Control System Design Analysis on Automated Guided Vehicle (AGV) at Engine Test

Yosua Alvin Adi Soetrisno[1], Eko Handoyo[2]

[1] Lecturer, Department of Electrical Engineering, Diponegoro University, Central Java, Indonesia
[2] Lecturer, Department of Electrical Engineering, Diponegoro University, Central Java, Indonesia

ABSTRACT

PT. Hino Motors Manufacturing Indonesia (HMMI) is a manufacturing company engaged in manufacturing diesel motors, assembling four/more-wheeled motorized vehicles and four/more-wheeled motor vehicle components and their accessories. One of the production units at PT. HMMI is a Drive Train Unit that produces, assembles, and tests components such as Transmission, Axle Assy, Engine Assy, and Engine Test using an Automated Guided Vehicle (AGV) as a tool to increase flexibility in planning the distribution of goods such as moving an assembled engine to a room. Engine Test for benchmarking on the machine. Automated Guided Vehicle (AGV) is a vehicle that is controlled automatically using a navigation system whose movement pattern control will follow a predetermined path. Writing this report aims to understand the working principle and analyze the control system of the AGV. Movement performance on AGV is controlled by RFID tags, such as stop, start, field change on radar, speed change, and auto-fill. The magnetic stripe is one part of the navigation system. The AGV will follow a track made of adhesive magnetic tape affixed to the floor. The control system on the AGV consists of two main controls controlling the AGV, namely PLC as a performance control and signaling on the AGV and CIZON controller as the primary navigation control on the AGV.

Keywords: *Automated Guided Vehicle (AGV), Industrial Robot, Line Follower Robot, Radio Frequency Identification (RFID)*

1. INTRODUCTION

The application of automation technology in the industrial world is very much at this time. The application of technology is intended to make it easier for humans to complete work. In logistics, efficiency and effectiveness are fundamental things that must be appropriately managed. Suppose these two things are not handled properly. In that case, it will result in more significant costs incurred, and the processing time in logistics also runs longer, so the quality of distribution services to customers or users will decrease.

To overcome this problem, industry and warehouses have used a robotic technology called AGV (Automated Guided Vehicle) to optimize material handling systems and as an alternative to solve the issues related to distribution system problems. PT. Hino Motors Manufacturing Indonesia (HMMI) is a manufacturing company that uses AGV to optimize material handling systems, such as moving the assembled engine to the Engine Test room to benchmark the machine [1].

In the manufacturing process, the AGV is a vehicle with hardware, software, sensors, and actuators responsible for directing the movement according to the planned route. The primary difference is that the AGV is guided and driven automatically without using a rider. The problem formulation of this research is based on the operating system, workflow, control, navigation system, and Human Machine Interface of the Automated Guided Vehicle in Engine Test.

2. THEORETICAL FOUNDATION

2.1 Automated Guided Vehicle (AGV)

Automatic Guided Vehicle (AGV) is generally used to identify vehicles capable of moving and performing specific tasks independently without operator assistance. Different AGVs are used in almost every finished goods manufacturing industry to carry a wide variety of products (usually using pallets). The functions performed by the AGV are similar to those of human-driven lift trucks [2].

2.2 Magnetic Sensor

The magnetic sensor on the AGV functions to detect the magnetic field above the magnetic tape in the horizontal and vertical directions and continuously calculates the actual deviation diagonally in the order of travel. Magnetic sensors will measure how far from the tape's center and provide information to the motor controller, which will adjust the steering wheel to keep the vehicle in the middle of the track. Magnetic tape is easy to install and is not affected by dirt.

2.3 Proximity sensor

The proximity sensor is a sensor or automatic switch that detects metal based on the distance it has obtained, meaning how close the sensor can detect the object. When this sensor is working or detects the presence of metal (iron), it will be marked with a small red or green light at the top of the sensor. It makes monitoring easier if there is a working scenario of the detection sensor.

2.4 Radar sensor

Radar is an abbreviation of Radio Detection And Ranging, which means an electromagnetic wave system that is useful for detecting, measuring distances, and making a map of objects in the vicinity. Electromagnetic waves emitted and reflected from a particular thing will be captured by the receiver. By analyzing the reflected wave, the reflector can be located [3].

