Design of Industrial Automation System Based on PLC with Factory I/O

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Abstract

Programmable logic controllers (PLCs) are built based on the increasing needs of various industries, which are considered the main and important components of the controller in automation projects. In the past, before the invention of PLC, a combination of electromechanical relays and pneumatic systems were used in automation control projects. The smallest change in the command circuit requires changing the hardware, high-energy consumption, lack of programmable logic, etc., which has led to the use of PLC for the automation work of various industries. Because changing its command circuit is possible with minimal hardware changes and only by adding or subtracting a few lines on the letter. In this thesis, the programming process of multi-floor warehouse control of products is done automatically by a PLC-based crane. The advantage of this work is to significantly reduce energy consumption, increase the productivity of industrial units, increase the security of human resources, etc. So the question is here? How to implement the ready project of this paper in the real industrial workshop? This is a major problem that may arise in all PLC projects. To solve this problem, we have used the possibility of communicating the combination of two PLC software programs STEP7-300 and Factory io software in the multi-storey warehouse control project of products automatically by a PLC-based crane. In this situation, it is possible to create a 3D graphic industrial environment. The advantage of this work is not needing a real industrial workshop, better understanding and image of the industrial workshop, better attention to the role of PLC in the switchboard and production line, etc. Another important result of this paper is reducing the cost and time of the project.

Keywords: Factory I/O, Industrial automation, PLC, STEP7 software

1. Introduction

The history of industrial automation goes back to the time when electromechanical relay control circuit and hydraulic and pneumatic systems were used in industrial works and factories. In this method, the process feeling of need led to the evolution of making new devices including PLC. PLC performance was influenced by a software program, with minimal hardware changes required. But it provided the possibility of implementing practical projects in various industrial fields. For this reason, it was a better choice to replace the old and traditional controller to open a new horizon for control systems and pave the way for modern control systems. and give it another color and effect. It is interesting to know that the PLC is now, with the first PLC in 1968, which was made by Richard Morley in the American General Motors company.

Due to its evolution, it has become very different, the most important of which are:

• In 1969, the first hardware was presented with 1 kilobyte of memory and 128 inputs and outputs and bit processing instructions.

• In 1971, the first industrial application with digital input and output data was carried out.

• In 1972, counter and timer commands were added.

• In 1973, data calculation and movement (MOVE) commands and communication between PC and PLC were added. In this year, PLC entered the German market.

• In 1974, the expansion of memory reached 12 kilobytes and the number of inputs and outputs reached 1024.

• In 1975, analog input and output was added to PLC, which had PID capability.

• In 1978, establishing communication between two or more PLCs was done.

• In 1980, modular PLC with high work upgrade capability was presented. This year, Remate I/O through the network to the PLC boomed.

• In 1983, the memory and the number of inputs and outputs were expanded to 8192.

• In 1990, Fieldbus and Profibus technology were presented for use in control systems.

• In 1993, after 12 years, IEC presented the international standard of electrical engineering programming languages.

• In 1996, the IEC 1131 standard presented the communication of PLC and monitoring systems in the Windows environment called OPC-OLE for process control, which allows communication between different control systems with an HMI and SCADA monitoring software with just one installation in the Windows environment of all PLCs. It could work.

• In 2001, fuzzy control programming was added to the standard [1]

Nowadays, nanoelectronics technology, new software, PROFINET industrial network and... In advanced PLC control systems with new analog and digital information processing technology, it works with a better process and has DCS features. That is, in case of failure of a path, the PLC system does not fail. It finds the so-called Redundant mode. Currently, the undeniable use of PLC in various industries of industrial, commercial processes, power plants, services, etc. is abundantly seen, and PLC is considered one of the main and important components of the controller in their automation projects. With the proper design of PLC, 90% of an industrial system is controlled by software [2]. Therefore, special attention is needed to ensure the practical work of PLC in the design stages of the project software process. For this purpose, Factory I/O software (factory production line simulator software) is used. In this paper, out of thousands of projects used in various industries, a modern project with its process design steps is tried to be carried out by PLC software, and then executed next to Factory I/o software. Our chosen project in this paper is the Cartesian robot, which plays the role of a factory storekeeper. In short, the duty of this station will be to receive parts, store and arrange parts, in different floors and different positions.

