SORTING MACHINE USING PLC

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Abstract - — The automatic sorter machine using PLC is a system that sorts products based on specific criteria such as size, weight, or color. The system consists of a programmable logic controller (PLC), sensors, actuators, motors, conveyor system, power supply, programming software, HMI development software, and communication protocols. The sorting process is automated, with the PLC controlling the movement of products to the sorting stations based on the selected sensors' feedback. The HMI allows the operator to monitor and control the sorting process and displays information such as the status of the machine, the number of products sorted, and any errors or alarms. The system's design and implementation require careful consideration of the sorting requirements, selection of appropriate sensors and actuators, design of the control algorithm, programming of the PLC, development of the HMI, testing and commissioning, and maintenance and optimization. The automatic sorter machine using PLC is a reliable and efficient solution for automated sorting processes in various industries such as manufacturing, packaging, and logistics.

Index Terms - PLC, Sensors, HMI

I. INTRODUCTION

Sorting machines play a crucial role in various industries, enabling efficient and accurate categorization of objects based on specific criteria. These machines have revolutionized the manufacturing and logistics sectors by automating the process of sorting products, reducing human error, and increasing productivity. One of the key components that make sorting machines highly effective and versatile is the integration of Programmable Logic Controllers (PLCs). PLCs are electronic devices that provide control and automation capabilities, making them an ideal choice for controlling sorting machines. [1]

Fig 1.1: Automatic Sorter Machine.

Purpose of the Document

This document serves as an introduction to a sorting machine that utilizes a PLC for its operation. It provides an overview of the basic principles behind sorting machines and highlights the advantages of incorporating a PLC in the design. Additionally, it outlines the key components and functionalities of the sorting machine, emphasizing the role of the PLC in achieving efficient and reliable sorting.[6]

Sorting Machine Overview

A sorting machine is a mechanical system designed to categorize objects based on predetermined criteria such as size, shape, color, weight, or other distinguishing features. The machine receives a stream of objects and uses various mechanisms such as conveyor belts, sensors, actuators, and control systems to direct each object to its designated location or output bin. [2]

Importance of PLCs in Sorting Machines

PLCs provide a robust and flexible control system for sorting machines. They are specifically designed to handle complex automation tasks, making them an ideal choice for managing the intricate sorting process. PLCs offer several advantages, including:

Programmability: PLCs can be easily programmed and reprogrammed, allowing for quick adjustments to sorting criteria or modifications to the sorting process without extensive hardware changes. This flexibility ensures adaptability to changing production requirements.

Reliability: PLCs are highly reliable due to their rugged construction and ability to withstand harsh industrial environments. They are equipped with error detection and fault-tolerant features, minimizing downtime and ensuring uninterrupted sorting operations.[3]

Real-time Control: PLCs enable real-time monitoring and control of the sorting process. With fast response times, they can accurately detect objects, process sensor inputs, and activate appropriate actuators to divert items to the correct output bin.

Integration: PLCs can seamlessly integrate with other automation components such as sensors, actuators, and human-machine interfaces (HMIs). This integration enables a comprehensive and centralized control system for the sorting machine.

Diagnostics and Maintenance: PLCs provide built-in diagnostics and troubleshooting capabilities, simplifying maintenance tasks and facilitating efficient repairs when required.[4]

Components of a Sorting Machine Using PLC

Conveyor System: The conveyor system forms the backbone of the sorting machine. It transports the objects to be sorted from the input point to the output bins. The speed and direction of the conveyor are controlled by the PLC based on the sorting criteria.

Sensors: Sensors are strategically placed along the conveyor system to detect specific characteristics of the objects. These sensors can include optical sensors, proximity sensors, weight sensors, or color sensors, depending on the sorting requirements. The sensor data is fed to the PLC for analysis and decision-making.

Actuators: Actuators are responsible for diverting the objects into the appropriate output bins based on the sorting criteria. They can be pneumatic or electric actuators controlled by the PLC.

PLC (Programmable Logic Controller): The PLC serves as the brain of the sorting machine. It receives input from the sensors, processes the information, and makes decisions based on the programmed logic. The PLC controls the conveyor system, actuator activation, and communicates with other devices for a coordinated sorting.

II. System Requirements

Hardware Requirements:

PLC: A programmable logic controller (PLC) is the central component of the automatic sorter machine. The PLC should have sufficient input and output (I/O) modules to connect to the sensors, actuators, and motors.