2.5 RFID (Radio Frequency Identification)

Radio Frequency Identification (RFID) is a general term for non-contact technology that uses radio waves to identify people or objects automatically. RFID uses radio frequencies to read information from a small device called a tag or transponder (transmitter and responder). The RFID tag will recognize itself when it detects a signal from a compatible device, namely an RFID reader (RFID reader) [2].

RFID systems, tags, or transponders are generally attached to an object. Each tag can carry unique information, including serial number, model, color, place of assembly, and other data about the object

When this tag passes through the field generated by a compatible RFID reader, the tag will transmit the information contained in the tag to the RFID reader so that the object identification process can be carried out.

2.6 Motor

In the Motor Automated Guided Vehicle (AGV) section located at PT Hino Motors Manufacturing Indonesia, it has several servo motors and motor drivers as drivers from the AGV in the form of Driving Motor and Turning Motor sections for AGV navigation and Roller Motors as conveyors to deliver the engine pallet where all servos The motor is controlled via a servo motor driver.

A servo motor, also known as a control motor, is a rotary device or actuator (motor). The engine is designed with a closed-loop feedback control system (servo), so it can be adjusted to determine and ensure the angular position of the motor output shaft. The use of servo motors on the AGV is used to move and provide the direction of the wheels on the AGV, and servo motors are also used on conveyors to deliver the engine to the engine test room for benchmarking.

The Pulse Width Modulation (PWM) technique is often used in regulating motor speed. The PWM technique works on the motor by providing a stable voltage source and a fixed working frequency, but the way to adjust the engine's momentum is by changing the amount of ton duty cycle pulses. Tons of varying duty cycle determines the motor's speed according to needs. A motor driver will control each servo motor, communicating with the PLC and CIZON Controller on the AGV.

2.7 Programmable Logic Controller (PLC)

Programmable Logic Control is a particular microprocessor-based controller that utilizes programmable memory to store instructions and implement functions such as logic, sequencing, timing, counting, and arithmetic to control machines.

PLC in this AGV as the central controller of all AGV work is mainly movement control, while the navigation system uses the CIZON controller as the controller.

2.8 CIZON Controller

The CIZON controller is the control center of the navigation system on the AGV, which includes the navigation control system and software. CIZON is a product of Hunan Cizon Robot Co., Ltd, an AGV (Automated Guided Vehicle) manufacturer engaged in mobile robots, including several AGV navigation principles, such as AGV Magnetic guide, AGV QR code guide, AGV Inertial guide, AGV laser guide [4].

2.9 Human-Machine Interface (HMI)

Human Machine Interface is a communication medium between humans and machines of a system. HMI helps operators more closely control a system plan and PLC operation at each stage of the plan operation as the basis for the system visualization process that connects all components in the system properly.
HMI systems usually graphically present information to operations personnel through specific diagrams. HMI itself on the AGV in its use displays many displays, such as the primary display of the condition of the AGV, for example, the shape of the RFID, the state of the battery, and others.

3. RESULTS AND DISCUSSIONS

3.1 Operating System on Automated Guided Vehicle (AGV)

AGV devices, such as electromagnetic or optical, can travel along the specified guide path carrier with safety protection and various transfer functions. The AGV is battery-powered and equipped with a non-contact navigation (guide) device for crewless transport operations. Its central part is for the AGV to be monitored by the computer, according to the track and requirements, running and stopping at the specified position accurately, and completing a series of work functions. AGV has the following components in Figure 1.

