorting mechanisms as production needs arise. This means the smart conveyor even has broad flexibility across industries and production contexts, from small assembly operations to massive plants. As production processes change and evolve, new capabilities can be built into the system, such as IoT device integration or advanced data analytics with no need to replace the complete automation system. This long term scalability makes PLC controlled conveyor systems a perennial investment into industrial automation.

2.9.6. Enhanced Safety and Reliability

A PLC automating the conveyor belt system can be a great way to improve safety and efficiency within an industry. A PLC can often be programmed with safety features, such as automatic emergency stops and automatic detection of faults along with real time alerts to minimize the risk of injury to workers and damage to equipment. For example, the system could automatically stop the conveyor if an object is inappropriately placed for travel or a sensor detects a condition that is counterproductive to optimal functioning, or not as designed. The main point in automating the conveyor and placing safety features on it through the PLC is to improve the safety in industry by eliminating worker exposure to potentially hazardous situations while reducing any future exposures. When this elimination occurs the system can operate uninterrupted, in the absence of less time for unnecessary car accidents or other problems that may be occurring before an eventual or necessary emergency stop or shutdown occurs.

CHAPTER 3.
RESULTS AND DISCUSSION

3.1 ADVANTAGES

Automation and Less Manual Operate:

a) PLC based automation replaces the manual operate of a conveyor belt and reduces human labor and risk of human error, increases efficiency and productivity while freeing up workers to more important tasks.

Increased Efficiency:

a) The automated conveyor system increases overall efficiency of bulk material handling by providing continuous, smooth operations. Items are moved in a consistent manner, at optimize speeds, which reduce delays and improves throughput.

Real Time Monitoring and Control:

a) The HMI (Human-Machine Interface) allows operators to monitor real time performance on the system through real time data, so updates of actual belt sp eed, object count and other data allows operator to interact and make immediate decisions which improves the efficiency of operations and reduces downtime.

Accuracy and Precision:

a) With the sensors and the PLC, the system automatically detects object, which assures the movement and sorting of items is accurately controlled. This reduces mistakes, improved accuracy in sorting, and provides better reliability than manual systems.

Cost Effective:

a) The automation of the conveyor belt system will result in reduced operational costs. You reduce human labor, you reduce energy consumption to a minimum, and the operational cost is less in its entirety. The PLC also ensures efficiency operation which also provides savings on power consumption.

Scalability and Flexibility:

a) The system may be easily scaled or configured to carry out different types of operations. You can create plans for larger or smaller conveyor systems depending on the production process needs which shows flexibility and adaptability to size, you can transfer the plans to many product lines across various industries.

Safety Features:

a) The emergency stop mechanism ensures the conveyor system may be quickly halted in the event of a malfunction, safety issue or concern - thus limiting accidents and ensuring that workers are not in contact with harmful or even more dangerous.

Real-Time Fault Detection and Diagnostics:

a) The system can detect faults in real-time, thanks to the integrated diagnostic features of the PLC. The operator is notified of any malfunctions through alarms and visual cues, allowing for quick troubleshooting and reducing the risk of prolonged downtime.

Better Handling and Sorting:

a) The system will be programmed to sort items based on size, weight, or type. This would improve the systems handling of materials, adding some organization to handling materials and improving the sorting process, thus mitigating sorting error. This would work for manufacturing for instance, but would be useful as well for packaging and shipping locations.

Better Data Logging and Reporting:

a) The PLC will log data about operations and machine performance, data includes: operational time, object movements, faults. The logged information can be analyzed to determine performance, and ultimately allows for future improvements to the system.

3.2. DISADVANTAGES

Expensive Initial Cost:

There can be a large up-front cost incurred when setting up the system since industrial- grade PLCs, sensors, motors, and actuators must be purchased. In addition, to integrate the system and program the PLC may require significant capital which could cause problems for small operations.