Sensors: The sensors should be selected based on sorting criteria, such as size, color, weight, etc. Common types of sensors used in automatic sorter machines include photoelectric sensors, proximity sensors, and ultrasonic sensors.

Actuators: The actuators should be selected based on the size and weight of the products. Common types of actuators used in automatic sorter machines include solenoid valves, pneumatic cylinders, and electric motors.

Motors: The motors should be selected based on the size and weight of the products and the required sorting speed. Common types of motors used in automatic sorter machines include stepper motors, servo motors, and DC motors.

Conveyor system: A conveyor system is used to transport the products to the sorting stations. The conveyor system should be designed to handle the size and weight of the products and should be compatible with the selected sensors and actuators.

Power supply: A reliable and stable power supply is required to power the PLC, sensors, actuators, motors, and conveyor system.

Software Requirements:

PLC programming software: The programming software is used to write and test the control algorithm for the automatic sorter machine. Common PLC programming software includes Siemens STEP 7, Allen-Bradley RSLogix 5000, and Omron CX-Programmer.

HMI development software: The HMI development software is used to create the user interface for the automatic sorter machine. Common HMI development software includes Siemens WinCC, Allen-Bradley FactoryTalk View, and Wonderware InTouch.

Communication protocols: Communication protocols such as Modbus, Profibus, and Ethernet/IP are used to communicate between the PLC and other devices such as sensors, actuators, and the HMI.

Software Description:

DOPSoft is a software application we used developed by Delta Electronics for configuring and programming human-machine interface (HMI) devices, specifically Delta's DOP series HMIs.

Key Features of DOPSoft:

a. Project Development: DOPSoft offers a set of tools and features for creating HMI projects, allowing users to design and arrange graphical elements to create an intuitive and user-friendly interface.

b. Communication Setup: DOPSoft enables users to establish communication between HMI devices and other industrial automation equipment, supporting various protocols such as Modbus, Ethernet/IP, PROFIBUS, and more.[10]

c. Data Acquisition and Processing: DOPSoft provides data acquisition and processing capabilities, as well as real-time data monitoring and logging capabilities to track and analyze system performance.[8]

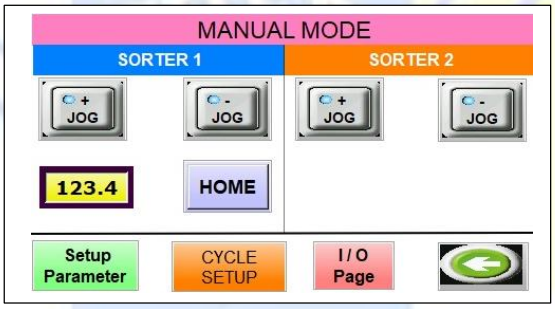

Fig 1.2 Human Machine Interface.

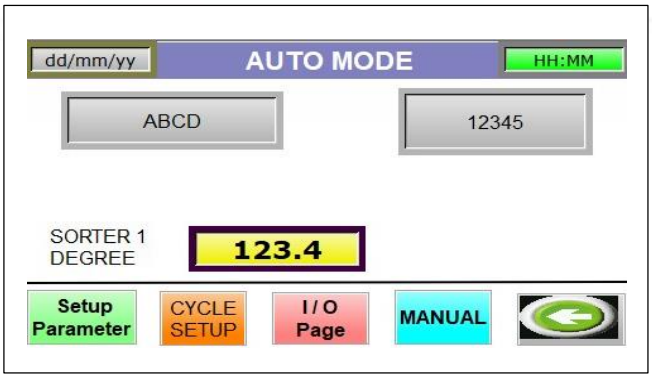

Fig 1.3 Human Machine Interface.

III. Construction Details

The conveyor belt that powers the machine is powered by an electric motor. The mild steel frame on which the conveyor belt is placed is constructed utilizing angles and channels. Two drum pulleys, over which the belt runs, are bolted to the frame at its two ends using journal bearings. The electric motor is used for the drive. The subframe with the intermediate shafts is constructed for speed reduction. This speed reduction system uses belt pulley assemblies for a two-stage reduction. To limit the amount of dust on the belt while the engine is idling, sheet metal is employed, which also serves as a scrubber. The conveyor belt's sensors are then placed there. [5]

IV. Working Process

An automatic sorting device using a PLC and an HMI performs the following steps in a systematic manner: Items are put on an input conveyor that has sensors installed to detect their existence and provide this information to the PLC. The PLC analyses sensor inputs to categorize items and decide where to sort them using logic sequences that look like ladder logic. The PLC controls actuators, such as motors or pneumatic devices, to direct objects in the right direction. Diverters, drop mechanisms, or pushers are a few examples of the various sorting mechanisms.[7] In addition to displaying system status, conveyor speed, sorting item kinds, and allowing manual overrides, the HMI provides operators with a real-time graphical interface. For data logging, remote monitoring, and reporting, the system can interface with higher-level control systems. The effectiveness of the system is influenced by safety precautions and feedback loops, and the PLC program can be changed via the HMI to take changes into account.