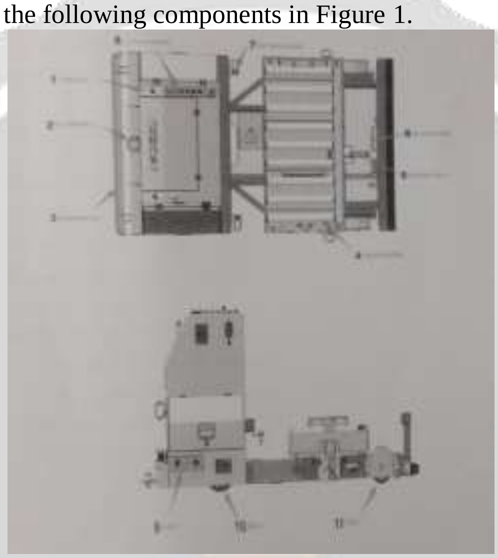

Fig -1 Component Overview on AGV

Based on Figure 1, it can be seen that the components of the AGV are:
1. E-stop button
2. SICK Laser Obstacle Scanner (Radar)
3. Safety Bumper
4. Electrical Roller
5. Roller Driving Motor
6. Magnetic Navigation Sensor
7. Pallet Proximity Sensor
8. Operation Button
9. Charging Plate
10. Play Driving Motor
11. Directional Wheels

The movement performance of the AGV is controlled by the RFID tag, such as stop, start, field change on the radar, speed change, auto-fill, and so on. The RFID coordinate information is stored in the AMS (AGV Management System) system so the AGV can report location data to AMS in real-time. The magnetic stripe is one part of the navigation system. The AGV will follow a track made of adhesive magnetic tape affixed to the floor. Magnetic sensors will measure how far from the tape's center and provide information to the motor controller, which will adjust the steering wheel to keep the vehicle in the middle of the track. Here is a picture of the RFID tag and magnetic stripe on the AGV.
The AGV system is equipped with an automatic charging system, the AGV will charge the battery every circle, and there is a charging bar that will contact the charging plate on the AGV. When the battery is low, the AGV battery will be charged automatically so that the AGV can run 24 hours continuously. Two photoelectric sensors establish

communication between the AGV and the charging system. The Battery Charging Process on the AGV is shown in Figure 2.

