

Smart Industrial Solid Waste Management System

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ABSTRACT

This paper presents a coordinated solid waste handling system including a waste moving conveyor, a solid waste crusher, and intelligent sorting components, improved by Human-Machine Interference (HMI) technology for observing and control. Considering the heightening test of solid waste management, the system means to enhance waste decrease, asset recuperation, and ecological manageability. The waste-moving conveyor gives controlled material transportation to the solid waste crusher, advancing the resulting handling stages. High-level instruments inside the crusher separate assorted solid waste materials productively. A sorting cycle, driven by programmable logic controllers (PLCs), sensors, and mechanical sorters, isolates recyclable and non-recyclable parts, directing waste streams towards reusing or removal. HMI technology works with continuous observation and control of the whole system, empowering consistent activity and information-driven navigation. The incorporation of HMI upgrades the accuracy, proficiency, and flexibility of waste handling. This paper's discoveries add to progressions in waste management works, offering an outline for practical and technology-driven arrangements.

Keywords: Solid Waste, Crusher, Intelligent Sorting, Programmable Logic Controllers (PLCs), HMI Technology.

1. INTRODUCTION

Various industries perceive the environmental and economic advantages of isolating metal and plastic waste for removal or recycling. The automotive area carries out cutting-edge arranging cycles to recover metal parts and reuse plastics from end-of-life vehicles. Electronics

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manufacturing companies fastidiously isolate metal and plastic parts from electronic waste for recycling. Packaging industries center on the partition of metallic and plastic packaging materials to empower powerful recycling drives. In addition, the shopper products area utilizes waste detachment techniques to recuperate important metals and reuse plastic compartments, adding to manageable practices and asset preservation (1). The contemporary flood in the solid waste age presents a dire requirement for creative waste management procedures that are productive, ecologically capable, and maintainable. As social orders proceed to develop and urbanize, the conventional techniques for waste removal have become progressively deficient and ecologically harmful. To address these difficulties, this paper presents a spearheading way to deal with solid waste management through the plan and execution of a coordinated waste handling system. The vital parts of this incorporated system involve a waste-moving conveyor and a solid waste crusher, supported by cutting-edge automation technology. The waste moving conveyor fills in as the underlying phase of waste dealing with, working with controlled and managed transportation of solid waste materials to the resulting handling stages. This conveyor system improves the material stream and limits functional disturbances, consequently upgrading the effectiveness of the general waste-handling process. The core of the system lies in the solid waste crusher, which is furnished with cutting-edge components fit for separating different clusters of solid waste materials. This essential part assumes a pivotal part in the waste decrease process, planning materials for ensuing sorting and isolation stages (2). The usage of trend-setting innovations in the crusher's plan guarantees ideal pulverizing productivity while limiting energy utilization and wear. Following the devastating stage, a modern sorting process is utilized, utilizing a mix of programmable logic controllers (PLCs), sensors, and mechanical sorting instruments. This intelligent sorting process productively isolates recyclable and non-recyclable parts from squashed waste materials. The subsequent waste streams are custom-fitted for capable removal and asset recuperation, encouraging manageability in waste management rehearses. The incorporation of PLCs into the system design enables continuous control and observation of activities. These PLCs computerize the working of the waste moving conveyor, the solid waste crusher, and the sorting components, upgrading execution and diminishing human intercession. The gathered information further gives experiences into waste age designs, empowering informed decision-production for future waste management methodologies (3). In synopsis, this paper presents a creative waste management arrangement that tends to the difficulties presented by mounting solid waste volumes. By joining trend-setting innovations with intelligent plans, the proposed system improves waste handling proficiency as well as adds to maintainable practices through asset recuperation and mindful removal. This study adds to

the developing scene of waste management, offering a diagram for the execution of comparable systems that line up with the standards of ecological stewardship and asset protection (5).