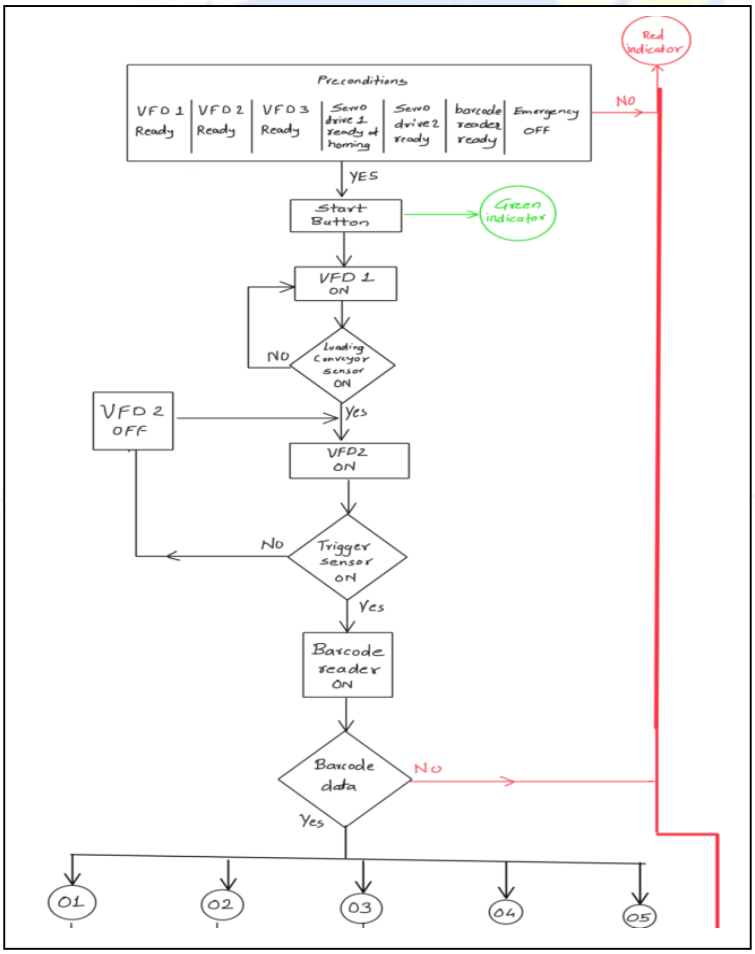

Fig 1.4: Working Flow Chart

V. PERFORMANCE ANALYSIS

The automatic sorter machine using PLCs (Programmable Logic Controllers) are widely used in industrial applications to sort various products based on their properties. The machine consists of various subsystems such as sensors, actuators, motors, and control algorithms that work together to sort the products.

To analyze the performance of the machine, various parameters such as sorting speed, accuracy, and efficiency can be considered. The machine has several advantages over other sorting systems, such as being programmed to sort various products based on different parameters, being easily integrated into existing production lines, and requiring minimal maintenance.

However, the initial cost of the machine can be high, and the programming of the PLC can be complex. Therefore, it is important to consider the advantages and limitations of the machine before implementing it in any industrial application. [11]