Fig- 2 Battery Charging Process on AGV

3.2 Workflow Design on Automated Guided Vehicle (AGV)

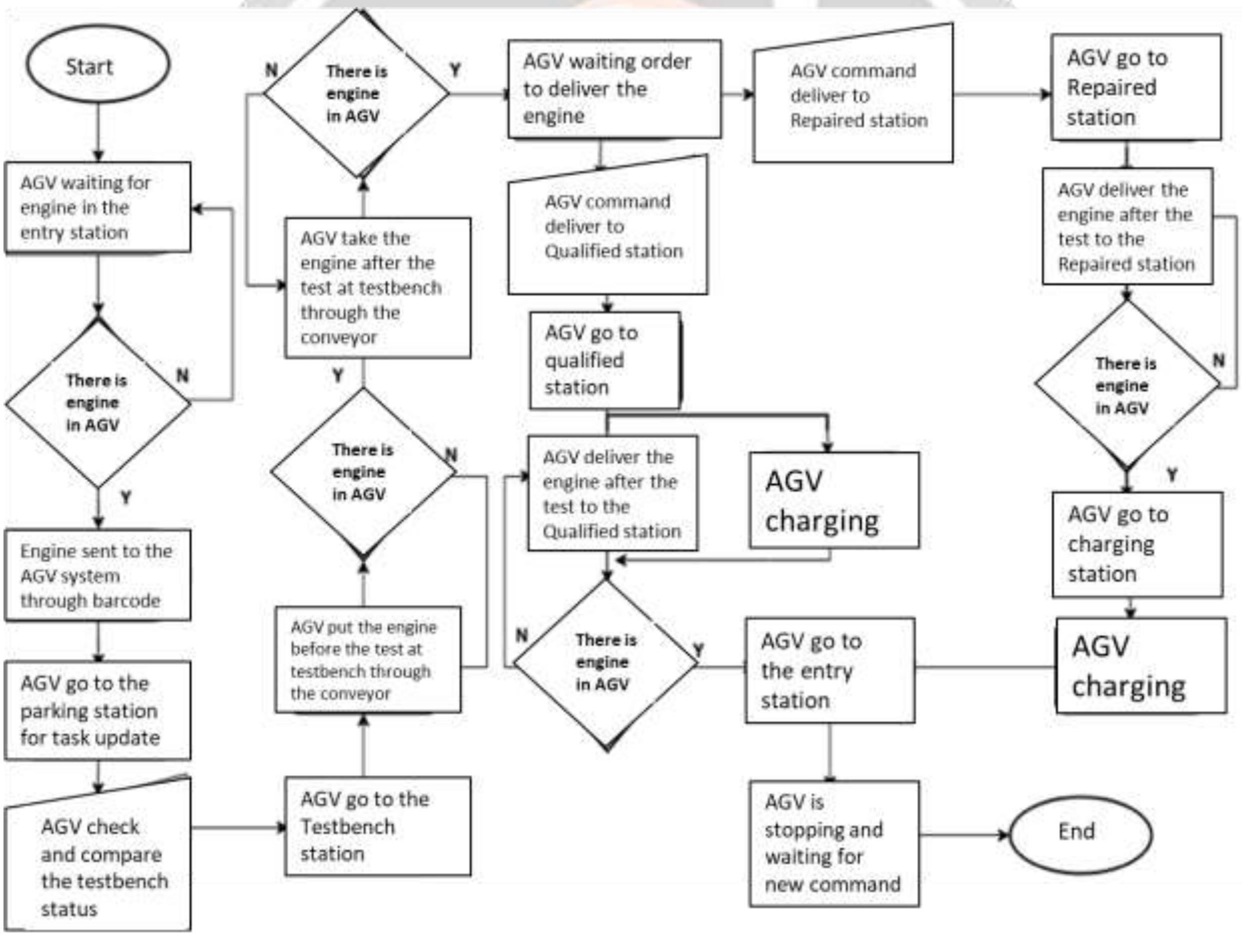

Fig- 3 Workflow Flowchart on AGV

In Figure 3, it can be seen that the workflow design of the AGV has three manual processes that are given manually to the AGV, namely the process when the engine testbench, the process when the qualified engine is, and the process when the machine is repaired on the engine test.

The engine testbench starts when the AGV waits for a command to accept the engine as a pallet on the AGV at the entry station. The assembled engine will be barcoded and sent to the AGV via a conveyor. The AGV will detect whether or not there is an engine in the AGV. Otherwise, the AGV will remain in place until the engine is seen. Detect the engine itself using the proximity sensor found on the AGV [4].

Fig- 4 AGV waiting for task update to Deliver Engine Before Test

After the AGV detects the engine, the AGV will go to the parking station to wait for a manual command from the operator. After receiving an order from the operator about which room is vacant and needs to be filled by the engine, the AGV system will check and compare to the testbench status. The AGV will go to the testbench station and deliver the machine before the test to the testbench room via a conveyor.

Fig- 5 AGV Delivers Engine Before Test to Testbench

The qualified engine process in Figure 3 shows that the AGV will detect whether there is an engine in the AGV. If there is, the AGV will remain in place until the motor before the test is delivered through the conveyor. Detect the engine itself using the proximity sensor found on the AGV. If the machine is provided before the test, the AGV will move and take the after-test engine on the right of the test bench via a conveyor.

When taking the engine after the test, the AGV will detect whether or not there is an engine in the AGV. Otherwise, the AGV will remain in place until the engine after the test can be taken. Detect the machine itself using the proximity sensor found on the AGV. When the after-test engine is on the AGV, the AGV will wait for commands from the operator. The order can be in the form of AGV being delivered to a Qualified station or a Repaired station. In this process, the AGV will provide the engine after the test to the qualified station. When given the order to return to the suitable station, the AGV will go to the eligible station. Then the AGV will deliver the after-test engine to the capable station via a conveyor [5]. When carrying out the engine delivery process, the AGV will charge automatically, as shown in Figure 2. In Figure 6, the process of AGV Delivering the Engine After the Test to the Qualified Station is shown below.

Fig- 6 AGV Delivers Engine After Test to Qualified Station

After delivering the engine to the qualified station, the AGV will detect whether there is an engine in the AGV. If there is, the AGV will be in place until the engine is delivered to the qualified station. Detect the machine itself using the proximity sensor found on the AGV. After there is no engine in the AGV, the AGV will go to the entry station and wait for a new command at the entry station.