2. METHODOLOGY

2.1. Advancing Solid Waste Separation: A Comparison of Automated and Manual Methods

In the past, the separation of solid waste primarily relied on manual sorting methods at landfill sites and waste collection centers. Workers were tasked with physically sifting through mixed waste to identify and extract recyclable materials such as metals and plastics. This approach had several drawbacks. It was labour-intensive, requiring a significant workforce and exposing workers to unhygienic and hazardous conditions. The recovery rates were often limited due to human error, and valuable resources were lost in the process. Additionally, the manual sorting approach did not efficiently segregate hazardous or non-recyclable materials, leading to potential environmental and health risks shown in Fig.1. In contrast, our waste management system represents a considerable advancement in waste separation technology. The integration of inductive proximity sensors and PLCs automates the sorting process, eliminating the need for manual intervention (4). This results in more accurate and consistent segregation of metal waste, enhancing the overall recovery rates of recyclable materials. The incorporation of pneumatic pistons for waste crushing not only improves waste reduction efficiency but also enhances the overall safety of the operation by minimizing direct human involvement in potentially risky tasks shown in Fig.2. Furthermore, the Human-Machine Interface (HMI) provides operators with real-time insights into the system's status and performance (7). This level of visibility ensures proactive monitoring and control, reducing the chances of errors and optimizing the entire waste processing operation. Our approach significantly reduces the exposure of workers to hazardous conditions and boosts the overall efficiency of the waste separation process. It also contributes to a more sustainable waste management solution by increasing resource recovery rates and minimizing the environmental impact of improper waste disposal. In comparison to traditional manual sorting methods, our system offers enhanced efficiency, accuracy, safety, and sustainability in the separation of solid waste (6).



Figure 1. Manual Solid Waste Sorting



Figure 2.Automated Sorting System

2.2. Delta Programmable Logic Controller

A Programmable Logic Controller (PLC) is a particular computer-based control framework utilized in industrial and producing cycles to robotize and control different electromechanical operations. PLCs are intended to execute explicit errands by handling computerized and simple sources of info, executing modified logic, and delivering comparing yields. They assume an urgent part in enhancing proficiency, accuracy, and unwavering quality across different ventures. A principal part of PLCs is their ability to communicate with the actual world through data sources and results. Inputs are signs or information obtained from sensors, switches, and different gadgets that screen the condition of the controlled cycle. These data sources are handled by the PLC's focal handling unit (computer processor) in view of the customized logic, deciding the suitable moves to make (8). Yields, then again, are signals sent from the PLC to actuators, transfers, engines, and different gadgets that impact the interaction. PLCs can deal with different kinds of data sources, including computerized inputs that address twofold states (on/off), and simple data sources that action ceaseless factors like temperature or strain. Essentially, results can be computerized or simple, permitting the PLC to control discrete gadgets or direct simple qualities inside the cycle. The connection between data sources and results lies at the center of a PLC's usefulness (9). By getting and handling input signals and afterward creating yield signals in view of modified logic, PLCs empower the automation of complicated undertakings. This automation upgrades efficiency, precision, and security in industrial conditions. PLCs can be customized to execute assorted operations, from basic logical choices to mind-boggling control groupings, working with the execution of assignments that would be unreasonable or mistake-inclined whenever done physically. In this project Delta DVP12SA2 module with eight digital inputs and six digital outputs, Program capacity up to 16k ladder steps and high executing efficiency, RS-232, RS-485 built-in com ports and it can be used as master or slave is shown in Fig.3