2. Definition of industrial automation

Industrial automation means the use of precise electronic tool systems and computers instead of human operators to control machinery, industrial processes and production lines. This concept is originally derived from the words Automatic and Operation meaning automatic operation. Automation systems usually consist of feedback loops and logical programs and are divided into various types including: hard or fixed automation, programmable automation and flexible automation. Today, increasing quality and productivity, improving production speed, adjusting the high cost of manpower and work safety are the main motivations in automation [3].

3. Industrial Automation Based on PLC

At present, industrial automation based on PLC benefits from the main motivation and uses control systems and equipment such as computer software and robots to perform tasks. Our proposed project is a programmable and updated type of automation for the design of multi-storey warehouse control of products automatically by a crane based on PLCS7-300. In fact, the Cartesian robot plays the role of a factory storekeeper [2].

4. Project Design Steps with PLCS7-300

The design stages are one of the important phases in the implementation of the industrial automation system based on PLCS7-300. It is only necessary that before starting work, the process is well studied, the inputs and outputs are known and the logic of the control system is known. With such information, it is possible to design the step-by-step programming steps of PLCS7-300 using STEP7 as follows.
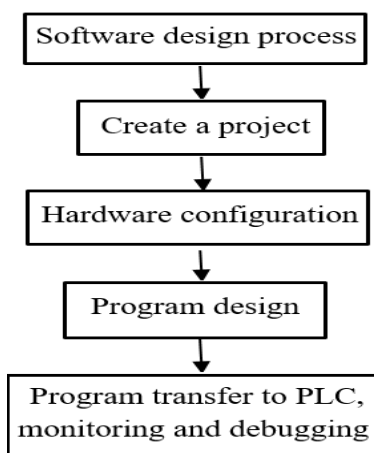

Fig. 1 step-by-step diagram of PLC programming

4.1. Project Creation Environment

After installing the SIMATIC Manager software, enter the software by double-clicking on its icon, select the New option from the File menu, and enter the project name in the corresponding window. After completing the above steps, click on the OK option to view the main page.

4.2. Hardware Configuration

After the project window appears, click on the project name and select from the Insert menu and from the Station option and then SIMATIC 300 so that the hardware configuration environment appears. By double-clicking on the specific HARDWARE option, we will enter the H.W Config software environment. In the environment of H.W Config software, in addition to the configuration and arrangement of modules, parameterization operations and settings related to CPU are also performed. In this environment, it is possible to configure the network stations and related settings, which can introduce the desired hardware for the PLCS7-300 software and tell the software which CPU to work with, or how many amperes its power. In this environment, it is possible to configure network stations and related settings. In this way, the desired hardware and CPU can be introduced for the PLCS7-300 software. In addition, it is possible to define the electric current of the power supply, the number and type of modules connected to the CPU. The process is shown in figure 2 [4].

