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IoT-Based a Control System for Household Waste Management Machines at Waste Disposal Sites using Human Machine Interface method

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Abstract

To manage waste efficiently and sustainably, *Integrating Algoritma Bellman-Ford in IoT-Based Control Systems for Household Waste Management Machines, the use of automation technologies based on the Internet of Things (IoT) is becoming increasingly relevant. The integration of HMI allows operators to manage and control the machine with precision and convenience. The synergy between IoT and HMI promises significant improvements in waste processing speed, accuracy, and safety. Developing a control system using the HMI method is not just a solution but an innovative approach that aims to find an effective solution in managing or destroying waste that requires less labor, so there is no need to increase assistance. The method that will be used in this research is the descriptive statistical method, namely, assessing the technical data needed to develop a control system that complies with the standard. This innovative approach is one of the solutions to the problem of labor shortages in landfills that simplify work and speed up the process of operating machines.*

Keywords: *IoT, Pyrolysis, Interlock system and interface, wet high-efficiency cyclone system, Human Interface, Motor Star Delta, Bellman-Ford Algorithm*

1. Introduction

Population growth is directly proportional to the amount of waste generated every day. A developing region's population density generally increases in direct proportion to the rate of development. One of the results of increased development, population growth, societal activities, and socioeconomic levels has resulted in a rise in trash accumulation. In Indonesia, there is a significant potential for utilizing waste to generate electricity and reduce carbon emissions. The importance of this research in addressing the problem of waste accumulation cannot be overstated. Indonesia's total national power capacity is approximately 1,879.59MW, producing around 168 million tons of carbon emissions annually. This is equivalent to the emissions produced by 80 million 4-wheeled vehicles annually. It is important to note that this calculation does not include the planned addition of 27 GW of new power plants. The 35 GW program is expected to add 162 million tons of carbon emissions annually. We can significantly reduce these emissions by harnessing the potential of waste utilization.

IT-PLN took the initiative to reduce existing waste problems by developing waste management machines using the human-machine interface method to make waste processing more efficient and optimized [3]. In an increasingly connected modern era, waste management is a global challenge that requires innovative solutions. The Internet of Things (IoT), as an idea for connecting devices and systems through networks, offers excellent potential for optimizing waste management. [3]Excessive waste is a prevalent problem in Indonesia that will persist without significant efforts to address it. The consequences of this problem are far-reaching, affecting various aspects of life, including the environment, aesthetics, health, and social well-being. The problem is escalating. Foul-smelling waste has a negative impact on the environment.

One crucial aspect of waste management is non-incinerator waste processing, and in this context, the pyrolysis method stands out as a promising alternative [1], [2]. Pyrolysis is a thermochemical process in which organic matter is decomposed into simpler products through heating at high temperatures and low pressure. Pyrolysis can convert organic waste into biochar, oil, and gas products in waste treatment. However, the efficiency and safety of the pyrolysis process must be carefully considered. IoT-based automation systems offer the potential to improve efficiency and accuracy in waste management [4]. Human interface integration (HMI) allows operators to interact with the machine intuitively, optimizing operation and monitoring. In this study, we focus on developing a control system for a household waste management machine that uses the non-combustion pyrolysis method and is equipped with a wet, high-efficiency cyclone. This study explores the potential use of IoT and HMI in managing household waste management machines.

Previous research [6] In his research, the author proposed that the TOSS (Local Waste Processing Place) is a stage in the People's Electricity method of producing waste briquettes as an energy source through a recycling process to solve the problem of urban waste and utilization of PLTD fuel. The results of the outreach increased local community knowledge. They directly and independently implemented how to process waste to be used as electricity to ensure energy availability and community access to energy at affordable prices while still paying attention to environmental sustainability.

