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Designing and Assembling of a Programmable LogicControls (PLC) Laboratory Trainer and Advanced Research Setup

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Designing and Assembling of a Programmable Logic Controls (PLC) Laboratory Trainer and Advanced Research Setup

Abstract:

A Programmable Logic Controller (PLC) is an industrialized computer control system that constantly monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices. Almost any production line, machine function, or process can be greatly enhanced using this type of control system. However, the biggest benefit in using a PLC is the ability to change and replicate the operation or process while collecting and communicating vital information. It is also a modular system. It can be mixed and matched the types of Input and Output devices to best suit of any laboratory application and industrial control application.

Training setup consists of an industrial grade PLC, Variable Frequency Drives, Servomotors coupled with drives, induction motors, Human Machine Interface (HMI), industrial networking capabilities, and many other ancillaries. The setup can be used for demonstrating the principles of programmable controllers and sequence control systems, advanced cam profile and advanced computation for controlling industrial processes. It is suitable for training both basic and advanced principles of PLC. Industrial grade PLC components are permanently mounted on the panel; it is also coupled, activated and controlled with numerous configurations such as with Variable Frequency Drive (VFD), servo drive, servo Motor, and induction motor, along with Human Machine Interface (HMI).This Laboratory Trainer and research setup system is fully integrated with PLC Motion Animation software that will help students observe and understand the control logic behind the operation of industrial PLCs. The software tool can be used as an offline and online animation tool with its collection of sample HMI applications. The trainer can be used alternately for operation and control of industrial manufacturing processes. The example ladder logic program in the trainer describes the methods of running servomotor and servo drive that are widely used in almost every industry where automation is required. Smart vision checking system which is used for sorting and many other purposes can also be interfaced with the setup. This setup has at least two VFD to control various functions of induction motor. Such as conveyor speed, acceleration, and many other motion related aspects of an induction motor.

The combination of software and hardware offers practical and effective trainer and research engine for industrial control and manufacturing. Also help students to know about smart vision checking system, servo drive, servomotor, induction motor, Variable Frequency Drive (VFD), HMI, industrial networking, and interfacing with real world packaging machines. In addition, one of the main advantages of this trainer setup panel is its modular capability. This trainer setup can be modified, coupled with any industry related control system that might need in the future for

training purpose. Above all, this laboratory training and control panel setup is performed in two stages. First, the machine design and electrical control for the entire operational process is conducted and then the study of effectiveness of re-configurable and portable Programmable logic controller system with proper statistical analysis.

Introduction:

Programmable Logic Controllers(PLC) are predominately laboratory based subjects as they require “hands on” electrical wiring, interface to industrial electrical components, to Human Machine Interfaces (HMI) and may be networked with conveyor system, vision checking system, Servo motor etc. (Rohner, P. (1996). PLC*)*. As PLC courses evolve to incorporate the IEC 6-1131 defined programming languages with the resultant extra software theory learning requirement and an increasing demand for in-company courses, a requirement arises for a PLC system which is portable, reconfigurable and can be accommodated in a training or class room with the small control system included conveyor, servo motor, Cognex Vision Checking etc.

This research started with performing the studies about each and every method how a small control system can be controlled by Programmable Logic controller in automation world. For an instant as the PLC is part of an automated system there are several modules that are included to this terminal. Those modules are software engineering, electrical design, and in some cases, mechanical design. Software engineering includes applying a Software Development Life Cycle (SLDC) approach to the system being designed and the ability to write the control program to control a real time control system. Electrical design encompasses electrical panel design (and construction) to the relevant standard. The PLC apart from being run as a “stand alone” is now an integral part of a system ranging from agricultural engineering to mechatronics and industrial automation. PLC application, as for all control engineering, it must deliver “a balance of practical skills and theoretical knowledge” and as such are laboratory based. Increasingly, in response to demands from industry PLC courses are being run in-house, in training rooms, away from the traditional venue of the automation laboratory using hardwired “kits” and PC based simulators (Bolton, W., & NetLibrary, Inc. {2006})

This system also describes the methods of running servo motor by servo drive (ultra 3000) which is widely used in almost every industry where automation required. Nevertheless it also includes conveyor system which is used almost everywhere where any kind of moving of product from one point to another is necessary in industry , and also Cognex Vision Checking system which is used for sorting out the product based on required standard in everywhere. Not only the system currently being run by Ladder Logic programming and digital I/O it also gives the idea about analogue I/O and the Sequential Function Chart (SFC) programming language, data capture and Overall Equipment Effectiveness (OEE) measurement. For the Ethernet module OEE data collected by the PLC networked and presented on remote PCs as part of a Management Information System (MIS).