5. Beginning of PLC programming in Block OB1

After configuring the hardware, new folders are added under the project name, which shows the type of CPU and the name of its projects. By double-clicking on OB1 (Organization Block), a window will open where you can select the initial settings of the LAD programming language and the name of this program. By clicking on OK, they enter the main environment for writing letters [5].
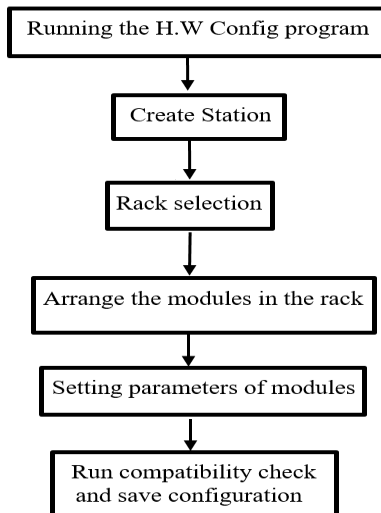
```
┌─────────────────────────────────┐
│  Running the H.W Config program │
└─────────────────────────────────┘
              │
              ▼
      ┌─────────────────┐
      │  Create Station │
      └─────────────────┘
              │
              ▼
      ┌─────────────────┐
      │  Rack selection │
      └─────────────────┘
              │
              ▼
┌──────────────────────────────────┐
│  Arrange the modules in the rack │
└──────────────────────────────────┘
              │
              ▼
┌──────────────────────────────────┐
│  Setting parameters of modules   │
└──────────────────────────────────┘
              │
              ▼
   ┌───────────────────────────┐
   │  Run compatibility check  │
   │  and save configuration   │
   └───────────────────────────┘
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Fig. 2. PLCS7-300 hardware configuration steps

6. Important Equipment used in this Project and their Recognition

Cartesian robot: Cartesian robot in this project is a rail overhead crane. Although this robot is not designed in human form. But this robot can perform its tasks with high expertise and low error. This robot is used to move and store heavy loads and includes a vertical platform and forks and can move in any direction.

6.1. Racks: The racks are vertical steel frames connected by horizontal steel beams for load storage. The existing shelf is a single-depth shelf and is also known as a selective shelf. Allows loads to be stored one pallet deep.

6.2. Conveyors: In this project, two special conveyors are used to carry heavy loads.

6.3. PLCS7-300: Programmable logic controller is one of the important components of industrial automation. 90% of an industrial system is controlled by PLC software. Basically, the role of the thinking brain of an automation system with PLC. The features of choosing PLCS7-300 in this project are: being widely used, medium performance area, modularity, many modules variety, easy to develop, STEP7 software program and easy connection with Factory I/O software [6].

7. Why use Factory I/O software

For intelligent and automatic operation of a system, we program PLCs as we want. But the problem starts here, due to the unavailability of a real industrial environment, a correct understanding of industrial automation project design is not associated with PLC. To solve this problem, the designed PLC project is run alongside the Factory I/O software to create a 3D graphic environment of the virtual workshop. The advantage of this work; Access to all equipment for the design project, a better understanding of the role of PLC in the electrical panel, a better understanding of the PLC in the design lines, project testing without damage to the industrial environment of the workshop, etc. According to this paper, we have designed the multi-storey warehouse control project of products automatically by a PLCS7-300-based crane first with SIMATI CManager software and use it along with Factory I/O software [6,7].

8. How to connect Factory I/O to the S7-PLCSIM simulator

Step 1: In the Factory I/O software, open the Driver window from the FILE > Driver Configuration menu.
Step 2: Select Siemens S7-PLCSIM from the drop-down list.
Step 3: To configure, select CONFGUATION option from the upper right part.
Step 4: Include settings according to the PLC hardware model selected in the simulator.
Step 5: Press the Esc key from the keyboard to return to the main driver window. Now click on connect to connect the emulator [6]