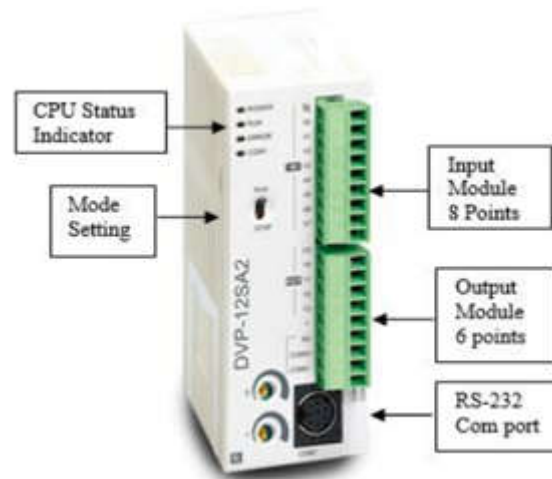


Figure 3. Delta Programmable logic controller DVP12SA2

2.3. Delta Human Machine Interference (HMI)

With regards to the waste processing system portrayed before, the Human-Machine Point of interaction (HMI) fills in as a crucial part that overcomes any barrier between administrators and the mechanized cycles. The HMI, frequently introduced as a graphical UI on a touch-screen board, gives a natural means to administrators to cooperate with and screen the system's tasks continuously. Through the HMI, administrators can get a visual portrayal of the whole waste processing system, including the waste moving transport, strong waste smasher, arranging instruments, and related parts. This visual portrayal shows constant information, like the situation with sensors, the development of waste materials, and the initiation of arranging components (10). By introducing this data in an unmistakable and understandable way, the HMI engages administrators to settle on informed choices, analyze issues, and answer speedily to changing circumstances inside the system. The HMI additionally works with control over the waste processing system. Administrators can start or stop processes, change functional boundaries, and design arranging measures straightforwardly from the touch-screen interface. This consistent collaboration smoothest out system the board, decreasing the requirement for manual mediations and upgrading functional proficiency. Moreover, the HMI upgrades system diagnostics and investigation. It can show alarms, alerts, and notices regarding unusual circumstances, breakdowns, or deviations from anticipated execution. This proactive methodology empowers administrators to distinguish and resolve issues expeditiously, limiting margin time and guaranteeing nonstop system usefulness (11). The combination of HMI technology into the waste processing system not only enables administrators with continuous experiences and control but also adds to improved well-being by permitting administrators to

cooperate with the system without direct actual commitment from a distance. In general, the HMI fills in as a crucial device that lifts the proficiency, control, and convenience of the waste processing system, lining up with present-day modern practices zeroed in on client-focused robotization and cycle streamlining. In this project, Delta HMI is used to monitor and control, and DOPSOFT is used to program the HMI shown in Fig.4