Purpose of Study:

The main reason for this study is that for many years, industrial processes were not directly monitored. The input and output were not given keen attention, which resulted into wastage (Jha, 2008). Also, the operations of machines in an industry were not well monitored. There was need for a system that can continuously monitor the input and output of machines. As a result, the research to design and fabricate a programmable logic controller was started (Bolton, 2006). This system will help monitor elements such as safety, fire, smoke, radiation emission among others. The best method to be used in this kind of research is the casual study. This is because the investigation is done in an industry where one does not necessarily have to attend classes.

Some of the data that was collected within the industry when the machines were investigated are as shown in the table below.

Factors investigated	Data collected before the installation of the PLC into the machines	Data collected after the installation of the PLC into the machines
The intensity of smoke emission	70 %	35 %
Number of accidents monthly	25	9
Emission rate in the industry	90 %	45%
Fire outbreaks in the industry	11	3

Table: 1(a) Comparison of industrial operation before and after PLC installation

Another purpose is that the study must help come up with a better design for the programmable logic controller. The new design must be more developed compared to the previous versions. PLC training module must always be able to perform a project or task correctly. This is possible because the PLC is equipped with a conveyor belt, robot arm and wired to a controller (Bolton, 2009).

PLC is used in the communication and technology industry hence making those industries very essential for research. The device is applied in the communication industry to monitor various elements making communication easier. Also, the PLC has become an important element of automation engineering especially where machines are involved. This qualifies the manufacturing and production industries this research. Improvements made on the logic controller are the key, as they help it integrate safety engineering, communication and technology (Jha, 2008).

Research can be shown based on data providing below between before installing PLC. and after installation.

Data type	Before installation of the PLC	After installation of the PLC
Number of workers	125	130
Number of accidents	30	15
Number of victims to injuries every month	20	10
Number of incidents of firebreak outs every month	7	4
Numbers of machines that breakdown every month	100	60
The intensity of the smoke	65%	40%
The rate of emission of smoke	2.84	1.24
The rate of output to input	70%	90%
The percentage of material wastage	60%	25%
The volume of production every month	78914 items	107524 items
The possibility of worker absence	70%	32%

Table: 1(b) Comparison of Industrial Operation Before and After PLC Installation

Sources of Data

There are three sources that were employed in this research. Since the research data was collected from industries, the sources were primary and secondary. However, it is important to note that since this was an academic research paper, it majored in the primary source for the purpose of getting firsthand [information (Kahn, MacQueen & Plotkin, 1984). Some of the examples of the primary sources employed by the research in the design and fabrication of the PLC included;

- Business letters that were wrote by the experts in the field of design and fabrication in the industries where research happened
- Business diaries and journals kept by the industries also helped in data collection
- Also, the engineering drawings, sketches, photographs & paintings among others
- The research concentrated on banners, advertisements and posters
- The company's news footage e.g. the videotapes, newsreels and audiotapes

Component Description:

Programmable logic controller (PLC) is an industrial computer system that monitors continuously the state of a machines input devices and decides upon a program to control the output device. For many years, PLC's have been widely used in a variety of applications which are the most important control elements of several subsystems requiring moderately slow data monitoring. These are personal safety, the radiation control, smoke, and fire alarm. PLC's are very crucial for monitoring and controlling a process. There are inputs and outputs which can be categorized into two types, which are logical and continuous. The input terminals in the PLC helps in interpreting high or low logical states from switches and sensors whereas the output terminals help in signaling power lights, contactors, small motors, solenoids and other devices. As they are industrial computers, their input and output signals are typically 120volts AC, similar to electromechanical control which they are designed to replace. The PLC module for training gives those students pursuing mechanical engineering more knowledge in mechatronics.

Servo Motor Motion Control:

Integration of PLC with a servo motor is quite easy. All that is required is that you have right settings, build right wiring and an accurate program. Right wiring is a key, particularly when you purchase the servo engine control with a driver.