9. Project Plan Design

In the industrial automation warehouse, first the pallet is placed on the conveyor (conveyor belt) for loading. By pushing the start button, the products are moved on the pallet of the first conveyor belt, and at the end of the second conveyor belt, when it is in front of the sensor, the conveyor belts are turned off by triggering the sensor. In this situation, the crane activates its left forks and performs the lifting operation. After the lift, the forks are closed again so that the crane can place the pallet in the defined rack based on the specified target. When the crane reaches the target shelf, the right forks are opened and finally the crane is released from the lift mode and the pallet is placed inside the shelf and the fork is closed again. After the fork is closed, the crane returns to the loading area. For this, the number 55 must be loaded in the target. A total of 54 shelves are designed in the rack. Therefore, with different scenarios in the design of PLCS7-300 programming in LAD programming language, we act as follows for this thesis project for better and clearer results of the initial design process of the multi-storey warehouse control project, the products are automatically controlled by a crane. First, with the considered scenarios, the program is written step by step by PLCS7-300 and tested with the FACTORY I/O software to reach the final stage of the project [7,8].

Fig. 3. Completed FACTORY I/O project

9.1 First Scenario

With the push of the thumb, the products will move on the first conveyor and at the end of the conveyor, when it is in front of the sensor, the conveyors will turn off.
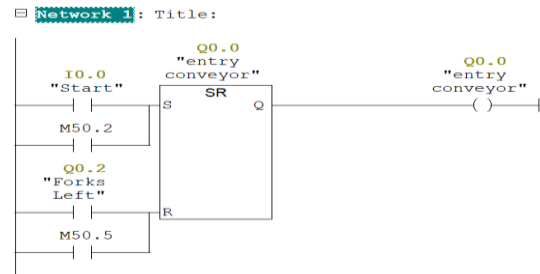
Fig. 4. LAD language programming of the first conveyor

Figure 4, Network 1, the first conveyor motor is turned on by pressing start. Products inside the pallet on the first conveyor belt, which is placed at the beginning of it is moved. Then the products enter the second conveyor belt. For this purpose, a start button (I0.0) and a flip-flop whose output is set with a Q0.0 coil are used.
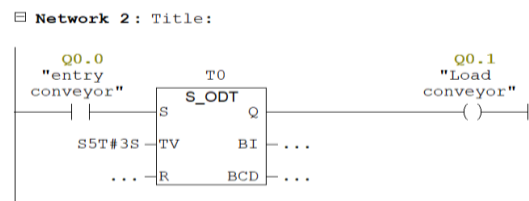
Fig. 5. LAD language programming of the second conveyor

Figure 5, Network 2, it is not necessary for the second conveyor to start at the same time as the first conveyor. Therefore, the duration of movement of the products on the first conveyor belt until it reaches its end is calculated. Then the second conveyor is started. For this purpose, a time delay timer with a time of 3 seconds and output Q0.0 is used as the input of the first conveyor to set the output Q0.1.

9.2. Second scenario

By crane engine, the crane first moves its fork to the left side and then to the top and picks up the desired product from the conveyor belt and returns to its original position.

☐ **Network 3:** Title:

Fig. 6. Sensor LAD language programming

Figure 6, network 3, is physically the installation location of the sensor on the end of the second conveyor to detect the position of the product pallet. By connecting the sensor to the output of the Q0.2 set, its operation starts. Its first function according to the first scenario, using Q0.2 in the reset input of the network 1 flip-flop, performs the function of turning off the conveyors so that the products do not move on the conveyors and remain in the waiting state. Second, according to the second scenario, the use of the sensor causes the crane motor to open its left forks.

☐ **Network 4:** Title:
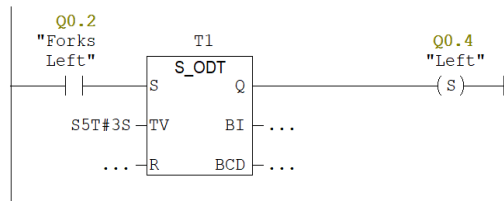
Fig. 7. Upper LAD tongue programming in crane

Figure 7, Grid 4, causes products to move up. For this purpose, Q0.2 output is used as a 3 seconds delay timer input to set Q0.4 output.
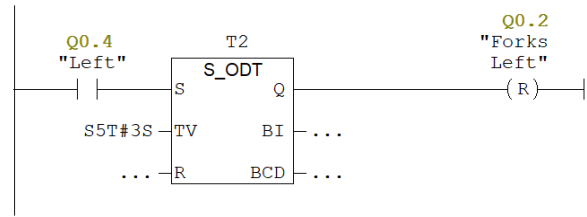
☐ **Network 5:** Title:

Fig. 8. LAD language programming reset sensor

Figure 8, Network 5 using the Q0.4 output for the time delay timer input, considering 3 seconds, the product stop command is issued from the left.
