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Research and Design of AGV System Application Based on PLC and RFID

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Abstract: ***A Flexible Manufacturing System (FMS) is a system which accommodates routine changes, whether predicted or unpredicted. The system consists of ability to apply multiple machines to perform the same operation on a part, as well as system ability to absorb large scale changes, such as capacity and volume. In order to improve the structure of the Flexible Manufacturing System ,Programmable Logical Controller(PLC) is used at control processing center, a card reader with recognition RFID is used for Detection device, an Automatic Guided vehicle (AGV) is used for Transportation purpose ,and computer network system is applied in Information management and control device. The application of an AGV in Automation Industries has broadened during the late 20th century; this is due to competitive in the worldwide economy, manufacturing operations has to react quickly for meeting clients demand while increasing competitiveness with regard to their own production costs. AGV is a mobile robot that uses independently operated, self-propelled vehicle that follows makers or wires in the flow or uses magnets or lasers for navigation. AGV are known for their flexibility advantages, for these reasons, they are applied in automated warehouses, airports, automated storages to optimize the transportation tasks, and as the result it helps in cost reduction. AGV body is the ultimate transport equipment; its electrical and mechanical properties are directly related to the performance of AGV delivery system. Besides, AGV body with excellent performance will reduce the workload of daily maintenance, and increases the service life of AGV system. In order to improve the AGV's system efficiency and reliability bh Siemens PLC and RFID technologies are applied for the design. This paper explains the application of PLC and RFID technologies in the AGV system design for industrial logistic systems. PLC has been widely applied in the field of Industrial Control Equipment; it is used as the controller due to its simple in operation, high reliability, easy programming, and high speed in operation. RFID technology will greatly enhance the efficiency of the Industrial Logistic System in contactless data transmission that guarantees a high suitability for industrial conditions and large scale implementation. SISO (input and output signal) for graphical controller design in Matlab. The aim of applying PLC and RFID for the system design is basically for control and enhancing the speed of data flow. RFID offers many characteristics which make it viable for efficient integration in variety of Industrial and commercial concerns. These data are queried from Automated Guided Vehicle AGV control system at the start of navigation. The PLC detects the position of AGV and the load stand, and controls the movements.***

Keywords: PLC，AGV，RFID，FMS

1. Introduction

As an important part of modern technology in logistic distribution and automated warehouse, the AGV is very useful means of transportation of products, parts and other materials. In order to increase the efficient of the AGV system, PLC and RFID technologies are applied in the research and design. PLC is a specialized industrial computer used in Automation Industries. Most of the leading processes and similar manufacturing companies have sophisticated Automation Systems in place that control the high-speed packaging lines in their manufacturing operations, and high-speed conveyors in their distribution facilities .All these systems are mostly controlled by PLCs .In this paper PLC is used as the controller for AGV system. RFID is the wireless communication in which data is transferred from one point to another by use of Electromagnetic waves. RFID ensures the constant, quick, and smooth data transfer. Both technologies are increasingly in use for improving the Automation System process. The diagram below illustrates an overall structure of the FMS; it shows Siemens PLC ET-200pro which used as system controller, RFID reader/writer used for wireless data transmission. The data bank is there to store , processes and exchange of information with the computer .Profibus is connected to all the controllers(PLC), and in this regard it is an MPI RS-485 cable which is connected to an MPI interface card in the Computer such as CP5512(PCMCIA).To connect Siemens PLC ET-200pro programming port recognizes this interface as PPI .Pofibus is used for communication between the PLC and the computer. The conveyor belt and Automatic Guided machines are used for transporting products from one point to another in the ware house.