2. Research Methods

2.1. Internet of Things (IoT)

The Internet of Things (IoT) is the convergence of the Internet with smart objects to exchange real-world information. In the Industry 4.0 era, IoT is a technology that supports industrial change. Here are some important aspects related to IoT[3]:

a. IoT Architecture Things are objects equipped with sensors and actuators. Examples include refrigerators, streetlights, vehicles, and production machines. Gateways Provide connectivity between things and the cloud. They enable data preprocessing and filtering before moving it to the cloud. Cloud Gateways facilitate data compression and secure data transmission between gateways and IoT cloud servers.
b. IoT can optimize the management of household waste bins. One way to apply IoT to waste management systems is to install Smart Sensors on Trash Cans. Ultrasonic sensors or capacity sensors can be installed on waste bins to measure the level of waste contents. This sensor will send data to the control system via the IoT network. Arduino or Microcontroller as System Controller: An Arduino Uno or similar microcontroller can be used as the system's brain. This microcontroller will receive data from sensors and make decisions based on the condition of the trash can. Servo Motor to Open and Close the Trash Can Lid: Servo motors can move the trash can lid. Based on data from the sensor, the servo motor will automatically open or close the garbage can lid. Visual and Sound Indicators: The LED, or indicator light, can light up when the trash can is full. A buzzer or indicator sound can provide a notification when an object approaches the trash can. Internet Connection and Remote Monitoring: This system will connect via WiFi or cellular

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technology. Cleaning officers can monitor the condition of the trash can remotely via an application or web platform.

Implementing IoT can make managing household trash cans more efficient, reducing manual work and ensuring that trash cans don't overflow.

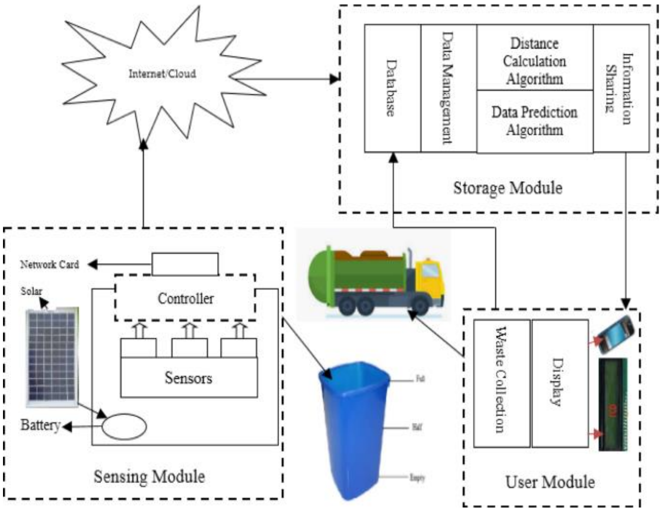

Figure 1. IoT can Optimize The Management of Household Waste Bins to Apply IoT to Waste Management System

2.2. Bellman-Ford Algorithm

The Bellman-Ford algorithm can help optimize waste management by finding the shortest waste collection route. This algorithm calculates the shortest distance from the waste collection point to the disposal location. [9]. By finding the shortest routes, waste trucks can visit more collection points in less time. To schedule waste transportation based on calculation results, the algorithm helps organize the waste transportation schedule. Pickup trucks can be directed to full bins first. Optimizing resource use By knowing the shortest route, fuel use and time can be optimized, reducing operational costs and environmental impacts. Problem Detection on Routes The algorithm can detect routes with negative weights (for example, damaged roads). This helps avoid inefficient routes. By implementing this algorithm, waste management can become more efficient and sustainable.

This algorithm was developed by Richard Bellman and Lester Ford, Jr. This algorithm is very similar to Dijkstra's algorithm, but this algorithm can handle weights. Negative in finding the shortest path in a weighted graph. Bellman-Ford algorithm is a development of the Dijkstra Algorithm; the Bellman-Ford Algorithm will be correct if and only if the graph contains no cycles with negative weights reached from the source. The algorithm steps are generally as follows (Cormen, 2009) to determine the vertex source and list all vertices and edges. Then, assign a value for the distance from the vertex source of 0. The others are infinite and start iterating over all vertices related to the source vertex with the following formula:

$$U = Origin\ Vertex$$
$$V = Destination\ Vertex$$
$$UV = Edges\ that\ connect\ U\ and\ V$$

If idistance V is smaller than idistance U + weight UV, then idistance V is filled in. with idistance U + iweight UV. Lastly, do this until all vertices are explored.

In summary, the Bellman-Ford algorithm is a powerful tool for finding shortest paths, especially when dealing with graphs that have negative edge weights.