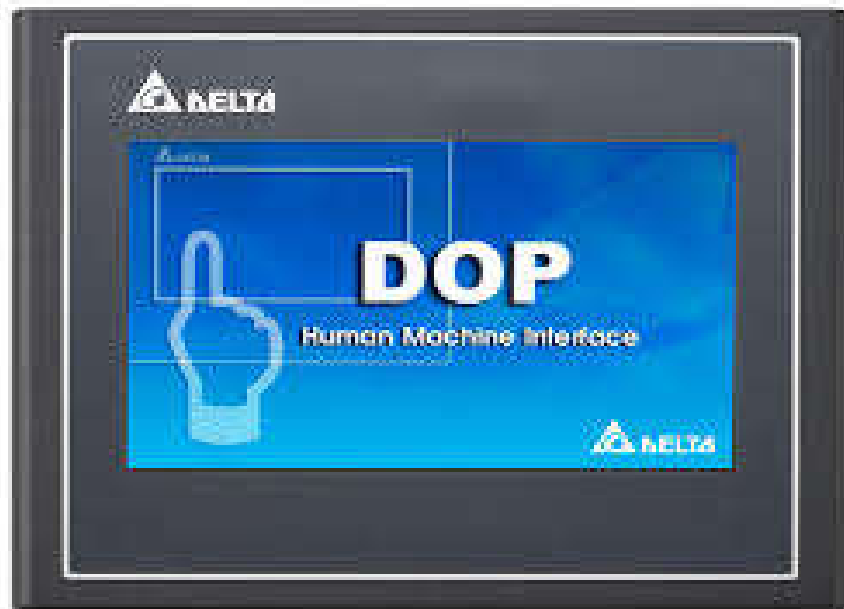


Figure 2. Delta Human Machine Interference

2.4.. Sensors and Actuators

The waste processing system depicted in this undertaking utilizes various sensors and actuators to work with productive and computerized waste sorting and taking care. Sensors are instrumental in recognizing and gathering continuous information from the climate, while actuators are liable for executing control activities in view of this information. Inductive proximity sensors are decisively situated along the waste-moving conveyor's way to identify the presence of metallic items (12). These sensors create signals when metallic waste things pass inside their location range. These signs are then communicated to programmable logic controllers (PLCs), starting the sorting system. The PLCs initiate relating actuators, which could incorporate pneumatic pistons or mechanical arms, to redirect the metallic waste things from the vital waste stream to an assigned assortment compartment. Actuators, like motors and solenoids, are additionally fundamental for controlling the development of the waste-moving conveyor and the activity of the solid waste crusher. These actuators answer signals from the PLCs, guaranteeing exact control over the transport and processing of waste materials (13). The waste-moving conveyor itself depends on an engine to ship waste things along its way, while

the solid waste crusher consolidates mechanisms to separate waste materials. Besides, the Human-Machine Connection point (HMI) fills in as a basic point of interaction that permits administrators to communicate with the system. The HMI uses contact screen technology as an info mechanism, and it gives visual input and constant information to administrators, permitting them to screen and control the whole cycle. Through the HMI, administrators can start activities, adjust settings, and get cautions with respect to system status (14). Aggregately, the reconciliation of sensors and actuators related to the HMI improves the system's automation, accuracy, and versatility. This strategy enables the waste processing system to productively distinguish, sort, and oversee waste materials, adding to improved asset recuperation, waste decrease, and by and large maintainability pneumatic piston and proximity sensor shown in Fig.5 and Fig.6

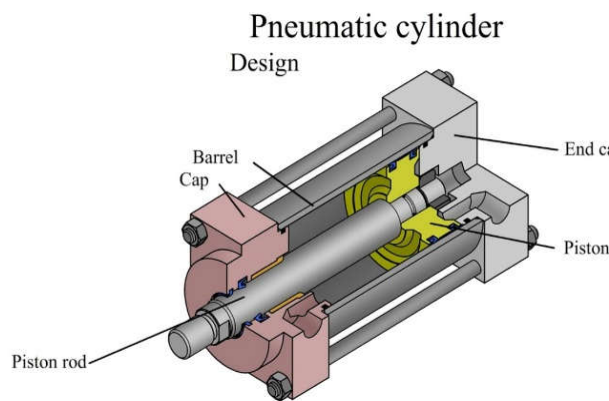


Figure 5. Pneumatic piston

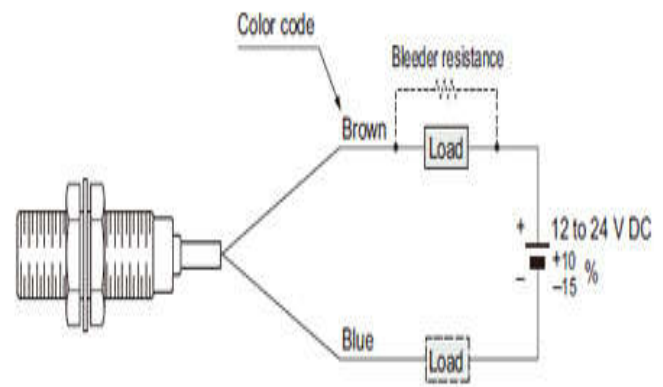


Figure 6. Inductive proximity sensors

2.5. PLC Methodology Implementation on Solid Waste Management System

The execution of Programmable Logic Controllers (PLCs) inside the solid waste administration system fills in as the foundation of automation and control, organizing different cycles to accomplish proficient waste dealing and asset recuperation. The PLC approach includes a few vital stages to guarantee consistent and powerful activity. The interaction starts with the coordination of sensors decisively situated along the waste-moving conveyor. These sensors, like inductive proximity sensors, screen the approaching waste stream for explicit qualities, like metallic parts. When set off by the sensor inputs, the PLCs start a grouping of activities. Endless supply of metallic waste things, the PLCs initiate the pneumatic cylinders coordinated into the solid waste crusher. These cylinders apply controlled power to squash the waste materials productively (15). The PLCs deal with the timing and coordination of the pneumatic cylinders, guaranteeing improved material decrease while forestalling jams or risky

