A Systematic Approach to Develop PLC Program for Automation of a Glass Handling Gantry System in Automobile Industry

Saruk Ajit Suresh
Postgraduate Scholar
M.Tech. Mechatronics
VIT University, Chennai, India

Dr. G. Sakthivel
M.Tech. Mechatronics
VIT University, Chennai, India

***Abstract* - In industries most of the time gantry system is used for the pick and place operation in inline loop. In this work the gantry system is modified slightly. Gantry system is used to assemble the front glass of the automobile. Three axis movements are given to the one single gantry to accomplish the required task. For the movement of the gantry rack and pinion arrangement is used.**

Automation in automotive assembly line would be useful for safety and large production. Automotive industry continuously strive to find better ways to increase output, improve quality and uphold the highest safety standards while decreasing cost. In this project work programmable logic controller (PLC) is used for the key activities of automatic glass assembly system and will focus on the improving the position accuracy by the use of combination of the encoder, limit switches and barcode reader. The feedback from these three sensors is given back to the PLC to control the speed of the servo motor.

Keywords:- Gantry; PLC; barcode scanner; encoder; limit switch (LS).

I. INTRODUCTION

In automobile industry the front glass of the vehicle is a very crucial and delicate part. This part should be carry with essential attention. Here automation is done to assemble front glass to the vehicle body. This is achieved with slight modification in gantry system and with the help of PLC programming. This system has proposed with three axis through which the gantry system move. This movement can be achieved by rack and pinion. Considering position accuracy as prime consideration in this work the servo motor has been selected. Achieving positional accuracy at high level is the main task. The positional accuracy can be achieved with limit switch, encoder and barcode reader. Most of the industry uses limit switch and encoder to achieve the position accuracy.

In this kind of application the position of the gantry system will be known by using hard and soft feedback. Hard feedback can be achieved by the limit switch and soft feedback can be achieved by using encoder. But most of the time break downs like over travel or under travel can occur. For minimizing probability and frequencies of such kind of breakdowns in addition to limit switch and encoder, barcode scanner system is used. Barcode is located throughout the rack of the gantry. This bar code is then scan by the laser barcode scanner. The signals of the limit switch, barcode scanner and encoder used to communicate with PLC and the PLC generates the corresponding signal through which the movements of the motors can be controlled in efficient way.

The proximity sensors are used for the sensing of the part. Ball and lever type limit switches are used to limit the movement of the gantry. As the part to be lifted is very delicate, vacuum cups are used.

II. MECHANICAL AND ELECTRONICS STRUCRURE

The rack and pinion arrangement is used for the transmission of the gantry. Three servo motors are used to achieve the desired location. Each servo motor is designed for the capacity of 2 KW. Servo motors are connected to the gearbox to bring down the motor speed to the required speed. The gearbox is designed in such a way that the gear ratio can fulfils the desired speed conditions. The front glass of the automobile is very mild in characteristics so using mechanical gripper may harm the glass. To handle the front glass of automobile without damaging it, vacuum cups are used. The pneumatic circuit is used for operating the vacuum grippers. In the pneumatic circuit the direction control valves are operated by the solenoid and solenoid is operated by the PLC.

Latch is used for controlling and supporting the vertical up and down movement of the gantry. Latch is operated by the solenoid. Servo motors are fixed on the gantry. It is very necessary to travel the servo motor with gantry. The connection to servo motor is given by the flexible cable which may suitable to operate at highly dynamic condition.

The fixture is designed in such a way that while picking up the glass there would not be any angular motion to the gripper. This brings the mechanical stability in operation. The gripper just need to go pick up position and then it can picked up the glass.

Fig. (a) shows the mechanism needed for the movement of the gantry and for achieving the desired position. Fig. (b) shows the enlarged gripper structure.