2.3. The Roadmap and Program Design

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Human Machine Interface is a tool or machine used as an interface for a particular process in a control system. Human Machine Interface (HMI) is a system that connects humans and machines. HMI can be used to control and visualize status either manually or through real-time computer visualization. The purpose of using this HMI HMI / Human Machine Interface is to visualize data in the form of graphs, diagrams, and other forms that humans can read. The main task of this HMI is to visualize a specific process of the machine automation system.

Figure 2. Human Machine Interface

HMI (Human Machine Interface) functions include providing an operating system on the panel for operators, interpreting interactions between humans and machines, monitoring factory conditions, setting factory parameter settings, responding appropriately if something unusual happens, sounding an alarm as warning signs, and displaying data patterns of events in the plant in real-time and over time.

The HMI display has two sorts of displays: static objects, which are directly linked to equipment or databases. Examples include static text and production unit layout. Second, dynamic objects enable operators to engage with processes, equipment, or databases while performing control operations. Examples include push buttons, lights, and charts. Last is alarm management; an extensive production system can monitor many alarms, which may confuse the operator. The operator must acknowledge each alarm to take appropriate action based on the type of alarm. As a result, alarm management is required to decrease unnecessary alarms.

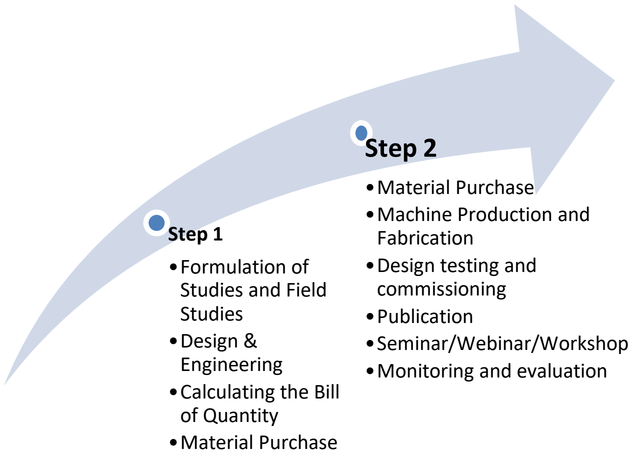

Figure 3. Research Plan

The research plan has been fully implemented. Start by forming formulas, searching and researching the literature review, design engineering, and calculating the costs, the manufacturing process, and the output required in the research being carried out.

2.4. Research Design

The method used in this research is a combination research method. The combination is a research method that combines both quantitative and qualitative methods. Quantitative methods are based on the philosophy of positivism, Which is conducted to study a certain population or sample. Meanwhile, based on the philosophy of post-positivism, which is used to study natural subjects and inductive data natural subjects, inductive data analysis and processing is carried out in triangulation. Data collection: This stage is carried out to collect data related to the research by direct observation, then analyze the data to complete clarity and completeness, describe the data in completeness, and describe the data in tabular form.

The following figure depicts a research flow diagram.