Figure 3 shows that when the after-test engine is on the AGV, the AGV will wait for orders from the operator. The command can be an AGV delivered to a Qualified station or a Repaired station. In this process, the AGV will provide the engine after the test at the repaired station. When given the order to return to the repair station, the AGV will go to the repair station. Then the AGV will take the after-test engine to the repaired station via a conveyor. After dropping the engine at the repair station, the AGV will detect if there is an engine in the AGV. If there is, the AGV will be in place until the machine is delivered to the repaired station. Detect the engine itself using the proximity sensor found on the AGV. After there is no engine in the AGV, the AGV will go to the charging station. Then the AGV will go to the entry station and wait for a new command at the entry station [6].

3.3 Control System on AGV

The system generally consists of two main controls in controlling the AGV: PLC as a performance control and signaling on the AGV and CIZON controller as the main navigation on the AGV. Figure 7 shows a block diagram of the system on the AGV.

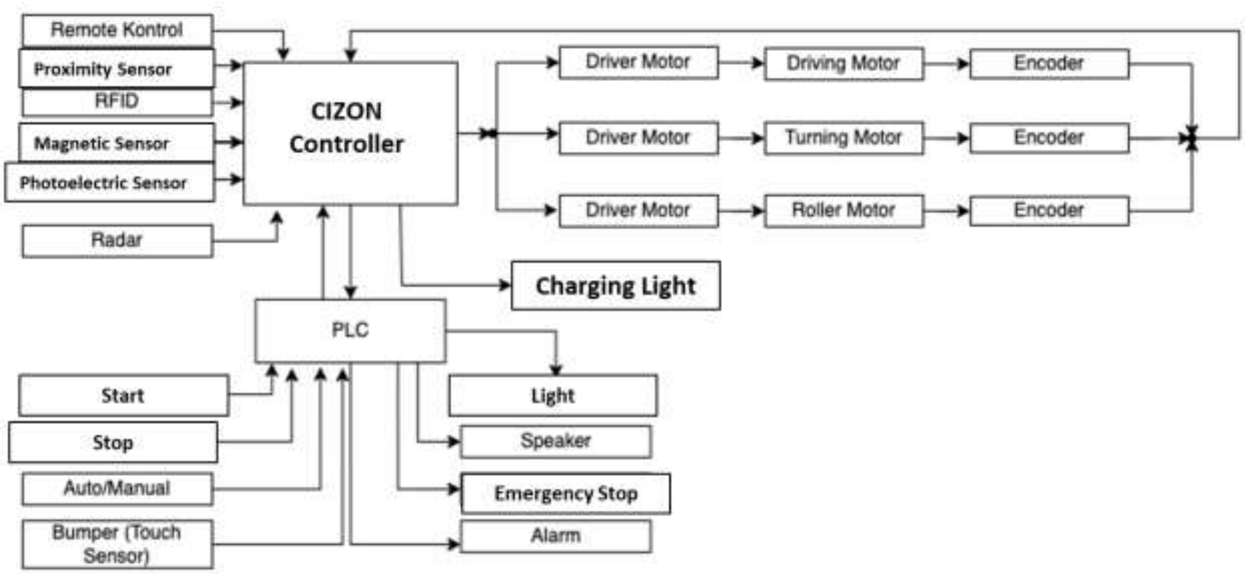

Fig- 7 System Block Diagram on AGV

In Figure 7, it can be seen that the Cizon controller has several inputs from sensors such as proximity, RFID, magnetic, photoelectric, and radar. The input serves to provide direction and move the AGV. In the navigation on the AGV, some input is given in the form of a magnetic sensor that functions as a magnetic field detection along the path that has been given a magnetic stripe on the AGV path. The AGV will follow a track made of adhesive magnetic tape affixed to the floor. Magnetic sensors will measure how far from the tape's center and provide information to the motor controller, which will adjust the steering wheel to keep the vehicle in the middle of the track. The Cizon controller will then move the motor driver connected to the driving motor for steering, turning the engine for turning on the AGV steering, and roller motor for driving conveyors when delivering or sending pallets. In AGV navigation, RFID is also used as a tag on each AGV path. With tag navigation, AGV determines and 'reads' RFID tags attached to the floor, or magnetic points embedded in the floor where each tag on the RFID has commands such as speed change, stop, turn, and so on. Radar on the AGV is used to detect objects where at a distance of about 3 meters in front, the AGV will experience a decrease in speed until less than that distance the AGV can stop. The AGV will move again when there are no objects in front that block it [3], [7], [8].
AGV can also be used via a remote control, where the remote control will move as an input and can move the AGV forward, backward, turn left and turn right. A proximity sensor to detect pallets on the AGV is used as input to the control. When the AGV detects the pallet, the Cizon controller will move the roller motor to deliver or receive pallets through the conveyor. Then the photoelectric sensor is helpful for the battery charging system, and the output will turn on the lights on the AGV when the charging process. The movement of the AGV is driven by a driving motor that a motor driver controls. There is an encoder that reads the motor's speed and will send it to the Cizon control so that the movement of the AGV can match the input. When the RFID detects a tag on the path to turning, Cizon will provide an input signal to the motor driver to drive the turning motor, giving the turning direction on the steering wheel on the AGV. There is also an encoder on the turning motor, which has the same function so that the input for turning on the AGV can match.