Correct Wiring: Output the servo RUN signal to the motor and reset signal to any alarm. You need feedback from the AC servo motor encoder for the input to the PLC from the servo driver. Tapping into the PLC pulse output complete signal from servo driver is also another option.

Writing of the Program: You can control a servo motor using ladder logic to give an effective and continuos supply of pulses in which the pulse can stop when the program instructs it to stop.

Servo Motor Control Using PLC

There is linear servo system and motion control system where each is unique from the other. Linear servo system supplies pulse into the motor drive then the drive gives power through the PWM to the AC servo motor. Feedback is in return given by encoder to the driver and driver does the error counter. Motion control system supplies pulse to the motion control unit, which gives analog input 0-10v to motor, driver. The motor driver gives power through PWM to the AC servo motor. Feedback is in return given by the encoder to the driver and driver gives error notification to the motion control unit to conduct the error counting (Rohner, P. 1996).

How Servo Motor Works

They are specifically designed to be used in control applications and in robots. They are also used for specific position and speed control consisting of a suitable motor, position sensor, and sophisticated controller. DC servo motor and AC servomotor are the categories of the servo motor.

A servomechanism is a closed loop system, consisting of controlled device, output sensor, controller, and feedback system. Its' application is most probable when position and speed are controlled.

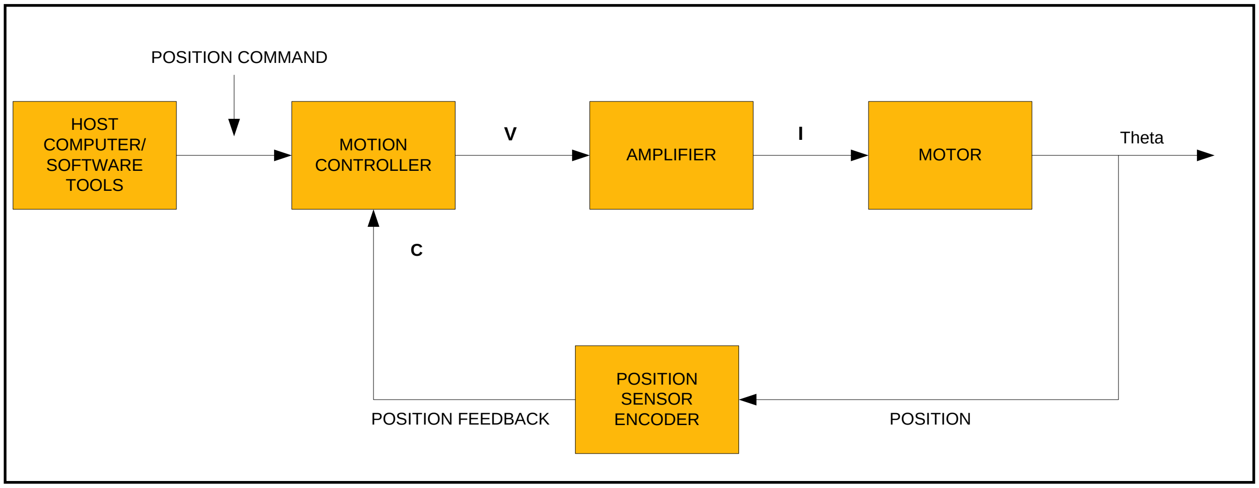

Figure: 1 Servo Motor Working Principle

Servo motors are used to control speed and position where the mechanical position of the shaft can be detected by use of potentiometer coupled to a motor shaft through gears. The current position of the shaft is then converted into electrical signal and compared with command input signal. Modern servo motors use electronic encoders or sensors to sense the position of the shaft. Based on the required position of the shaft, the command input is given.

If the feedback signal is different from the given input, an error signal is generated. The error is applied as the input to the motor which leads to rotation of the motor. When the shaft is at the required position, error signal becomes zero making the motor stay standstill holding the position.

Design And Assembly of Trainer Panel:

This trainer Panel is designed in mainly three steps

1. Mechanical Design of the trainer
2. Electrical Schemtic for wirning the component
3. Devlop the ladder Logic for the controller

1.Mechanical Design:

In this project the mechanical frame is built using the AutoCAD® software and SOLIDWORKS. This is the very first step of building this trainer Panel. To design the trainer

Panel Components were pre-selected, which gave the idea how it has to be built in a way that the entire component can be place in it in a systematic way, and also keeping in mind that future expansion of component is possible if needed.