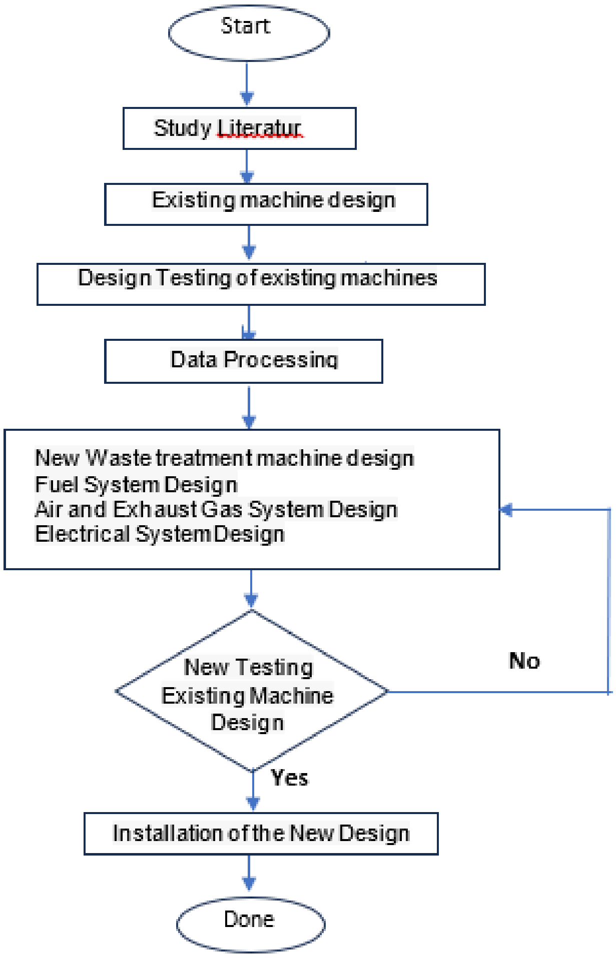

Figure 4. Research Flow Diagram

Based on research from [15]It is stated that the human-machine interface has a 100% success percentage in conveyor machine simulations. This shows that the presence of a human-machine interface does not affect the performance of the conveyor system. Still, the presence of the human-machine interface feature makes processes in the industry easier. Other research results from [16] Show that the sorting station control system can work according to real-time performance monitoring with the HMI control function during operation. Research from [3] states that combining the system with information technology can enable trash cans to be monitored remotely. The automatic motor drive can make it easier for people to dispose of rubbish. Other research from [17][18] shows that the working principle of smart trash cans with an IoT platform can be monitored and provide notifications to users or cleaning staff, as well as the application of capacitive proximity sensors and inductive proximity sensors in IoT-based smart trash cans for sorting metal and dry waste. And wet has been successfully realized. Waste will automatically be sorted according to each type. Based on previous research results, we are researching developing a control system for household waste management machines at landfills using the human-machine interface method.

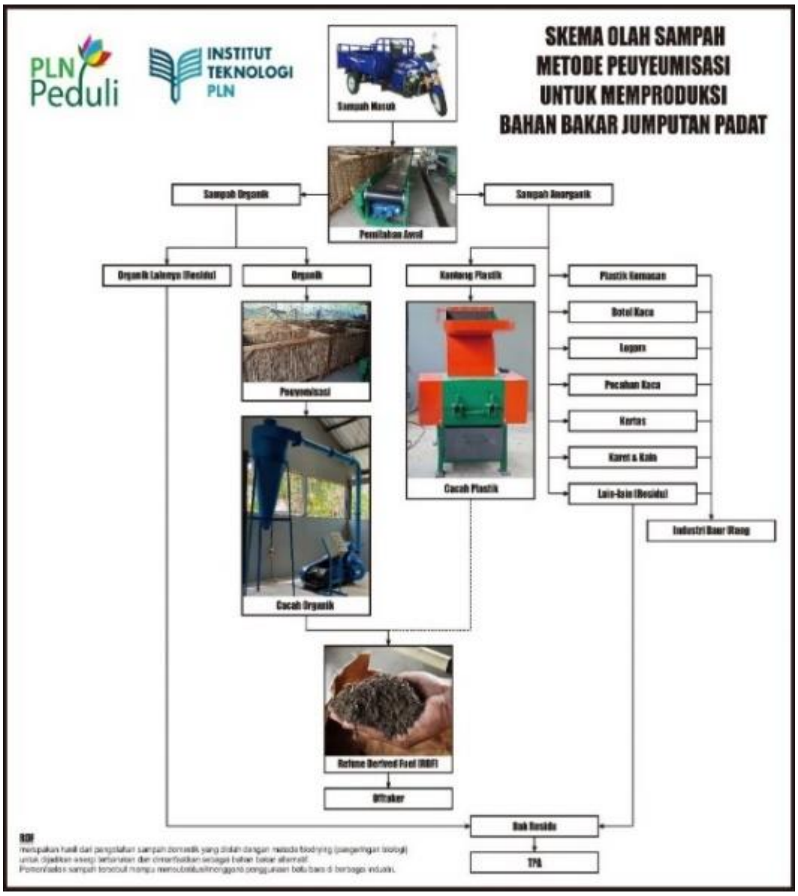

Figure 5. Research Design

West to Energy Engine Power Requirements. To start Electrical Installation planning, calculations are needed regarding the power requirements in each component of the electrical machinery in the Workshop. Here are the specifications of all the machines used.