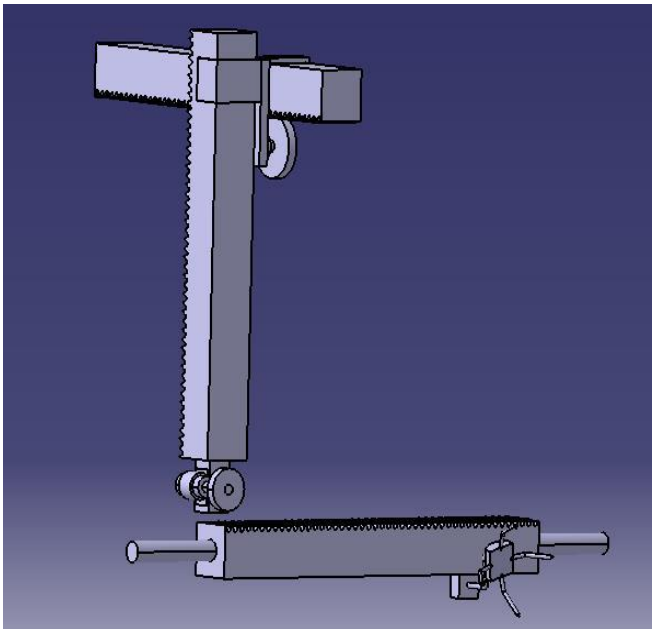

Fig. (a) Internal mechanism for the movement of the gantry system

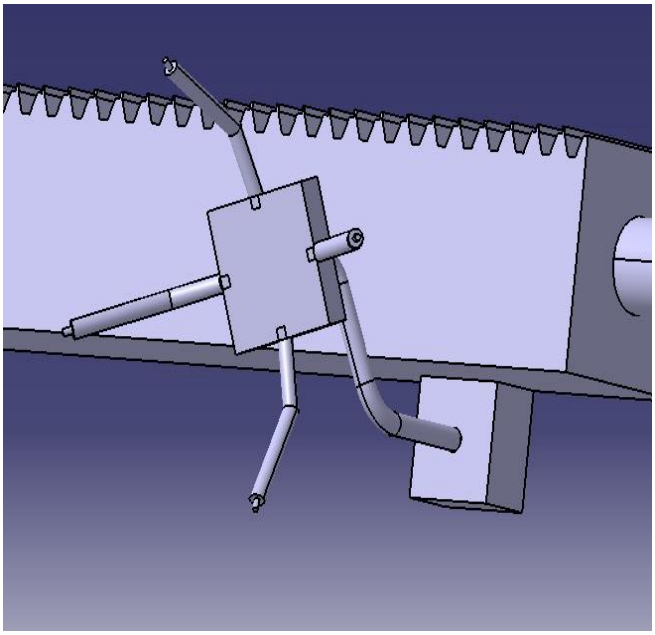

Fig. (b) Gripper gantry system

The electronics parts such as proximity sensors, limit switches, encoder, and servo drive are controlled by the PLC. Servo drive is used to control the speed of servo motor by varying the frequency. Frequency and speed are directly proportional. The sensors signals are gathered in the junction box and then only one cable has been taken out and connected to the remote I/O. From remote I/O the Ethernet cable is used to communicate with PLC.

III. CONCEPT OF CONTROLLING A SYSTEM

The concept of controlling a system involves the following steps

A. Sequence of Operation

In this step, identification of the equipment and its working plays a vital role. The main purpose of using PLC controller is to control the external system. In PLC logical conditions are given and PLC produces the output according to these given conditions. The output of the PLC is given to the controlling parameters which controls the movement of the gantry. To achieve this one need to develop the sequence of operation and understand detailed operation.

Initially the gantry is at home position. Two part present proximity sensors are used at conveyor to let PLC knows that the body is present at the conveyor. And another two capacitive type proximity sensors are used to sense the presence of the front glass of the automobile. When these four proximity sensors signals are true then the operation can be started. Three servo motors are used to guide the gantry in X, Y and Z direction. Let the name to each motor is given as X-Motor, Y-Motor and Z-Motor. When the start signal is given by the PLC then the Z-Motor is started and helped the gantry to move down. Then the solenoid is operated and the vacuum cups come into operation. Vacuum cups hold the glass with the help of four capacitive proximity sensors located at near to the each vacuum cup and then Z-Motor used to lift the gantry. After wards the Y-Motor starts running and bring the gripper above the conveyor. The position of the gantry at this position is set already. Then the X-Motor start moving and helps to bring the gantry at parking position. Parking position is sensed by the parking ball type limit switch. Anti-collision sensor is used to avoid the collision of the gantry with the automobile. The range of anti-collision sensor is adjusted at minimum level in such a way that it will not create any problem while assembling with the automobile. Two proximity sensors are used of different ranges. When the gantry is at parking position the automobile body will start moving towards the gantry. When the proximity sensors used for getting feedback of assembly operation is done, are activated then that signal is used for releasing the glass. Maximum travel distance limit switch is used to set the maximum distance at which the gantry can move. Then X-Motor starts moving fast to maintain a safe distance between automobile and gantry. After that X-Motor stop and Z-Motor starts running to move the gantry up. Then again the X-Motor starts running to bring the gantry towards home position. Y-Motor starts running to move the gripper away from the conveyor. And the gantry system is parked at the home position. Home position limit switch is used to get the feedback of the gantry position at home position.