circumstances. At the same time, the PLCs start the sorting mechanisms. This includes initiating mechanical arms, air jets, or other sorting gadgets to redirect the identified metallic waste things from the super waste stream into assigned capacity holders. The non-metallic waste things proceed with the conveyor for additional processing or assortment. To furnish administrators with an obvious sign of this sorting system, the Human-Machine Connection point (HMI) shows continuous visuals of the sorting activities, offering knowledge into the fruitful redirection of metallic waste things. On account of the devastating system, the HMI likewise gives a visual sign. As the pneumatic cylinders are enacted by the PLCs for waste pulverizing, the HMI shows related illustrations or liveliness, permitting administrators to notice the crusher's activity continuously (16). This visual criticism improves administrator certainty and comprehension of the cycle. The PLCs assume a significant part in information securing, processing, and navigation. They ceaselessly screen the sensor inputs, system status, and criticism from different parts. This constant information illuminates the PLCs' logic, empowering them to pursue canny choices regarding material isolation, crusher actuation, and sorting mechanism coordination. All in all, the PLC strategy's execution inside the solid waste administration system addresses a comprehensive way to deal with automation, control, and enhancement. Via consistently organizing sensor inputs, pneumatic cylinders, and sorting mechanisms, the PLCs work with proficient waste decrease, material isolation, and asset recuperation (17). The joining of an HMI improves administrator oversight and system customization, offering visual signs of sorting and squashing processes, and at last, adding to a supportable and smoothed-out waste administration process shown in Fig.7 and 8