Table 1. Machine Type

No	Machine Type	Power
1	Plastic Shredding Machine	20 kW
2	Organic Shredding Machine	22 kW
3	Belt Conveyor Machine	0.75 kW
4	Mixer Machine	3 kW

After knowing the specifications of each machine in the Workshop, it is necessary to calculate the electricity usage of each machine. The following is the calculation:

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Conveyor Belt Machine with 0,75kW power
$P = Vx\ I\ x\ cos\ \ phi\ \sqrt{3}$
$750\ W\ =\ 380\ V\ X\ \ I\ X\ 0{,}5\ X\ \sqrt{3}I\ =\ 750\ W\ /\ 329{,}089\ V$
$I\ =\ 2{,}279\ A$

Plastic shredding machine with 22kW power
$P = V\ \times I \times\ \ cos\ \ phi\ \sqrt{3}$
$22.000\ W\ =\ 380\ V\ X\ \ I\ X\ 0{,}5\ X\ 3$
$I\ =\ 22.000\ W\ /\ 329{,}089\ V$
$I\ =\ 66{,}851\ A$

Organic Shredding Machine with 20kW power
$P = V\ \times I \times\ \ cos\ \ phi\ \sqrt{3}$
$20.000\ W\ =\ 380\ V\ X\ I\ X\ 0{,}5\ X\ 3$
$I\ =\ 20.000\ W\ /\ 329{,}089\ V$
$I\ =\ 60{,}773\ A$

Mixer Machine with 3kW power
$P = V\ \times I \times\ \ cos\ \ phi\ \sqrt{3}$
$3.000\ W\ =\ 380\ V\ X\ \ I\ X\ 0{,}5\ X\ 3$
$I\ =\ 3.000\ W\ /\ 329{,}089\ V$
$I\ =\ 9{,}116\ A$

Calculation of apparent power in each machine in the workshop:
Conveyor Machine
$P\ =\ V\ x\ I$
$P\ =\ 380V\ X\ 2{,}279\ A$
$P\ =\ 866{,}02\ VA$

Plastic Shredding Machine
$P\ =\ V\ x\ I$
$P\ =\ 380V\ X\ 66{,}851\ A$
$P\ =\ 25.403\ VA$

Organic Shredding Machine
$P\ =\ V\ x\ I$
$P\ =\ 380V\ X\ 60{,}773\ A$
$P\ =\ 23.093\ VA$

Mixer Machine
$P\ =\ V\ x\ I$
$P\ =\ 380V\ X\ 9{,}116\ A$
$P\ =\ 3.464{,}08\ VA$

Table 2. Machine Calculation on Workshop

Machine Type	Capacity (kW)	Power (Va)	Energy Consumption	Cost (IDR)/day
Conveyor Belt Machine	0,75	866,02	3,75	5.415

Machine Type	Capacity (kW)	Power (Va)	Energy Consumption	Cost (IDR)/day
Plastic Shredding Machine	2	25.403	110	158.840
Organic Shredding Machine	20	23.093	100	144.400
Mixer Machine	3	3.464,08	15	21.660
Total		48.496	228,75	330.315

Installation Planning
The waste briquette production process plan requires land to accommodate several processing machines. It utilizes vacant land with a land area of 30m x 22.5m, covering an area of 675 m2. There are four 3-phase machines. There are six 40-watt lamps and 4 points of contact stock.

Total power used.
$W = \Sigma W\ in\ group\ 1 + \Sigma W\ in\ group\ 2$
$W = 22{,}750\ W + 23{,}000\ W$
$W = 45{,}750\ W$

So, the overall power we use in the workshop is 45,750 W. Which if we change it to VA units, the formula is
$kW = kVA\ X\ pf$
$kVA = kW\ /\ pf$
$kVA = 45{,}75\ kW\ /\ 0{,}8$
$kVA = 57{,}187$
So, the overall power we use in the workshop is 57.187 kVA.