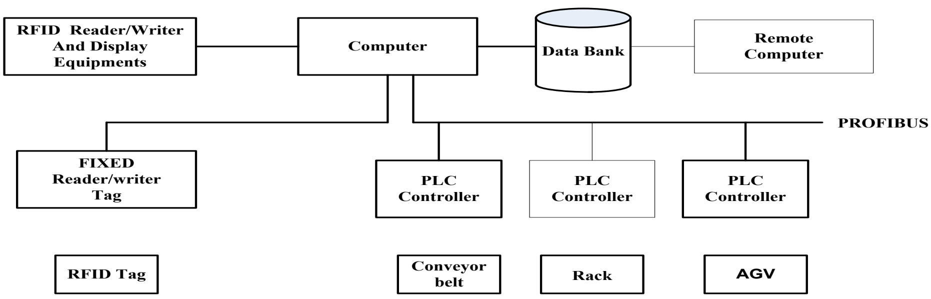


Figure 1: Structural diagram of FMS

2. Automated Guided Vehicle (AGV) Design and Applications

According to the research, the use of Robots in manufacturing and processing industries is growing in popularity, with automobile manufacturing companies is without exceptional .In most industries ,the main cost is associated with the manual handling of materials, and effective material handling solution can increase profit to 35%.With the use of Robots rather than human labour has enabled the manufacturing and processing industries to ensure that work is performed according to the expectation in a given time. Robots are more useful in comparison to human workers in considering factors including speed accuracy and lifting heavy items. As safety plays an important role in all the industries, this is the major key factor to put in to consideration. One advantages of the robots are that they eliminate the need of human risk to perform task in dangerous zones or task that may be harmful to human health. With the increasing in the number of company using mobile robots there is an improvement in production and most automated industries are likely to satisfy their client's demands. The research is based on the design of AGV system that is capable of performing the task in the ware house without too much human intervention. The developed system of an intelligent material handling system composed of three items; the AGV, the guide path and intelligent controller. The AGV model consists of information about its design and the operation of the AGVs in the system like assignment of work to each other and conflict resolution. The guide path design model consists of the RFID used for guiding the AGV in motion, and the guide intelligent controller contains the information about the intelligent of AGVs in a system, it contains the PLC Control mechanism, and method of controlling of multiple AGVs.

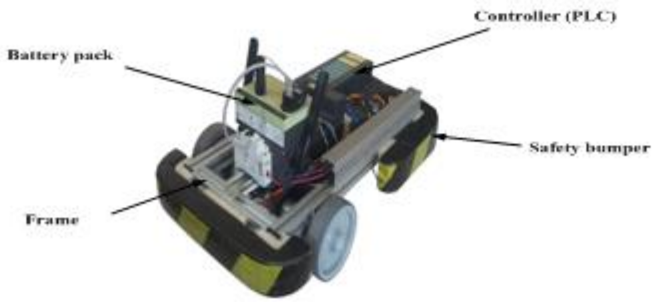


Figure 2: structural diagram of an AGV

The central control system uses the PLC Siemens ET-200pro for controlling AGV mechanism .The system structure has the controller in which an AGV is equipped with RFID reader that provides the information about the AGV position .The controller may automatically help to stop the AGV where servicing or battery charging for the AGV is required.

3. Basic characteristics of RFID

RFID system consisting of set of components that synchronizes to capture, integrate and utilizes data and information. The basic component which includes Sensors, Tags, Antennas, Connectors, cables networks, Readers, Controllers, data, information services and software. The most important component of the RFID system is data. Readers broadcast a signal, and tags respond. They are actually Two categories of software's (RFID middleware and application software). These elements are attached to a substrate; a material which protects it. Below is a diagram of an RFID tag and its principle of operational. There are three types of tags, passive tags, active tags and semi passive.

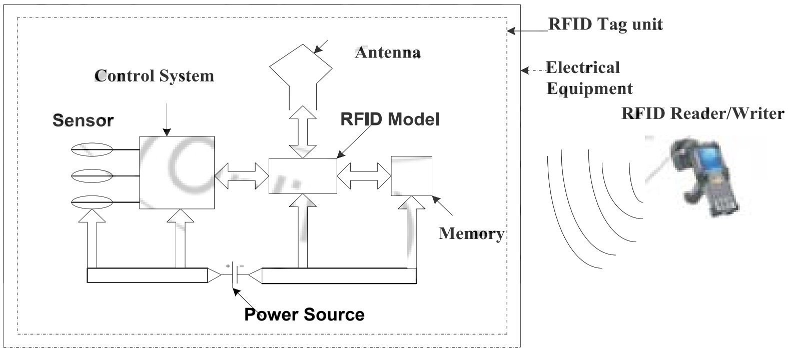


Figure 4: RFID Tag principle of operational diagram

The RFID tag unit internally also composed of the electrical element which is part of the circuit, and model. Memory is used for storing data such as the reader configuration parameters and a list of tag reads. If the connection between the reader and the controller/software system goes down, not all read tag data will be lost. A controller is an entity that allows an external entity, either a human or a computer program, to communicate with and control a reader's functions and to control annunciators and actuators associated with this reader.