B. Assignment of Inputs and Outputs

Devices connected as input and output must have specific ferrule number. The input devices that are connected to input module of PLC are

1) Proximity sensors
2) Limit switches
3) Encoders
4) Barcode scanner

The output devices that are connected to the output module of the PLC are

1) Servo motors
2) Latches
3) Solenoids

Before start writing the actual ladder PLC program the wire numbers should be given because after that only PLC could trigger the require output. So assigning input and output wire number is important.

C. Develop Timing Diagram

The clear understanding of the process is understood by the timing diagram. Timing diagram is shown in the Fig. (e).

D. Develop Flow Chart

Flow chart is drawn considering the sequence of operations of control process. Fig. (c) shows the flow chart of sequence of operation.

E. Writing of the program

While writing the program attention is paid to the following steps

- Task requirements.
- Software design techniques.
- Documentation.
- Program testing.

IV. POSITION ACCURACY

Achieving the position accuracy at high level is the necessity of this work. For achieving this accuracy the combination of limit switch, encoder and barcode reader is used.

A. Encoders-

Encoder modules interface encoder device with programmable controllers. This type of module operates independently of the processor and I/O scan. An encoder module is an integral part of a programmable controller system when it is used in applications requiring position information. Absolute encoder and incremental encoder are the type of encoders in this work incremental encoder is used. This encoder has two signals for one rotation with 90^0 phase difference; it then determines the direction of rotation by sensing the leading waveform. These pulses are then count in marker, and marker gives these pulses as input to the input module.

In PLC program counter block is used which count the rotation of the motor shaft and correspondingly gantry displacement is measured.