The PLC controller in this AGV is given inputs such as start, stop, run manual/auto mode, and touch sensors on the bumper for safety. Control systems on PLC and Cizon communicate with each other, especially in movement and signaling. It can provide input by running the mode manually, or auto on the AGV connected to the PLC when operating. Also, the PLC is given a pushbutton input to stop or start the AGV. The AGV is provided with a bumper with a touch sensor that functions. If an object hits it, the AGV will stop and turn on the lights. The speakers on the AGV function to produce output in the form of music. Then on the PLC, there is a radar input with three conditions. First, if the AGV detects an object at a distance of three meters, then the AGV will experience a decrease in speed. The second condition is if an obstacle is detected on the radar stop, it will send a signal to the PLC control, the AGV will stop and give an output light, and an alarm will sound. In the third condition, if the E-Stop radar detects an obstacle that makes the AGV unable to move, the radar via Cizon communication will send a signal to the PLC control, and the AGV will provide a condition in the form of an emergency stop output (E-Stop) on the AGV [6].

3.4 Navigation System on AGV

The navigation system on the AGV is controlled through the CIZON controller, which is the control center of the navigation system on the AGV, which includes the navigation control system and software. An RFID tag (landmark) used to determine the position of the AGV is used on the AGV path. The RFID tag on the AGV can be installed in several ways. In most cases, the RFID Reader will be mounted under the AGV with the RFID tag mounted inside or on the floor, allowing the AGV's logic to understand its location and make decisions to stop, turn, change speed or continue straight ahead. There are several parts in the RFID localization process: RFID landmark information and action, RFID landmark defining, RFID landmark program, and RFID traffic avoidance system.

Fig- 8 RFID Tag (Landmark)

An RFID tag (landmark) includes two things: landmark information and landmark action. Landmark information provides information about the current landmark number (location) and relevant information about other AGV traffic. The AGV will perform the appropriate action after reading the landmarks passed during the trajectory, such as start, stop, speed change, etc.

Before being used on an AGV track, RFID landmarks must first be identified by assigning a number to the RFID landmark through the connection between the PC and the AGV controller. After the connection between the PC and the AGV controller is successful, on the AGV software display, we can choose the appropriate brand and type of RFID. To identify an RFID landmark, we place a new RFID landmark under the RFID sensor and type the landmark number on the software interface by typing "1". Then click the "write" button. After this operation, the new landmark number was assigned as "1".

The landmark program controls the movement of the AGV. The user must identify each landmark action by software on the AGV. The AGV will perform different actions according to the landmark defined by the user. Users can define more than one action for each RFID landmark, such as start, stop, charge, wait, radar field switch, speed change, and so on. Usually, there is more than one RFID landmark in an AGV route, resulting in different actions. The AGV will maintain the same status on its path until it detects the next new landmark.