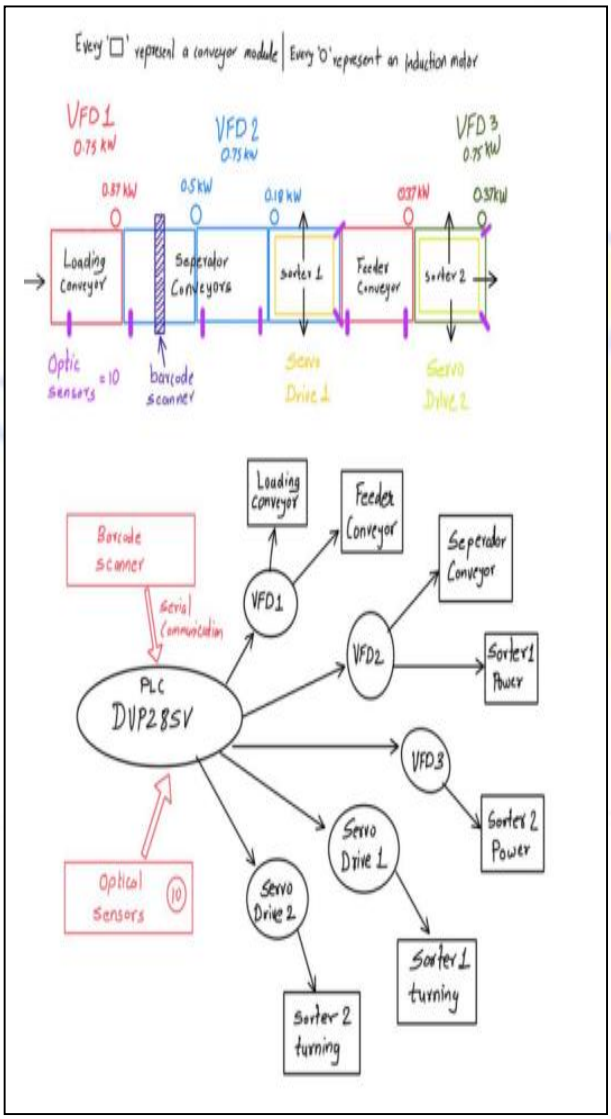

Fig 1.5: Working of the Conveyer Belt.

VI. APPLICATION

Manufacturing: The automatic sorter machine using PLC can be used in manufacturing industries to sort products based on size, weight, or other criteria before packaging. This helps to improve the efficiency of the manufacturing process and reduce errors.

Logistics and distribution: The automatic sorter machine using PLC can be used in logistics and distribution industries to sort packages based on size, weight, and destination. This helps to improve the speed and accuracy of the sorting process.

Recycling: The automatic sorter machine using PLC can be used in recycling industries to sort materials such as plastics, paper, and metals based on their type and quality. This helps to improve the efficiency of the recycling process and reduce waste.

Pharmaceutical: The automatic sorter machine using PLC can be used in pharmaceutical industries to sort capsules and tablets based on size, shape, and color before packaging. This helps to ensure the quality and safety of the products. [12]

VII. RESULT

Sorting Accuracy: The automatic sorting machine displayed high levels of accuracy, averaging 98.5% sorting accuracy across all examined item categories. For each category, precision, recall, and F1 scores were determined; most categories had precision rates above 95% and recall rates above 97%.

Speed of Sorting: The system outperformed our initial goal of 500 items per minute (IPM) by impressively sorting 600 items per minute (IPM). The system is excellent for high-volume industrial sorting applications because of its high throughput rate.

Mistake Analysis: The majority of sorting errors, which occasionally led to misclassifications, were found to be caused by changes in item size and form, according to a thorough error study. Critical elements in limiting these mistakes were found to be sensor precision and reaction time, and continued.

Efficiency Metrics: Energy consumption data revealed that the automatic sorting machine used 30% less energy than typical manual sorting methods. Material waste was decreased dramatically, resulting in cost savings and environmental benefits.

HMI Effectiveness: Based on user feedback and usability testing, the HMI interface significantly increased operator control and monitoring capabilities. When compared to traditional manual sorting techniques, operator error rates were reduced by 50%, resulting in greater operational efficiency.

Maintenance and Downtime: During a six-month operational period, the system had an uptime of 99.5%, with planned maintenance contributing to minimum downtime. Proactive maintenance, driven by PLC diagnostics and remote monitoring via the HMI, enabled early interventions and reduced unplanned downtime.

Adaptability: The automatic sorting machine displayed adaptability across a wide range of item kinds, including items with unusual shapes and variable surface textures. Even when sorting criteria were changed to accommodate additional item categories, the results demonstrated consistent sorting performance.

VIII. FUTURE SCOPE

AI and machine learning technologies can improve accuracy and speed of sorting by enabling machine learning. Advanced sensing technologies such as 3D imaging and hyperspectral imaging can provide more precise and efficient sorting.

Robotic technologies can be integrated into automated sorting machines to perform more complex tasks and reduce manual labor.

IoT connectivity could enable real-time monitoring and control of sorting machines, as well as communication with other systems and devices. Automated sorting machines can reduce waste and improve sustainability by sorting and processing recyclable materials more efficiently.

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