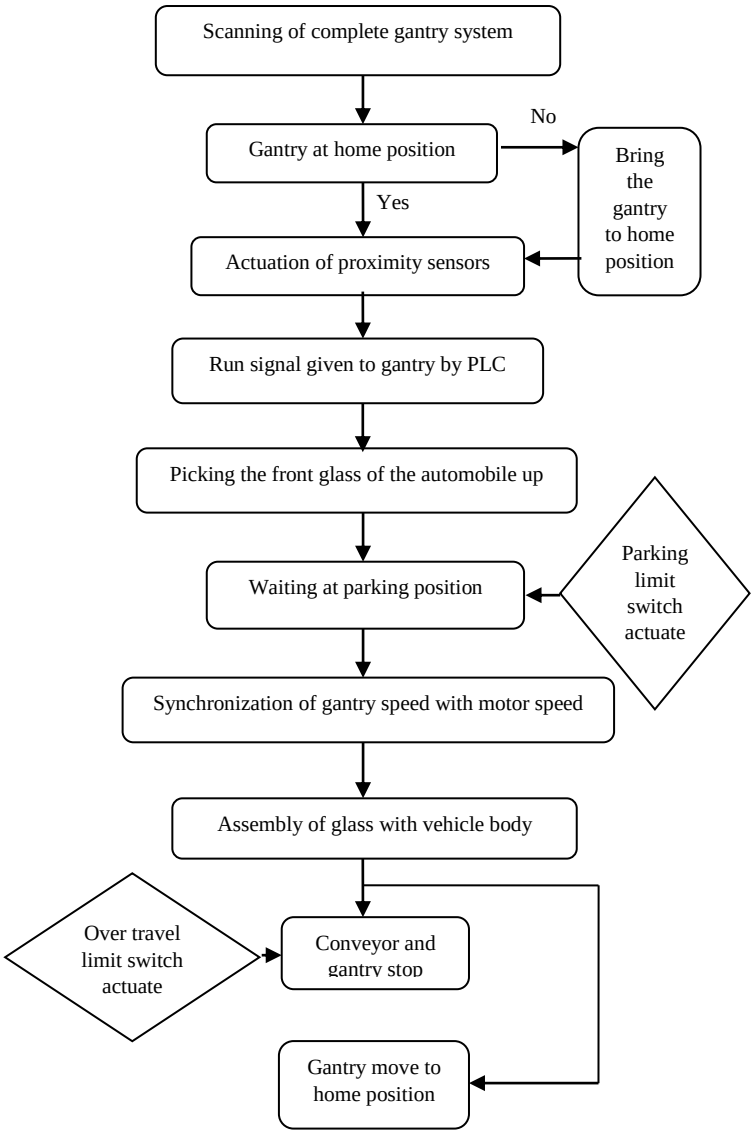

Fig. (c) Flow chart of sequence of operation

B. Limit switch-

Limit switches are used to limit the movement of the gantry. In this project work double ball type limit switches and lever type limit switches are used. When the limit switch hit by the gantry then it produces signal. That signal is given to the input module of PLC. In PLC program logic integration of limit switches is done.

C. Barcode reader-

Barcode readers are used to get higher position accuracy. Barcode and barcode reader is installed at each rack for each movement of the gantry system. The laser/line barcode reader are used. Signal from the barcode reader is in the form of wave. The black and white color lines are used in barcode. When the light is emitted on the barcode by the barcode reader then light will get reflected from the white line and some light will get absorbed by the black line. Then according to the light received in the barcode reader receiver the corresponding wave form is generated. After wards the waveform is converted into

either binary number or integer number. The integration of the barcode reader with PLC is done by the RS232 cable. When the signal is received by the barcode reader then that will be the location of the gantry.

Barcode reader, encoder and limit switches are used to get better position accuracy. Fig. (c) shows the integration of these three sensors with PLC module.

The 24V power supply is given to the PLC. When servo motor starts running then the incremental encoder counts the number of pulses. These numbers of pulses are then count in counter block of PLC. At the same time when gantry hit the limit switch, the limit switch will generate a signal and at the same time the barcode reader read the barcode and gives the exact position value of gantry.

PLC logic is developed in such a way that when these three signals are true only then the next command will be given to the gantry system. Encoder, limit switch and barcode reader are connected in series in ladder programming

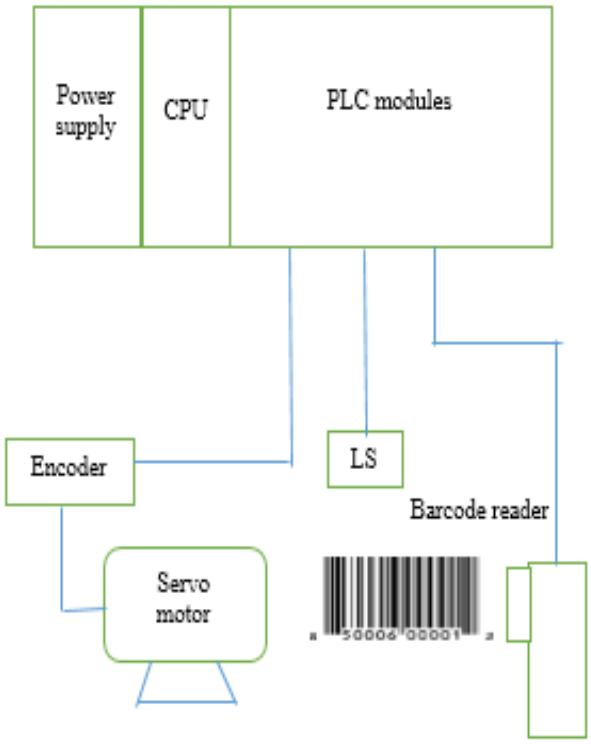

Fig. (d) Integration of encoder, limit switch and barcode reader with PLC

Sr. No.	Sequence of Operation	Length of Occurance of Different Processing Signals
1	Home position limit switch	
2	Capacitive type proximity sensor	
3	Body present proximity sensor	
4	Operation start signal	
5	Picking position achieved by gantry	
6	Conveyor running signal	
7	Synchronization of gantry and conveyor speed	
8	Parking limit switch	
9	Over travel limit switch	
10	Component hold by gripper	
11	Component assembled signal	
12	Gripper lift signal	
13	Activation of bar code scanner for X-Motor	
14	Activation of bar code scanner for Y-Motor	
15	Activation of bar code scanner for Z-Motor	
16	X-Motor	
17	Y-Motor	
18	Z-Motor	