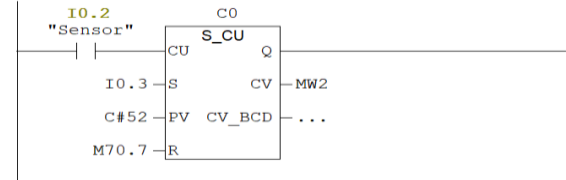
☐ **Network 6:** Title:

Fig. 9. LAD counter language programming

Figure 9, network 6, the operation of the sensor at the entrance of the high counter causes the counting order of 1 to 54 products on the conveyor.
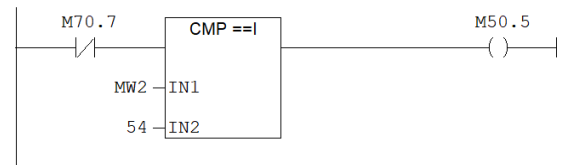
☐ **Network 7:** Title:

Fig. 10. LAD programming language comparator

Figure 10, Network 7 is used to control the count up to 54 in the counter and reset the first conveyor.

9.3. The third scenario

The product warehouse is numbered in order and the products can be stored in the product warehouse in order from number 1 to number 54.
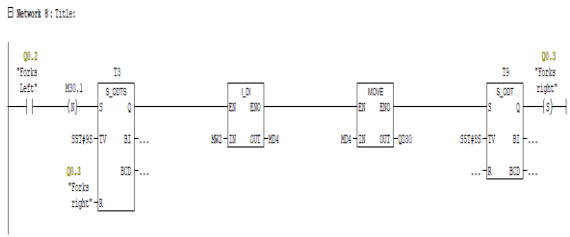
Fig. 11. LAD programming language transfer products

Figure 11, network 8 from the output of Q0.2 in the input of the delay timer used in the dwell time, an optimal time of 9 seconds is given to it so that the products are placed in front of the shelves at the specified time. For this purpose, an integer Word to Dword converter and the MOVE command have been used. The delay timer T9 is set at 8 seconds to command the forks to open to the right with output Q0.3.
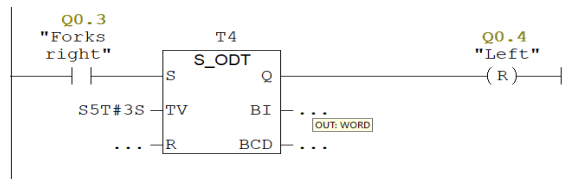

Fig. 12. LAD language programming of the upper side of the crane

Figure 12, network 9, Q0.3 output is used in the time delay timer input with a time of 3 seconds to reset the upper side in gravity.
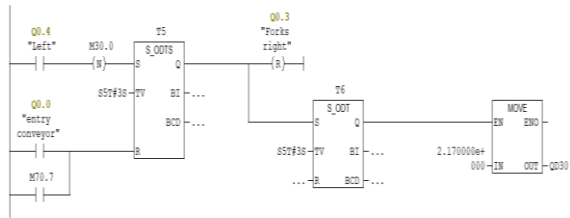

Fig. 13. LAD programming language transfer products

Figure 13, network 10 using reset Q0.4 in the permanent delay timer input, while the first conveyor is off, the timer will turn on after 3 seconds. In its output, two commands are issued. First, the reset command is given on the right side. Second, with a delay of 3 seconds, it performs the MOVE command to transfer and store the products on the shelves.

9.4. fourth scenario

when the product warehouse is full, new products are not allowed to enter the conveyor and the conveyor is stopped.
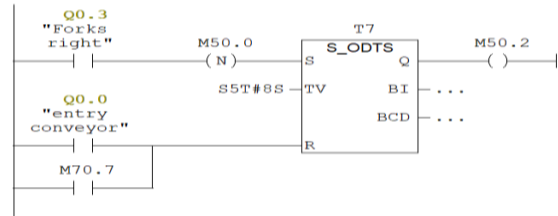

Fig. 14. LAD language programming for reproducibility

Figure 14, network 11 using the reset command from Q0.3 output including 8 seconds while the first conveyor is off, output M50.2 is issued to be used in the first conveyor set for program repeatability.
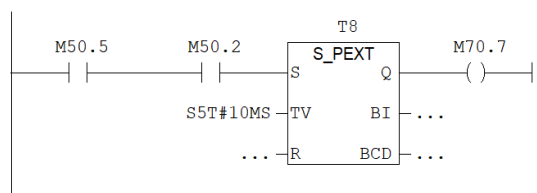

Fig. 15. LAD language programming Stop the whole program

Figure 15, network 12, with the activation of comparator output and M50.2, after 10 milliseconds, M70.7 is commanded to be activated to return the whole program to its initial state.

10. Conclusion

10.1. PLCS7-300 usage results

PLCS7-300 as a part of the planner in the automatic control of the multi-storey warehouse of products by a crane leads to a significant reduction in energy consumption, a very high response speed, an increase in the security of manpower, high accuracy and flexibility, and... leading to the findings Increases productivity, improves the quality of industrial units, etc.

10.2. Results of using PLCS7-300 software Along with Factory I/O software

By using the Factory I/O and STEP7 software program, you can benefit from the powerful 3D graphic simulation technology and any project using the PLCS7-300 software along with the Factory I/O software can be used as an educational aid software. He showed that the results of this work are not needing a real industrial workshop, better understanding and image of the industrial workshop, better attention to the role of PLC in the electrical panel and production line, etc.

10.3. General Results

The general results that we have achieved in this paper. The significant reduction of costs and time consumption is 90 percent, which in the old systems requires spending money and especially time, and the need for time sometimes causes the desired idea to never be implemented.

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