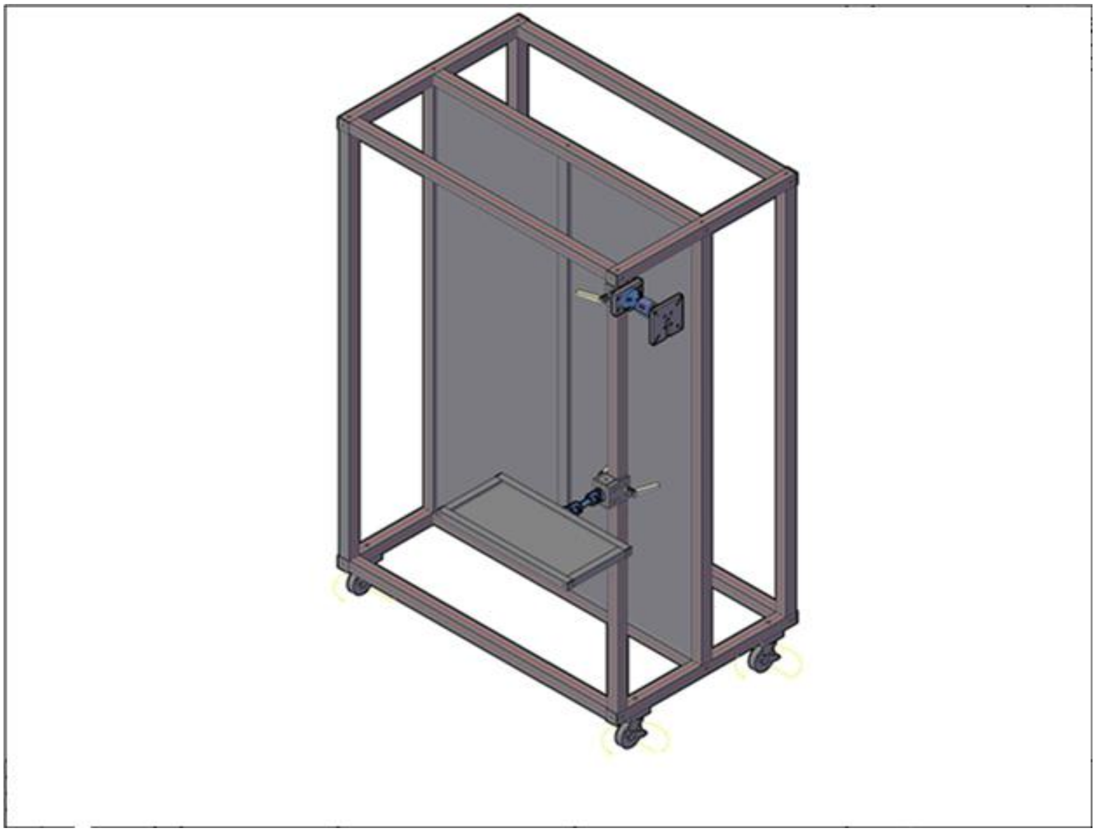

Figure 2: 3D Design (Preliminary) of the Trainer Panel.

For this trainer panel, a well-designed cubic structure was built with keyboard and monitor mounting hardware for the trainer computer. The first 3D design of the panel was helpful to divide the space into 6 equal sub-panels and layout the component. The bottom most row consisting of two sub-panels were fixed to mount 2 Allen-Bradley MPL series Servo motors.