Fig. (e) Timing diagram for glass handling gantry system

V. SOFTWARE DEVELOPMENT

After deciding the sequence of operations, inputs and outputs are sorted out from the sequence of operation of gantry. These inputs and outputs are used for the I/O card of PLC. Correspondingly ferrule number for each input and output is given in tables. Timing diagram for glass handling gantry system was developed as shown in Fig. (c). According to sequence flow chart was made for the gantry system. After it, ladder program was written by the following steps of control system sequence of operation as written in section III.

Depending on the type of processor used in the PLC the power supply was given I/O generation was done.

Afterwards ladder programming was done and feed that program into PLC memory with the help of RS Logix 5000 programming software. And program is checked for any errors by software simulator. PLCs self-diagnostic functions enabled for easy and fast troubleshooting of the system. Before the actual start of PLC operation the wiring connection is cross checked thoroughly. Once confirmed the actual operation of PLC started. Test run was done until it was safe to operate by any skilled or unskilled person.

VI. CONCLUSION

Automation not only reduces the human fatigue but also helps to improve the production rate; it helps to reduce the energy consumption, production cost in assembly line. So this paper is appropriate to fulfill those requirements of the assembly line of automotive industry.

In this work, application of PLC program is discussed for the vehicle front glass assembly system with slight modification in the gantry system in automotive industry. PLC applications are typically highly customized systems so the cost of a packaged PLC is low compared to the cost of a specific custom-built controller design. Ladder diagram PLC programming is used in this application. By understanding the necessity of the position accuracy in such a delicate application, combination of barcode reader, limit switch and encoder is used with various sensors and its integration with PLC is done. Front glass of the vehicle body is assembled with efficient way than the human method and cost is reduced drastically. Requirement of the workers is minimized.

REFERENCES

[1] S. K. Singh, D. Prasad, G. Agarwal, M. Parikh, P. Ramadhyani, J. S. Parikh, A. Datta and S. Chatterjee, “PLC based industrial automation”, Electrical India, vol. 50, no. 6, June 2010.

[2] A. Mikkor and L. Roosimolder, “Programmable logic controllers in process automation”, Proc. of the 4th International DAAAM Conference on Industrial Engineering – Innovation as Competitive Edge for SME, Tallinn, Estonia, April 29-30, 2004.

[3] R. Kirubashankar, K. Krishanamurthy, J. Indra and B. Vignesh, “Design and implementation of web based remote supervisory control and information system”, International Journal of Soft Computing and Engineering, vol. 1, no. 4, September, 2011.

[4] Shizhuang Lin, Jingyu Liu, Yanjun Fang, “Zig Bee Based Wireless Sensor Networks and Its Applications in Industrial”, IEEE International Conference on Automation and Logistics, 2007, pp:1979 – 1983.

[5] Mohammed Bani Younis and Georg Frey.,” A Formal Method Based Re-Implementation Concept for PLC Programs and Its Application”, 1-4244-0681-1/06/2006 IEEE.

[6] LiLing Wang1, Hong Yingwei, “development of a distributed control system for plc-based applications”, Proceedings of the Ninth International Conference on Machine Learning and Cybernetics, Qingdao, 11-14 July 2010, 978-1-4244- 6527-9/10/©2010 IEEE.

[7] Vijay Kumar Khatri, Ahsan Javed Ghangro, Jetandar Kumar and Syed Jaad UI Haque, “Industrial Data Acquisition and Control System using two PLCs’ Networked over MPI Network”, 2009 IEEE symposium on Industrial Electronics and Application (ISIEA2009), October46,2009, Kuala Lumpur, Malaysia., 978-1-4244-4/09/@2009IEEE.

[8] Coia Ferrater-Simon, Lluis Molas- Balada, Oriol Gomis Bellmunt, “A Remote Laboratory Platform For Electrical Drive Control Using Programmable Logic Controllers”, IEEE Transaction on Education, Vol,52, No.3, August 2009.