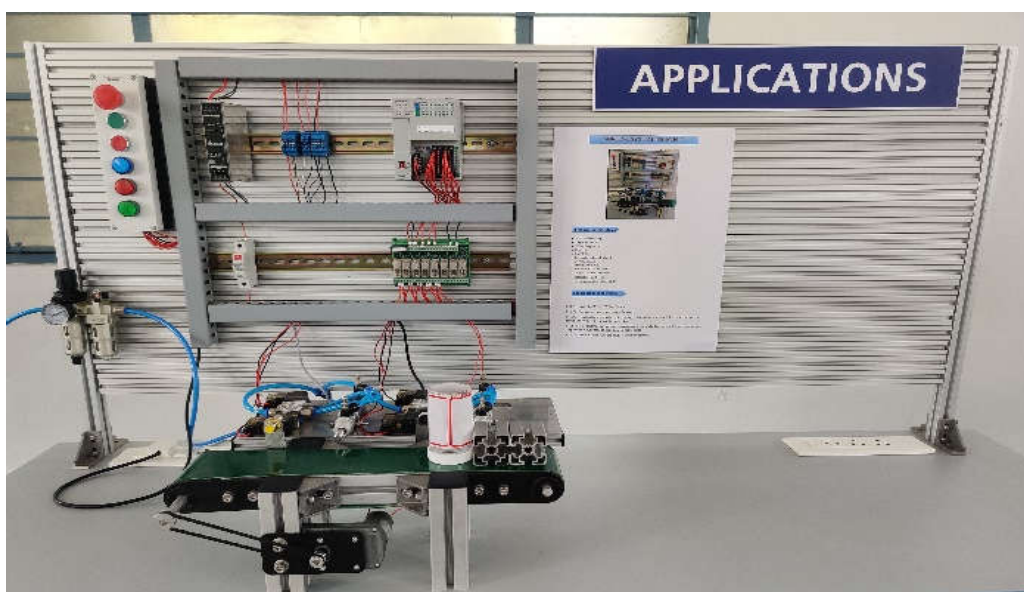


Figure 7.Metal Shorting Conveyor

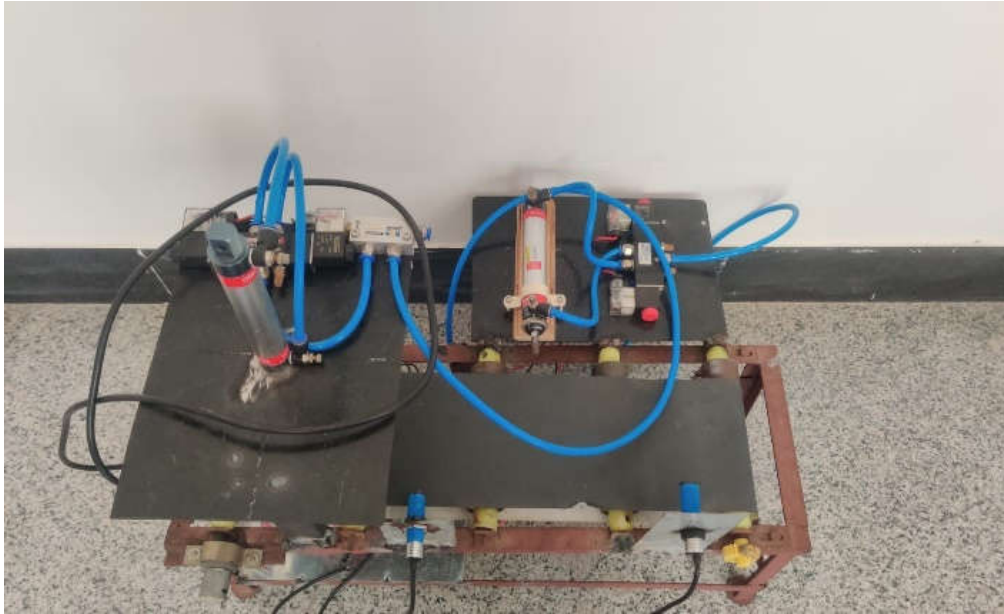


Figure 8.Crushing Machine

3. RESULTS AND DISCUSSION

3.1. Ladder Diagram development on WPL software

The development of the Ladder Diagram utilizing the WPL (Waste Processing Logic) software yielded promising outcomes, successfully exhibiting the automation and control functionalities of the solid waste administration system. The Ladder Diagram is filled in as the visual portrayal of the control logic executed through the Programmable Logic Controllers (PLCs), coordinating the different phases of waste processing. Through systematic programming utilizing WPL, the sensor inputs were effectively incorporated into the control logic. The Ladder Diagram precisely answered the signs from the inductive proximity sensors, setting off the actuation of the pneumatic cylinders for waste pounding and starting the sorting mechanisms (18). The graphical point of interaction of the WPL software worked with the creation and game plan of ladder logic components, guaranteeing an intelligent and coordinated portrayal of the control succession. Conversation encompassing the Ladder Diagram development centres around its dependability, adaptability, and easy to use interface. The logic planned through WPL showed hearty responsiveness to ongoing sensor inputs, reliably captivating the suitable mechanisms for waste processing. The measured quality of the Ladder Diagram empowered simple alteration and extension of the control succession, working with future system upgrades or transformations. Additionally, the representation given by the Ladder Diagram supported fathoming the system's working, making investigating and diagnostics more available. The logical progression of the diagram worked with clear correspondence among

project partners, cultivating cooperation and arrangement about the automation processes. The fruitful development of the Ladder Diagram utilizing the WPL software highlights the meaning of powerful programming apparatuses in modern automation. The result features the similarity of WPL with the solid waste administration system, mirroring its commitment to proficient waste decrease, isolation, and asset recuperation (19). This accomplishment additionally positions the venture well for additional improvements, underscoring the potential for consistent advancement in waste administration automation. Ladder logic diagram shown in Fig.9 and Fig.10