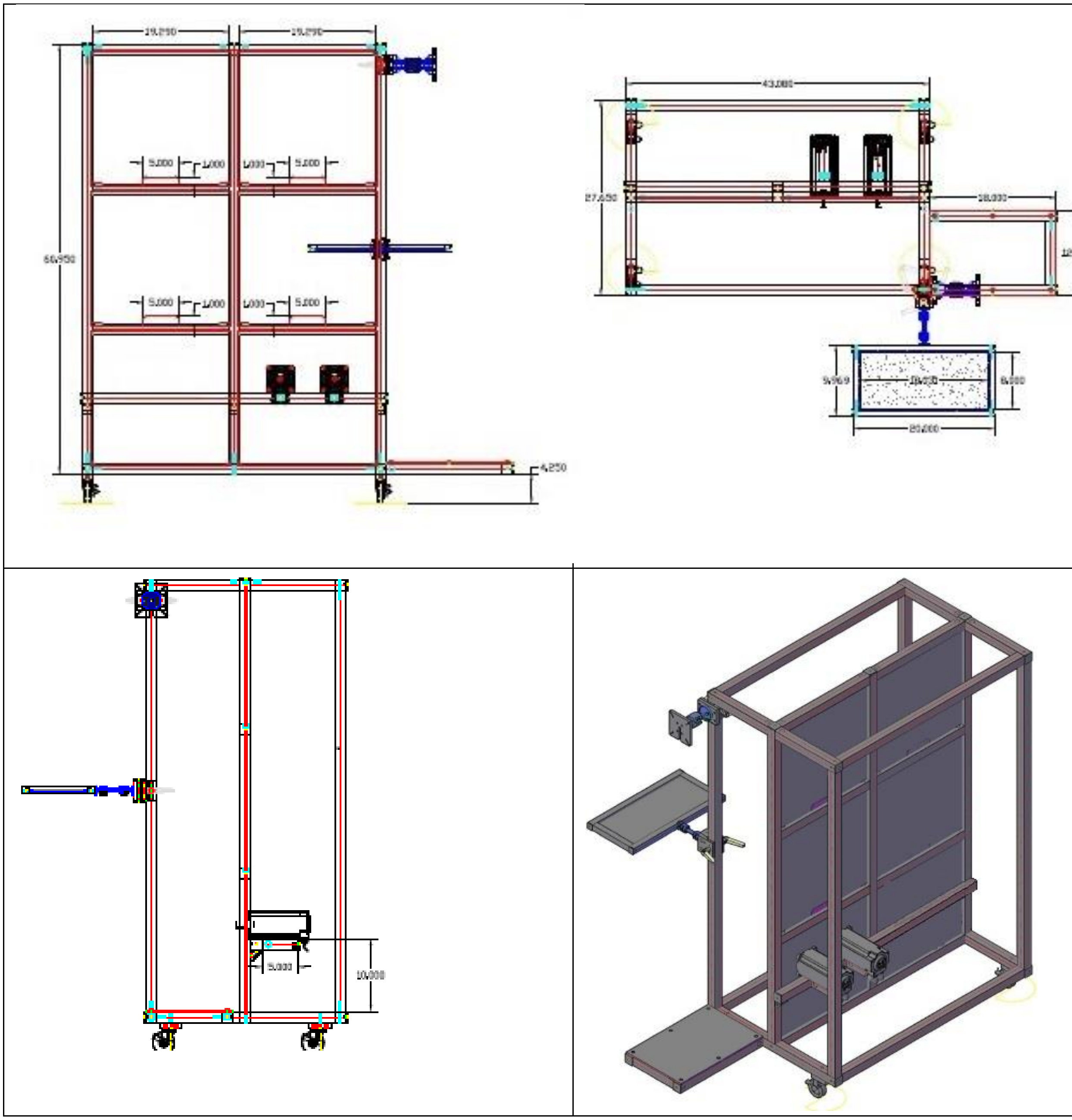

Table 1: Finalized Drawing of Different View of the Trainer Panel

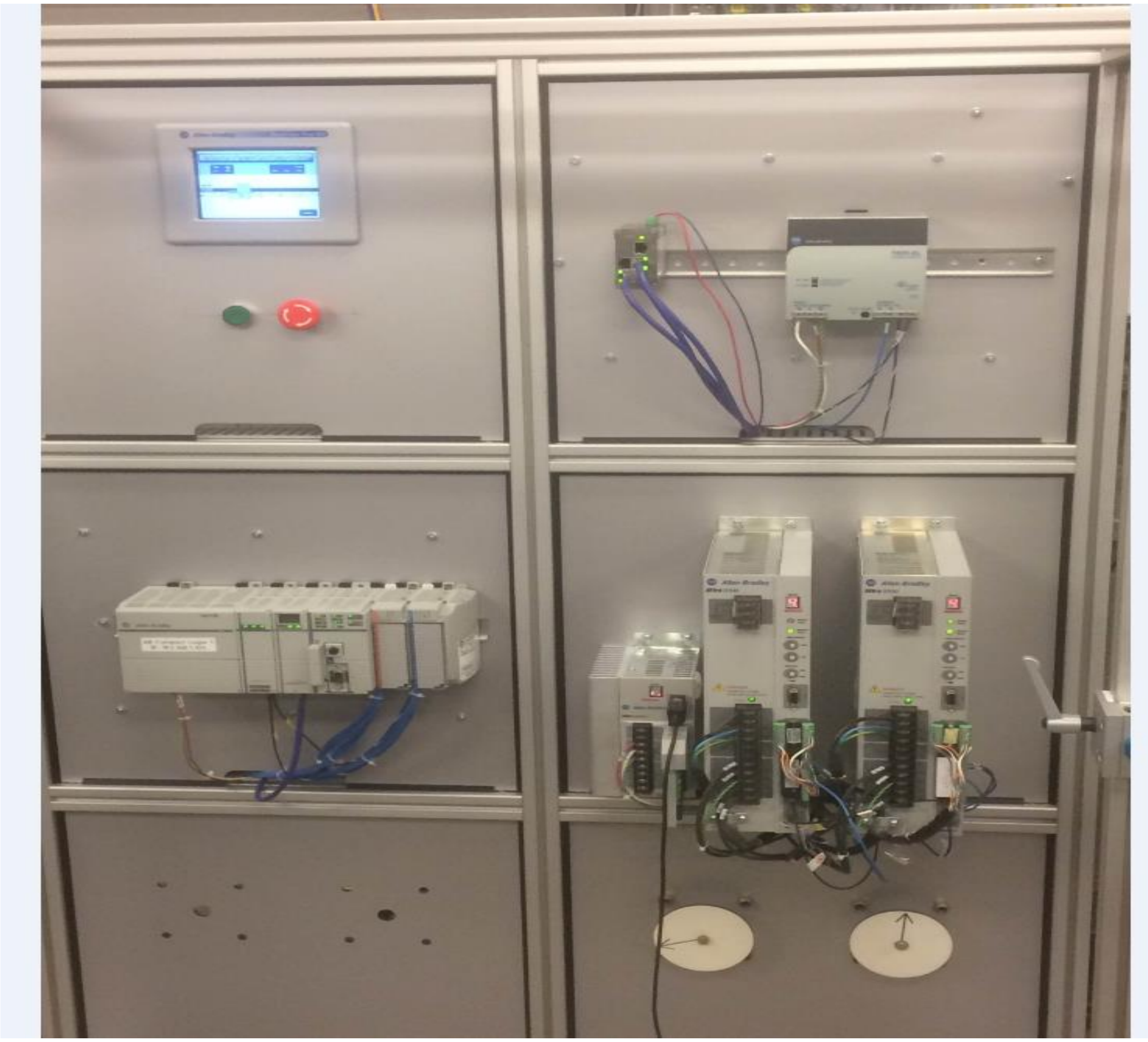

Figure 3: Real time PLC Laboratory Trainer Panel

Some of the important panel components can be known from the table below:

PLC and I/O Modules	Parts No
Compact Logix PWR	1768-PA-3/A
Ethernet Module	1768-ENBT/A
Sercos Interface	1768-M04se/A
Compact Logix L43	1768-L43/A
Isolated Relay out 8pt.	1769-OW81/B/3
Sink/Source Input 16pt.	1769-IQ16/A/2
End cap	1769-ECR
PowerFlex 4	cat no 22A-B2P3N104
Servo Drive	
Line Interface Module	2094-AL50S
Ultra 3000 servo drive	2098-DSD030-SE
Ultra 3000 servo drive	2098-DSD030-SE
Line Filter	2090-XXLF-X330B
IAM	2094-AC16-M03-S
AM1	2094-AM03-S
AM2	2094-AM03-S
AM3	2094-AM03-S
Motor Cable	
Motor Feedback Cable	
Feedback connector	
Servo Motor	
MPL series servo Motor	MPL-430P-MJ24AA
Eye Vision Checking System	
Cognex Vision checking System	5100C
HMI	
Panel view 1000 plus	

Table 2 List of Components for Trainer Panel

2. Electrical Layout

After the Mechanical design it is needed to identify the I/O of the components which are mounted on the panel. The next step was to make electrical panel layout and wiring diagram of the electrical wiring. Depending on the I/O of the component the wiring diagram of the machine has been changed. Here is the main power diagram of electrical Layout for the trainer Panel