The RFID Traffic Avoid System uses a broadcasting system where traffic avoidance is controlled through landmark information. Each AGV unit will notify other AGVs of landmark information, such as avoidance systems on the AGV path. Figure 8 illustrates the method for avoidance on the AGV path.

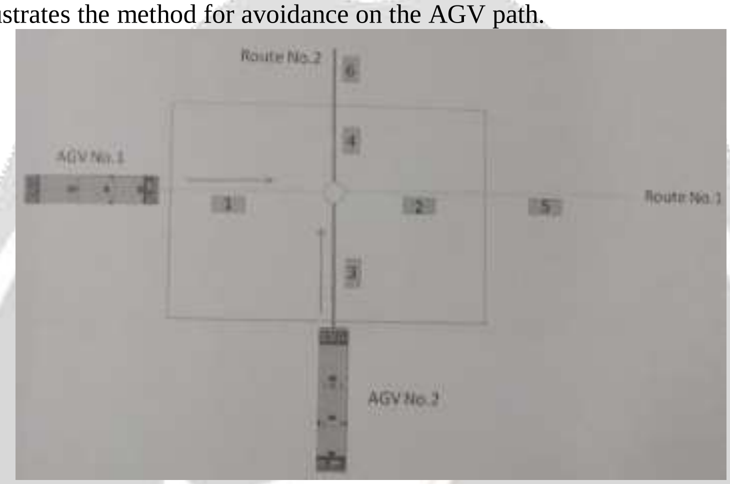

Fig- 9 Program display on landmark

Based on Figure 9, it can be seen that there are two AGV routes in the room, the first route and the second route. There is one AGV on each way, which moves in the direction indicated by the arrow. The area that contains numbers, called the black box area, is the traffic avoidance area. If AGV No.1 arrives at landmark one, it will send landmark information on AGV No.2 by AGV No.1. AGV No.2 will stop at landmark three and wait automatically until AGV No.1 arrives at landmark 5, then AGV No.2 will restart automatically.

3.5 Human Machine Interface (HMI) on AGV

The Human Machine Interface (HMI) on the AGV functions to monitor the operating status of the AGV, where the device and operational level on the system can be displayed in real-time, then also functions as a notification to the operating system if there is an error in the system or device and provides countermeasures and other information required. The HMI can also perform manual control on the AGV without going through the remote control. In this discussion, the HMI is in the form of a station monitor page.

Fig- 10 HMI Station Monitor on AGV landmark

In Figure 10, it can be seen that users can check delivery tasks on the AGV, which can be monitored with the following details:

1. Buttons Station: Five stations indicate five buttons with three buttons: call, qualified, and repair. The AGV system will record all tasks from the call button stations. There is a clear button to cancel the call
2. Current Task: Indicates the delivery of the current command
3. Modify Task: Operator can manually change orders and change delivery destination on AGV
4. Clear Next Task: Cancels the next command
5. Task Remaining: The order of tasks will be displayed here

4. CONCLUSIONS

1. Using an Automated Guided Vehicle (AGV) in the engine test line can solve the problems of the material handling system and distribution system on the engine before and after the test.
2. The movement of the AGV is based on a line follower, which will follow a track made of adhesive magnetic tape attached to the floor.
3. Movement performance on AGV is controlled by RFID tags, such as stop, start, field change on radar, speed change, and auto-fill.
4. The workflow design of the AGV has three manual processes that are given manually to the AGV, namely the process when the engine testbench, the process when the engine is qualified, and the process when the machine is repaired on the engine test.
5. The control system on the AGV consists of two main controls in controlling the AGV, namely PLC as a performance control and signaling on the AGV and CIZON controller as the primary navigation control on the AGV.
6. In the RFID localization process, there are several parts: RFID landmark information and action, RFID landmark defining, RFID landmark program, and RFID traffic avoidance system.
7. Human Machine Interface (HMI) on the AGV functions to monitor the operating status of the AGV, where the device and operating status on the system can be displayed in real-time. It also serves as a notification to the operating system if there is an error.

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