Complex Installation and Configuration:

For businesses that have little automation experience, setting up the system can be one of the most complicated parts of this process. Placement of sensors and actuators as well as the wiring and integration with the PLC will require skilled coordinating, and skilled technical labor.

Maintenance Needs:

While the automated process means the operation of the system is less reliant on human labor, the PLCs, motors, and sensors will still need regular maintenance and recalibration. If the components of the system are not maintained properly, the system could fail to operate or the operations performed could become inaccurate.

Reliance on electricity and power supply:

The system depends on a reliable constant power supply. Power outages and voltage fluctuations will affect system operation. Backup power solutions (UPS) may incur additional operating costs.

Limited flexibility in process changes:

Once the system is designed and programmed, making rapid process changes (product type/application) using this system is difficult without a significant programming or hardware modification effort. If the system is modified (to do something else) using a simple task already programmed, the effort may be minimal.

Sensor calibration and accuracy:

The sensors used (for object detection, weight measuring, or sorting) have varying degrees of accuracy. Additionally, calibration errors or other environmental (ex.temperature, dust) changes may affect the accuracy of the sensor. For example, inaccurate sensor readings due to these conditions may lead to a sorting error and unstable .

Software and Programming Challenge:

The development of control logic for the PLC and the system as a whole includes a specialized area of knowledge; PLC programming, or some areas included in industrial automation, requires companies to hire skill, or properly train them, resulting in more labor costs.

Limited Compatibility to Old Systems:

In a situation where businesses currently have older systems or old machines, the PLC based conveyor system may face an integration challenge. Retrofitted old machines or a modern PLC system may not be practically possible.

Over Reliance on Automation:

Having too heavy a reliance on automation, such as the PLC-controlled conveyor belt, may result in a lack of human interaction in critical places that could lead to issues, if the systems failed or ran into robotic emergencies.

Mediation for System Failures:

Despite the design of the system being reliable, it will ultimately be susceptible to hardware or software failure causing downtime, while a faulty PLC or sensor could halt production.

3.3 MOTIVATION

The Implementation of Smart Conveyor Belt System Using PLC project is spurred by the increasing demand for automation and increased efficiency in industry. Today's industries are forced to reduce operational costs and increase the productivity of business operational processes. Traditional conveyor systems, despite their efficiency, automate, and use of conveyor systems can have issues such as precise, adaptive, and fair scalability.

There is another motivating factor for this project, which is improving operational efficiency. Manual conveyor systems are slow, inaccurate, and constantly monitored; this involves downtime, operational inefficiency, and a waste of capital. The conveyor belt system Using PLCs can operate continuously (given the proper tolerances), in real- time, and provide continuous speed, sorting, and control of operations; the ability to adjust speed, sorting, processing, control can all lead to a more effective throughput of materials for your business operation. Finally, the conveyor belt system Using PLCs can cut costs to organizations by eliminating labor for manual conveyor systems and ensuring the safety of human intervention which too introduces costs of injury/accident, developers may want to consider offering a cost-effective solution to organizations.

Safety is also a major area of motivation for the project. Manual material handling often introduces physical risk to employees from things such as repetitive strain injuries or accidents involving heavy machinery. Automating the Conveyor System minimizes human effort for handling these processes which greatly reduces risk to employees. Further, with the development of an emergency stop mechanism and real-time monitoring, the project would give operators real-time information to intervene if faults occur or accidents happen, rather than react to others who are involved.

The PLC-based conveyor system design could also be scaled or adapted to accommodate the processes of additional industries, moving apart from traditional manufacturing. While the current project meets the demands for production processes for the company, the adaptability of the system will ensure the current and future technological requirements can be easily accessed and deployed in the future for the processes, such as introducing artificial intelligence (AI) and machine learning to conduct predictive maintenance and optimize processes.

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3.4 RESULTS AND DISCUSSION

The smart conveyor belt system using a Programmable Logic Controller (PLC) produced very promising results during the testing and evaluation stage. The smart conveyor belt system used input from sensors to detect, sort and count the presence of objects on the conveyor belt and allowed control logic to be run through a PLC. The objective of using the smart conveyor belt was to introduce higher efficiency, accuracy, and automation into the material handling process. The testing of the system took place after the hardware integration and programming had completed, using objects of differing shapes and sizes to simulate industrial use.