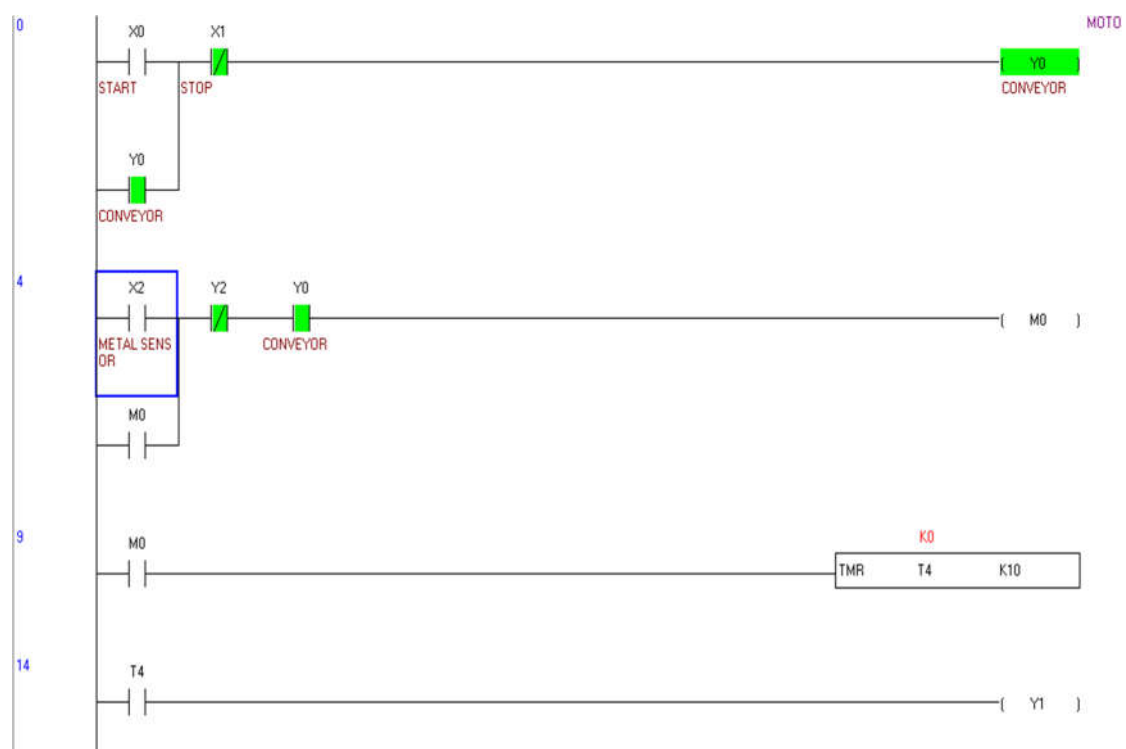


Figure 9. Logic for Metal and Non Metal Sorting System



Figure 10. Logic for Crushing System

3.2. HMI working Screen development of Solid Waste Management system

The development of the Human-Machine Connection Point (HMI) working screen for the portrayed solid waste administration system ended up being an essential part of the venture, improving functional permeability and control. The HMI screen furnished administrators with a thorough visual portrayal of the whole waste processing process, passing on constant data and empowering intuitive commitment. The HMI working screen integrated a few critical components to work with successful system observing and control. At the front, the screen showed a powerful flowchart portraying the grouping of tasks, from the waste contribution on the conveyor to the sorting and squashing processes (20). This visual flowchart permitted administrators to follow the advancement of waste materials, acquiring experiences in their ongoing stage inside the system. For the sorting system, the HMI screen exhibited the enactment of sorting mechanisms through visual pointers, for example, energized symbols or variety changes. As the inductive proximity sensors distinguished metallic waste things, the HMI gave constant input, featuring the effective recognizable proof of metal and the ensuing redirection of these things for reusing. Also, the HMI showed the enactment of the pneumatic cylinders during the devastating system. This was shown through graphical movements that reproduced the devastating movement, furnishing administrators with a visual affirmation of the continuous waste decrease process (13). As far as usefulness, the HMI working screen additionally

empowered administrators to intercede when essential. Crisis stop buttons and manual supersede choices were conspicuously shown, guaranteeing that administrators could rapidly end or change processes if there should be an occurrence of unanticipated conditions. The UI of the HMI was planned considering ease of use, highlighting the natural route and clear marking. Administrators could get continuous information about the situation with sensors, hardware, and by and large system well-being. Authentic information, patterns, and cautions were effectively available for investigation and informed direction. The fruitful development of the HMI working screen highlights its job as a scaffold among administrators and the automation system. The connection point's dynamic representation and intuitive components engaged administrators to screen, control, and fathom the waste processing tasks successfully (6). This accomplishment adds to the task's general target of effective solid waste administration and positions the HMI as a pivotal device for improving system execution, security, and supportability. The HMI working screen is shown in Fig.11