The application of RFID depends on the customer's mandate, and the specifications of frequency is likely to determine the type of RFID to use .The table below shows RFID frequency characteristic summary

4. RFID Standards and Regulations

Table 1: RFID Frequency characteristics

FREQUENCY	LOW FREQUENCY	HIGH FREQUENCY	ULTRA-HIGH FREQUENCY	MICROWAVE
	9~135kHz	13.56~15.567MHz	860~930MHz	2.4~2.4835GHz
Typically application	Aeronautically and Marine communication	Smart cards, Personal identification	Electronics toll collections	Microwave ovens, Cordless telephones, 802.1 Wireless computer networks
Standards	ISO/IEC 18000 Part 2	ISO/IEC 18000 Part3,ISO 15693, ISO14443 Part A and B	ISO/IEC 18000 Part 7	ISO/IEC 18000-4
RFID applications	Animal tagging Access control Vehicle immobilizers	Access control Payment ID,item Level tagging, Luggage control Library books, Pharmaceuticals, biometrics	Supply chain (case and pallet level) Asset management, And access control	Security ,access control, work tracking for factory Automation RTLS
Frequency Wave length	2300 m	22 m	33cm	12cm

The International Organization for Standardization (ISO) has standards, which include the frequencies choices, for RFID applications. In this paper, RFID tag operating at 13.56MHz is applied for data assembly and transmission for the design of AGV system. The high frequency range is located in the middle of the short-wave length range, it's the range suitable for transcontinental connections and telecommunications. The high frequency RFID systems around the world use13.56~15.56MHz waves about 22 meters long. High frequency communication is governed by three (3) publications; ISO/IEC specifications18000-3ISO/IEC specifications 15693, and ISO/IEC specification 14443,and These are less expensive than the lower frequency tags, and the technology is very stable and mature .HF communications for RFID takes place using magnetic coupling rather than exchange of radio waves.

5. RFID in AGV Systems

RFID performs a number of functions in an AGV system. It supports the AGV functions itself, identifying articles and activating gates to route the article to its correct destination. RFID monitors the AGV systems report amount, location, and identify of inventory located on the AGV. It can also report the location of products in real time. If products are perishable or subjected to degradations by moisture or temperature or other environmental effects, sensors located in the tags can record and report these problems. Another advantage of RFID is that can be reconfigured even after being placed; this allows the path to be changed without any complex physical changes.

There are some challenges of an RFID reader in the an AGV system application .The systems must be able to read tags regardless of where there are located on the packages and regardless of orientations .If the application requires to the tag while its travelling, there is always the danger of encoding the wrong tag .In designing the system ,it's important to consider the various sizes and heights of items passing the reader .On a moving AGV the reader must be able to read the tags reliably regardless of the speed of the AGV, orientation ,angle or location of packages on AGV.To avoid such a problem AGV is placed in front of the safety bumper in the central of the RFID tag to ensure forward movement when the start button is placed .Forward movements of an AGV will bring about the scanning process of all the RFID Tags. The configuration of the tags will help to detect and collection of timing information which is useful for the controller.

6. Application of PLC for System Design.

In this paper Siemens PLC SIMATIC ET 200pro is applied as the controller ,this is because it comprises interfaces module to connect the PROFIBUS or PROFINET with standards .SIMATIC ET 200 pro is characterized by a comprehensive range of modules; motor starters, Analogy and Digital I/O ,power modules, frequency converters and RFID which makes it flexible for Automation requirements.ET 200 pro can be used when mechanical load is high, its applied in a system when a modular design is required directly ,and even under harsh conditions .Its reliable for integration in safety technology .In this this research ET 200 pro is applied with a PROFIBUS DP speed of 12Mbits/s, and operating at the ambient temperature between 0 to 60°c and relative humidity between 4 to 100%.The interface module of ET 200 pro is connected to the bus system through PROFIBUS .RS485 or RS232 .In this paper PROFIBUS RS 485 is used due to its wide advantageous . PLC is used as Controller for both in the FMS and in AGV system. The research is on the AGV system design with the aid of PLC and RFID technologies. The vehicle movement controlled by an inboard PLC do not need physical guide.