3. Result and Discussion

The Bellman-Ford algorithm finds the shortest path from one point to all other points in a weighted graph. In this case study, we will apply the Bellman-Ford algorithm to optimize an IoT-based control system for household waste management machines at a landfill. The following are the steps and discussion regarding applying the Bellman-Ford algorithm to this case.

The IoT-based control system aims to manage household waste management machines at landfills. Human-machine interface methods are used to control and monitor machine operations. Each waste management machine is considered a node in the graph. The weight on each edge represents the distance or cost between two machines. This graph will help find the shortest path from one machine to another. Each node is assigned the value of infinity (except the starting node). The initial node is given the value 0. Iteration is carried out n times (where n is the number of nodes). At each iteration, it will check each edge and update the value of the destination node if a shorter path is found.If dist[v] + weight(u, v) < dist[u], then we update dist[u] with a smaller value. After n-1 iterations, each edge is rechecked.If it can still update the value of the destination node, then there is a negative cycle in the graph. Negative cycles indicate that there is no shortest solution. Once the iteration is complete, it will have the shortest value from the starting node to all other nodes. You can use this value to optimize IoT-based control systems.

Waste management machines are nodes, and the distance between machines is weighted on the edges. The following graph is used:
Representation Graph:
a. Each waste management machine will be represented as a node in the graph.
b. The weight on each edge represents the distance or cost between two machines.
c. The following is a graph illustrating the relationship between the machines:

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A -> B (3)
A -> C (5)
B -> C (2)
B -> D (6)
C -> D (4)
D -> A (1)

Here, (3) denotes the weight of the edges between the vertices. This graph will help us find the shortest path from one machine to another.

Initialization:

a. Each node is assigned the value of infinity (except the starting node).
b. The starting node (for example, A) is given the value 0.

Edge Relaxation:

a. Iteration is performed n-1 times (where n is the number of nodes).
b. At each iteration, we check each edge and update the value of the destination node if a shorter path is found.

For example, we update the value of B from infinity to 3 (value A + weight A->B). Negative Cycle Detection:

a. After n-1 iterations, we recheck each edge.
b. If we can still update the value of the destination node, then there is a negative cycle in the graph.
c. Negative cycles indicate that there is no shortest solution.

The final result:

Once the iteration is complete, we have the shortest value from the starting node (A) to all other nodes:

```
A: 0
B: 3
C: 5
D: 9
```

This shows that the shortest distance from A to B is 3, A to C is 5, and so on. Before relying on the results, check whether there are negative cycles in the graph. The Bellman-Ford algorithm works well for graphs with negative weights.

This study includes the following categories of electrical work:

a. Electrical installation for the pyrolysis machine.
b. An electric control panel.
c. The human-machine interaction automation system, with Key Components:
    1. Arduino Atmega 2560: Serves as a data processing center.
    2. Touch Sensor and Inductive Sensor: Detects the type of waste (organic, non-organic, and metal).
    3. Servo Motor: Used to sort and open the lid of the trash box.
    4. NodeMCU ESP8266: Connects the system to the internet network.
    5. Ultrasonic Sensor: Detects the capacity of the trash can.
    6. 16x2 LCD: Provides status information.

Production Process

The production process includes processing raw materials and supporting materials into finished materials or products. After going through a production process, the products or goods are stored in the warehouse in preparation for the marketing stage, or they can be sent directly to the buyer.

Waste Collection

The team will bring waste from the community to TPS, and then the collection process will be carried out using a garbage truck from the local government. This process is carried out at the beginning by collecting domestic waste, which is a mixture of organic and inorganic waste. From storage (initial collection), the waste is sorted into four types: organic, inorganic, items with economic value, and residue.

Waste Sorting

Conveyor machine: This conveyor belt machine specifies that it uses a power of 0.75kW, 3 Phase, and a speed of 7 meters/minute. The dimensions used on this machine are 800x70x87 cm. An inverter on the panel converts AC into AC, which can be adjusted to a desired voltage and added to the human-machine interface to make the sorting process more manageable. Because the conveyor belt machine requires a speed that is not too fast, the speed can be adjusted from the voltage to how fast we want.