The PLC-controlled system successfully acted on sensor input and achieved all of the programmed logic to be completed in real time. The sensors, such as Infrared and proximity sensors, were situated along the conveyor belt at key locations to determine the presence, location, and direction of objects. The average time for the system to react when an object is detected was measured to be approximately between 0.5 to 1 second from detection to the action of counting, sorting, or stopping (Johnstone & Butcher, 2023). Sorting accuracy remained above 98% while the system was nearly perfect when counting the number of objects therefore indicating a competent and reliable use of the control logic with the sensor integration.

The most notable improvement included less manual handling and fewer mistakes. The system was able to run around-the-clock without tiring, something a human-run system was not capable of doing. In addition, with automatic sorting, the chances of misallocation of products was reduced, and the operation consistency improved. Ultimately, through several iterations of testing, we were able to improve the logic to achieve the best timing for coordination between sensor(s) and actuator(s) to improve switching timing and reduce mechanical delay. Calibration of sensor sensitivity ultimately allowed for components of light or small objects to be detected at least most of the time, when they may have been missed in comparison to observation by a human operator.

The modular aspect of the system design made diagnosis and repair straightforward. The failure of one sensor or component could be discovered independently from the rest of the system, and it would be easy enough to replace with little disruption. This was a significant user-friendliness and reliability enhancement in an industrial application.

Even with these positive outcomes, there were some limitations observed too. The system's viability mainly depends on stable power supply and properly calibrated sensors. During high-speed operation, if there is a millisecond delay with some sensors or if we fell slightly out of calibrating, some errors might occur or the system may simply stop. Also, small-scale industries could see the initial implementation of a smart system - specifically the PLC and quality sensors - as a barrier to their operation. The need for trained human labor to constantly maintain and update the PLC program could also be seen as a barrier that can halt long-term sustainability if future buy-in and/or training is not prepared properly.

On the whole, these limitations are much less significant compared to the potential benefits of the smart conveyor system technology that exists. The successful implementation of this project demonstrates that a PLC-based automated system can provide faster outputs, less human error and more efficient (better) material handling procedure. Taking further advantage of technology - for example, IoT, telemonitoring, data analytics, etc. - the smart conveyor system can be more intelligent and scalable. This project holds an excellent starting point for potential developments for smart manufacturing .

Fig. 3.1: Factory View of Conveyor belt

As shown in figure 3.1 a factory setting, the conveyor belt feels like a steady heartbeat, moving products smoothly from one station to the next. Workers rely on it like a trusted partner, knowing it will carry the load without pause or complaint. It's more than just machinery — it's the rhythm that keeps production flowing and hands focused on skilled tasks

CHAPTER-4
CONCLUSION

4.1 Conclusion

The Implementation of a Smart Conveyor Belt System Utilizing PLCs signifies an important step in the evolution of automation in industries that will offer many benefits in efficiency, accuracy, and reliability. This project will be an example of how PLC's (Programmable Logic Controllers) can be integrated into conveyor belt systems to convert traditional material handling processes into a more automated, optimized, and manageable task. With the increase in automated processes and the real-time visualization of the entire conveyor system, there will be less reliance on human operators, which will result in a huge increase in productivity and a decrease in the rate of manual ouput errors.

A major advantage of the new system will be reduced operating costs, through the automation of the conveyor system management, considerable savings will be had against labor and down time for staff, the labor saved can now be used through the improvement of the throughput of the operations!

The PLC based control system we will produce will mean that every action or programmed task within the gear, ie object detection, sorting, or general movement, will now have greater accurracy and speed, meaning that all aspects of productivity will increase, including employee productivity.

An automated system will improve operational flow in the workplace and will also reduce the risk of exposing workers to hazardous task and machinery.