7. AGV Speed Control

There are basically three (3) different types of steering control system; the differential speed control, the steering wheel control and the combination of both differential and steering wheel control systems. In this paper, the steering wheel control is used for a three (3) wheeled AGV.It is accurate in following the programmed path; it is the only system that is used in many applications, and mostly used for towing. AGV make decisions on path selection. This is achieved through different methods: the frequency mode which is composed of wired navigation, the path select mode composed of wireless navigation and the magnetic tape on the floor. These are there to guide and provide steering and speed commands. The actual path required of the AGV is defined by line and circle .The main function of the path is basically to guide the AGV mobility, and this is stored in the memory of the controller PLC for the AGV system. During AGV mobility an error may occur that is between the defined path and the actual position of the vehicle. The error, driving command signal and the steering can be analyzed and converted to analog signal by the controller (PLC). A rotary Electrical machine which converts electrical power to mechanical power is called a DC motor .A DC motor gives both mechanical and electrical equations .In order to obtain transfer functions and state space ,the motor equations are set in differential .Below is the circuit diagram of the motor consists of the armature circuit and the mechanical load.

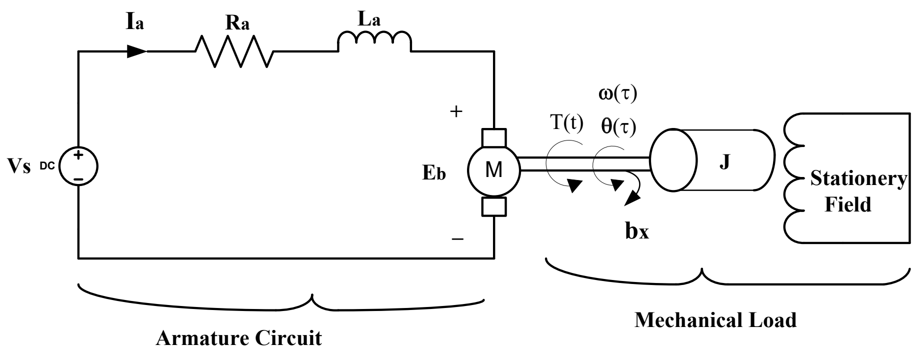


Figure 5: Circuit diagram of the DC motor

By assuming that the magnetic field of a DC motor remains constant, the torque of the DC motor is directly proportional to the strength of the magnetic field and the armature current (I_a) by a constant factor k_t, mathematically Torque in the DC motor is given by the equation

$$T = k_t I_a Ø \qquad (1)$$

The back EMF, E_b is proportional to the angular velocity of the shaft by a constant factor k_e

$$E_b = k_e \theta \qquad (2)$$

Applying Laplace transformation, we obtain

$$E_b(s) = k_e s(\theta) \qquad (3)$$

By applying Newton's law and Kirchhoff's voltage law;

$$J\theta + b\theta = ki \qquad (4)$$

Kirchhoff's voltage law gives;

$$V_s = L_a \frac{di_a}{dt} + R_a I_a(t) + E_b(t) \qquad (5)$$

Applying Laplace transformation for the equation (5), it gives;

$$V_s = R_a I_a(s) + sL_a I_a + E_b(s) \qquad (6)$$

Using equations (5) and (6), we obtain

$V_s(s) = RaIa(s) + sLaIa + Kbs\theta$

$$I_a(s)\,(R_a + sL_a) = V_s(s) - Kbs\theta(s) \qquad (7)$$

Applying the Laplace transform function, the above modeling equation can be expressed in terms Laplace variable s, we get;

$s\,(Js+bx)\,\theta(s) = KI_a(s)$

$$(Ls+R)\,I_a(s) \qquad (8)$$

When Ia(s) is eliminated between the two equations above, we obtain open loop transfer function when the armature voltage is considered input and rotational speed is output, mathematically gives;

$$\frac{\theta(s)}{Vs(S)} = \frac{K}{s(Js+bx)(sLa+Ra)+sKe} \qquad (9)$$

Where;

La= Armature inductance, Ra=Armature resistance,
Ke=Motor constant, bx =Friction coefficient

Expressing the above equation in state space the Vs is considered as the input and the rotational speed as the output. The state space is expressed as

The feedback law states that

$$u = -\begin{bmatrix} K_1 & K_0 \end{bmatrix} \begin{bmatrix} X1 \\ X \end{bmatrix} \text{ or simply} \qquad (10)$$

$$u = -K \begin{bmatrix} X1 \\ X \end{bmatrix}$$

$$\frac{d}{dt}\begin{bmatrix} \theta \\ i \end{bmatrix} = \begin{bmatrix} -bx/J & K/J \\ -K/L & -R/L \end{bmatrix} \begin{bmatrix} \theta \\ i \end{bmatrix} + \begin{bmatrix} 0 \\ 1/L \end{bmatrix} V$$

$$X = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} \theta \\ i \end{bmatrix} \qquad (11)$$

8. PID Controllers

According to the research more than half of the industrial controllers in use today are PID controllers or modified PID controllers. PID controller is a proportional, integral and derivatives controllers in application in the system. The usefulness of PID (Proportional, integral, derivative) controller based on their general applicability to most control systems, in particularly, when the mathematical models of the plant is not known. Therefore analytical design methods cannot be applied, PID controls proves to be most useful. This feedback control mechanism continues to calculate an error value which is the difference between the command input and the output. The major role of the controller is minimize the error over time by adjustment of the control variable .Below is the structure diagram showing feedback control system using PID controllers.