Waste Destruction Process Organic Shredding Machine

The results will be processed using a 3-phase motor and a star delta configuration circuit on an organic chopping machine. The circuit reduces the star current surge in a 3-phase electric motor. When starting the motor, the circuit works by connecting the motor to the power source with a star configuration and then connecting to the power source with a delta configuration after the motor rotates. In the power circuit, we can see that there are several components, the first of which is a 3-phase MCB, so the electricity source from PLN goes directly to the MCB, which functions to protect against overload and as a circuit breaker in the event of a short circuit or short circuit. Then there are three contractors: the first is the main contractor, the second is a wye configuration, and the third is a delta configuration. There is a TOR, which also functions as a safety, and it will be connected to the motor. Also, a panel of HMI uses IoT-based control to integrate all machines. The Bellman-Ford algorithm allows the machine to operate efficiently and faster than the manual.

Plastic Shredding Machine

In addition to the organic chopping machine, there is a waste processing process using a plastic chopping machine to make RDF. A Plastic chopping machine is used to cut or chop plastic waste into small pieces of a specific size. This machine consists of several main components: a container for chopped plastic crackle (hopper), electric motor, flywheel, belt, shaft, static knife, and dynamic knife where the power used in the Plastic Shredding machine is 7.5 kW.

In the power circuit, we can see that the current enters through a 3-phase MCB, which functions as a protection against surges. Then, from the MCB, it is directly sent to the contactor and TOR. TOR here also functions as additional protection in the event of a disturbance. Then, from TOR, it will be directly connected to the three-phase motor.

In the control circuit of the star circuit for plastic chopping machines. In this circuit, we use a 1-unit MCB 1 phase, a protection in case of overcurrent. Then, after the MCB 1 phase, there is a NO NC button. The NO button serves to start or restart the motor. Then, after the NO button, contacts 13 and 14 are on the contactor, which functions as a lock so that the motor stays ON. In the plastic chopper control circuit, there is a TOR, which is an additional safety in case of interference with the motor. Then turn off the motor by pressing the OFF button.

For the human-machine interface work process, the touch sensor and inductive sensor first detect the type of incoming waste. Based on these detections, the servo motor sorts the waste and opens the lid of the appropriate box. This data is processed by the Arduino Atmega 2560 and sent via the NodeMCU ESP8266 to the server so that users can monitor waste status via a web-based application or cellphone. Data is processed by Arduino Atmega 2560 and sent via NodeMCU ESP8266 to the server. Users can monitor waste status via a web-based application or mobile phone. This system has the advantage of efficiency in the automatic sorting process in reducing manual labor. Notification: the system can send notifications when the trash bin is full, and Optimization, namely trash bin usage data, can be analyzed for further improvements. The IoT applied in the research helps use human-machine interfaces to control the operation of waste processing machines. Machines with human-machine interface panels can be connected to the internet and controlled and monitored remotely.

4. Conclusion

An IoT-based automation system for non-incinerator waste processing machines can increase efficiency and reduce environmental impact. The application of this technology can help solve the waste problem more intelligently and sustainably. Application of the Bellman-Ford algorithm to optimize an IoT-based control system for household waste management machines in landfills. Developing a control system for household waste management machines in landfills using the human-machine interface method to process waste in the form of waste particles and exhaust gas. The development of waste processing machines has been successful because of its initial objectives; they can be controlled automatically using a human-machine interface, and changes to manual/conventional machines have been replaced by the Delta Star-Delta series.

In this study, the incoming waste per day is 10 tons to be processed into Refuse Derived Fuel (RDF); after carrying out several stages of crushing from an electric machine, the Refuse Derived Fuel (RDF) produced is as much as 50% of the incoming waste. The assumption of 50% RDF results from incoming waste can be seen from several research on processing waste into RDF; for example, West to Energy in Bekasi, the project proves that the amount of incoming waste, when it has been processed with several stages to become RDF, is as much as 50% RDF. So, the total Refuse Derived Fuel (Rdf) per day is 5 tons. The price of 1kg of Refuse Derived Fuel (Rdf) is worth RP.350. Similarly, assuming that the yield from waste into Rdf is pegged to 50%, projects in Bekasi have also marketed their sales results and received a market price of Rp. 350,

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