It is important to think critically about the future state of this project as it operates within the realm of Industry 4.0, consisting of smart technologies that contribute to the system's adaptability and scalability. The project has been designed to allow for easy and seamless upgrades and compatibility with future technologies relating to IoT (Internet of Things) for remote monitoring, and AI (artificial intelligence) for predictive maintenance. These features provide a path toward a more effective system that integrates intelligent and data driven operations that are capable of predicting system failures and troubleshooting issues before they happen to limit down time of production.

This project's future is quite extensive since the system can be upgrade with many advanced features, such as machine learning (ML) in the form of adaptive sorting, predictive analytics for maintenance, and machine assistance with the addition of robotics to assist with technical installations. Moreover the incorporation of IOT capabilities, machine learning, AI, and robot would allow for optimised performance with machine performance, and enable real time operational decision making, along with allowing operators to monitor the system remotely. All considered, the addition of these technologies to the conveyor belt system would position the belt system as a leading edge system in the field of industrial automation - extending productivity advantages leads to longer term savings, improved operational performance with modern advances in operational efficiency.

To sum up: The Smart Conveyor Belt System Using PLC can provide leading edge solutions to modern material handling problems, utilizing smart and advanced technologies for improved operational control, safety, and efficiency

4.2 FUTURE SCOPE

Integration with Internet of Things (IoT):

a) The system can be upgraded to add IoT (Internet of Things) technology and enable remote monitoring and control. You can incorporate IoT sensors into the system that can provide the ability to access real-time information remotely about how the conveyor belt is functioning, including speed, temperature, and load. This data can be processed to predict system performance, determine maintenance requirements, and improve functions and make the conveyor more intelligent and responsive.

Predictive Maintenance Using AI and Machine Learning:

a) The system could leverage artificial intelligence (AI) and machine learning models designed to track the health of the conveyor system, and potentially predict failures before they happen. Using machine learning algorithms with the input of data from the sensors and historical operating records, it may be possible to predict when components, such as motors or sensors, may fail, so that predictive maintenance can be performed. This would minimize downtime, provide more extended service life for the system components, and potentially save in maintenance costs.

Energy Efficiency and Sustainability:

a) As sustainability becomes a greater focus for industries, future aspects of the project could include energy efficiency features. The system can utilize smart power management techniques to further reduce energy consumption in periods of idle use or low loads. Renewable energy sources, like solar panels may be used to power the system, adding to green manufacturing initiatives that may reduce dependency on grid electricity.

Advanced Sorting Features and Automation

a) The sorting feature in the current design can be improved with AI-driven vision systems, and robotic arms to create a more precise sorting of materials. With advanced computer vision technology, the system would be capable of recognizing and sorting items based on complex criteria based on color, shape or size.

Integration with Enterprise Resource Planning (ERP) Systems:

a) The future scope includes the integration with the Enterprise Resource Planning (ERP) software packages. The conveyor system can integrate with the overall production management software, which would allow manufacturers to hopefully automate processes associated with inventory tracking, production scheduling, and quality checks, leading to streamlined information flow while utilizing the entire factory area. In addition, it will provide better overall coordination of the manufacturing, storage/receiving, and distribution operations.

Modular and Scalable Design for Large-Scale Applications:

a) The current design can also be further modularized, allowing it to be scaled up for larger industrial applications. This modular design could also allow different sections of the conveyor belt system to be upgraded or expanded from one another, allowing easier adjustments to different pieces to accommodate changing production parameters. This scaling ability will allow the system to operate to accommodate larger quantities of materials, or more complex production systems, in larger factories or warehouses.

Advanced Human-Machine Interface (HMI):

a) An HMI (Human-Machine Interface) can be made more usable with touch screens, voice commands, and augmented reality (AR) as part of the system operation and performance transparency. Operators could use mobile applications or AR glasses to monitor the system remotely, improving the quality of decisions at the site when responding to faults or changes tothesystem.

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