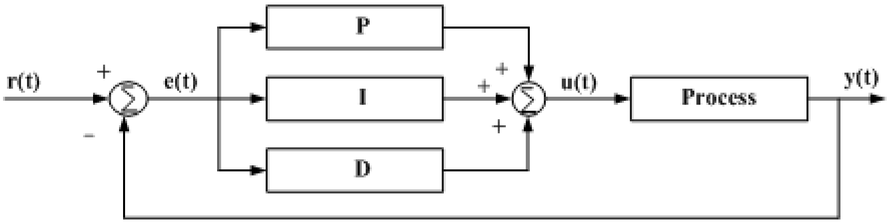


Figure 6: A block diagram of a PID Control

The definition of u (t) as the controller output, mathematically it is expressed as

$$u(t) = K_p\, e(t) + K_I(t) \int_0^t e(\alpha)\, d\alpha + K_D \frac{de(t)}{dt} \quad (12)$$

Proportional (P) = K_p e (t),

Integral (I) = $K_I (t) \int_0^t e(\alpha)\, d\alpha$ and

Derivative (D) = $K_D \frac{de(t)}{dt}$. K_P, K_I and K_D are non-negative

T_P, = is proportional gain, turning parameter, K_i= in the integral gain, turning parameter and T_D= derivative gain, turning parameter e (t) = SP –PV (t) is the error, (SP is the set point and PV(t) is the process variable) , t is the instantaneous time ,the variable α taken as the value from 0 to the present t

The control variable u(t) is sent to the plant and the new output y(t) is obtained.

9. Characteristics of PID Controllers

A proportional feedback control (Kp) lead to reduced errors to disturbances but still has a small steady –error .If the controller includes a term proportional to the integral of the error, the error to a step can be eliminated .However, there tend to further deterioration of the dynamic response .Finally, additional of proportional to the derivative can add damping to the dynamic response .These three (3) terms combined form the classical PID controllers.

The effect of each of the three (3) controller parameters (K_P, K_I and K_D) on a closed loop system are summarized on the table below.

Table 2: Characteristics of P, I and D controllers

CL Response	Rise Time	Over shoot	Settling Time	S.S Error
K_p	Decrease	Increase	Small change	Decrease
K_I	Decrease	Increase	Increase	Eliminate
K_D	Small change	Decrease	Decrease	No change

If the process mathematical model cannot easily be obtained, then an analytical or computational approach to design of a PID controller is not possible .The experimental approaches to the turning of the PID controller is applied .The process of selecting the controller parameters to meet given performance specification is known as controller turning .This method is one of the effective that uses PID controllers in the control system. It is based the trial and error method by running the controller considering Kp and making K_I and K_D to be zero, increase value of Kp until the system oscillate ,take controller over time period. Ziegler and Nichols suggested rules for turning PID controllers to set the values of K_p ,K_I and K_D based on the experimental step response or based on the value of Kp that result in marginal stability when proportional control is applied. There are two methods called Ziegler –Nichols turning rules. In this paper the second rule is used which suggest that set values of the parameters K_p ,K_I and K_D according to the formulae in the table below.

Table 3: Ziegler-Nichols turning method based on critical gain and Critical period

Types of Controller	K_p	K_I	K_D
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$1/1.2\ P_{cr}$	0
PID	$0.60K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

10. Results of PID using sisotool in MATLAB

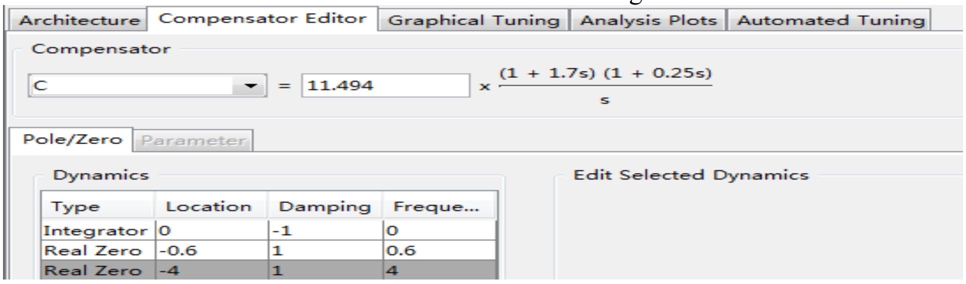
The process (DC motor) transfer function is given by;

$$G(s) = \frac{1}{(s+1)(s+2)(s+3)},$$

The transient requirements being of tr, ts<5s, (1%) and Mp(20%).