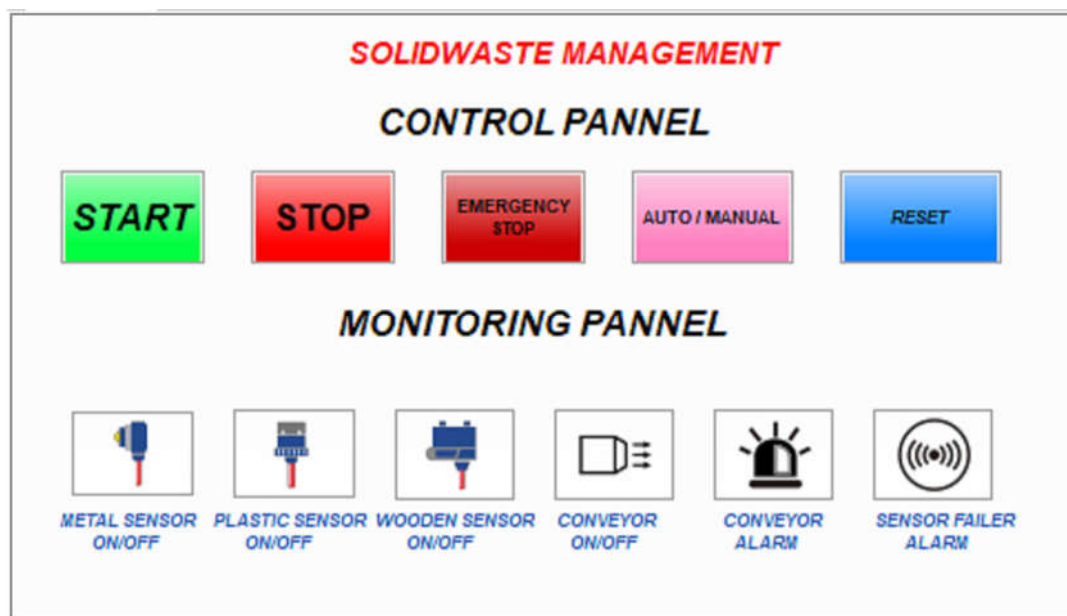


Figure 11.HMI Screen for Solid Waste Management

IV.CONCLUSION

Our solid waste management system embodies a transformative approach to addressing the challenges of waste handling and resource recovery. By harnessing the power of automation, advanced sensor technology, and efficient control mechanisms, we have successfully engineered a system that optimizes waste reduction, enhances material segregation, and promotes environmental sustainability. The integration of inductive proximity sensors and

PLCs eliminates the reliance on labour-intensive and error-prone manual sorting methods, ensuring accurate identification and separation of metal waste. The utilization of pneumatic pistons for crushing not only enhances waste reduction efficiency but also prioritizes safety by minimizing direct human involvement in potentially hazardous tasks. The inclusion of the Human-Machine Interface (HMI) empowers operators with real-time insights and control, streamlining monitoring and enabling informed decision-making. By amalgamating these technological advancements, our waste management system achieves unprecedented precision, efficiency, and eco-consciousness. Valuable resources are reclaimed through meticulous sorting, contributing to circular economies and minimizing waste's impact on the environment. Our system not only addresses immediate waste management challenges but also aligns with global sustainability goals, emphasizing responsible resource management and reduced environmental degradation. As we move forward, this innovative solution sets a benchmark for waste management practices, inspiring other industries to adopt technology-driven approaches for a cleaner, greener future.

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