The design in SISOTOOL was found in the compensator editor as illustrated the figure below.

Table 4: The sisotool for design



Architecture | Compensator Editor | Graphical Tuning | Analysis Plots | Automated Tuning

Compensator

C = 11.494 × $\frac{(1 + 1.7s)(1 + 0.25s)}{s}$

Pole/Zero | Parameter

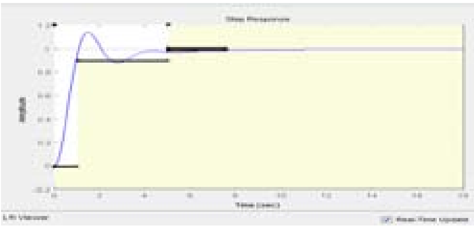
Dynamics | Edit Selected Dynamics

Type	Location	Damping	Freque...
Integrator	0	-1	0
Real Zero	-0.6	1	0.6
Real Zero	-4	1	4

Below is an illustration of the PID results which were found by SISOTOOL in MATLAB, it gives an explanation to how the transfer function of the plant (DC) motor was used in the experiment. Figure (a) Gives an illustration of large steady -error having 3 seconds rise in time and 5seconds settling time. Designing of a controller eliminating steady error, and reduced both rise in time and settling time was achieved. (b) It's the graph giving the design requirements based on transient's requirement stated above (c) illustrate the overshoot after adjustments to the parameter of the design, and figure (d) gives the Step response of the system with PID controller with controller having Kc. From the plot on figures (a) and (c) the rise in time, settling time and steady state error are high. There trying the PID controller with small K_D and K_I gives an improvement to the system shown in figure (d).

Figure (a): Rising and settling time are higher

Figure (b): showing design requirements



Figure(c): An overshooting after adjustments to the parameters

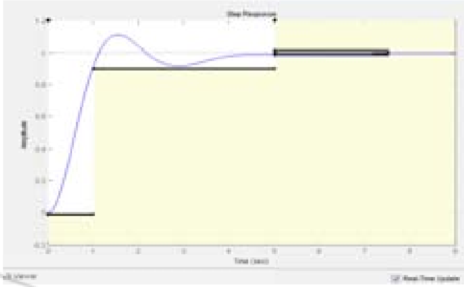


Figure (d): Step response of the system with PID controller

11. Conclusion

The application of PLC and RFID technologies for the design of the AGV system is becoming widely used in the automated industries. As both technologies provide advantages to the AGV system. PLC has been widely applied in the field of Industrial Control Equipment; it is used as the controller due to its simple in operation, high reliability, easy programming, and high speed in operation. The RFID plays an important role for the system design; RFID technology will greatly enhance the efficiency of the Industrial Logistic System in contactless data transmission that guarantees a high suitability for industrial conditions and large scale implementation. The application of AGV is widely used in the logistic industries for transporting of materials and parts from one point to another. AGV offers more advantages to use than conveyor belt, One AGV may be stopped for service or charging the battery when other AGV are on operational. The battery of an AGV may be charged every after 8hours of use, the AGV system may automatic give a signal if there is a problem without affecting other AGVs which is time saving. AGV eliminate the human element of delivering parts to lean assembly lines, which results in consistent and reliable cycle times, and addresses error-proofing initiatives. This vehicle can operate in the condition not suitable for human operators such as hazardous environment, and they are part of a more complex system operation that offers benefits to a wide range of markets.PLC is used to control the DC motor which runs the AGV. The sisotool in MATLAB was used for the graphical design of the PID controller. According to the research in 10~15years, there will be an increase in the application of AGV systems in the automated industries due to its reliability and cost saving. With the increasing in the number of company using mobile robots there is an improvement in production and most automated industries are likely to satisfy their client's demands. The research is based on the design of AGV system that is capable of performing the task in the ware house without too much human intervention

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