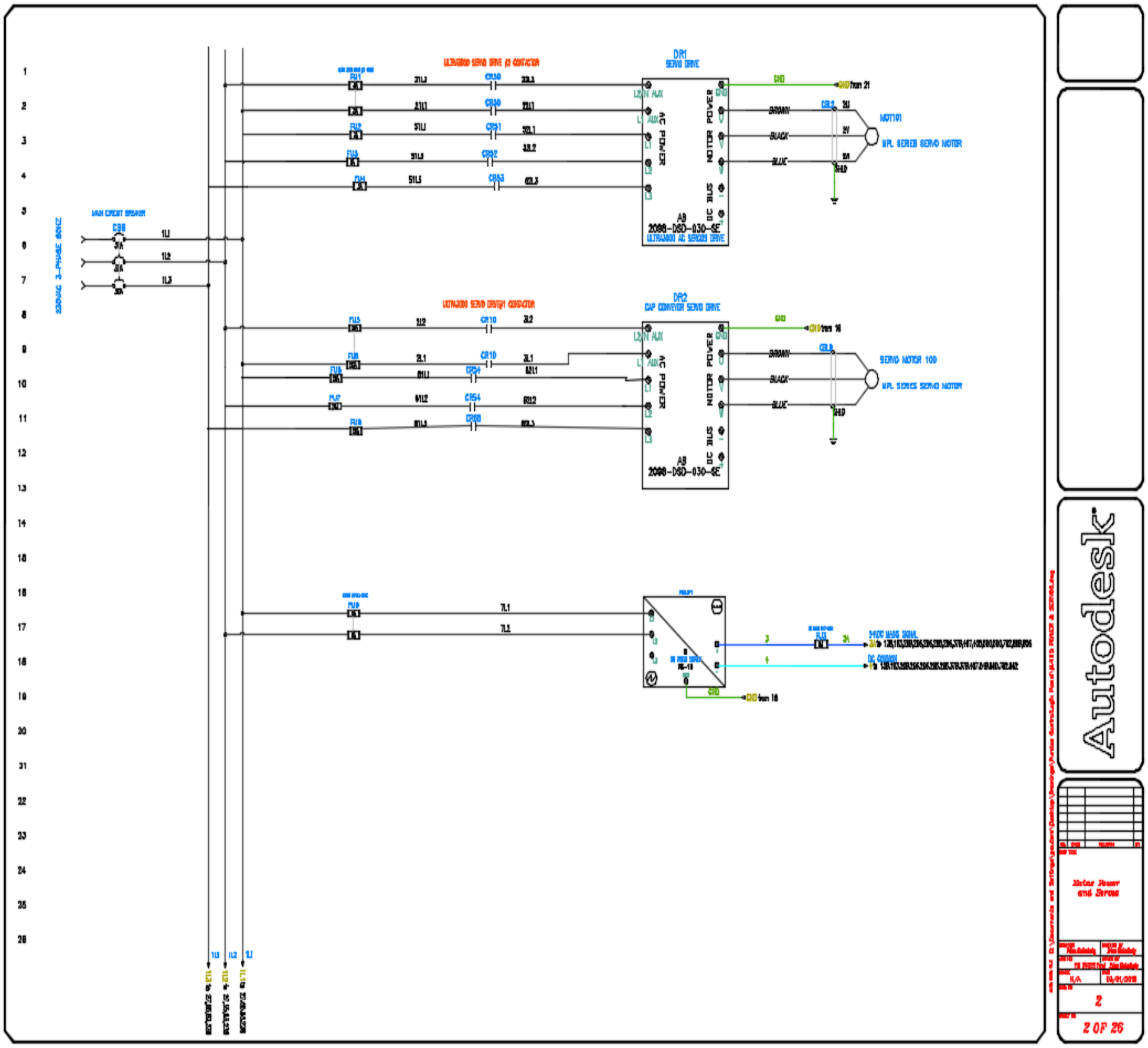

Fig 4: Main Power Diagram of Ultra 3000 Servo Drive in The Trainer Panel

4. Ladder Logic

After completing the electrical wiring the Ladder logic of PLC has been designed. Using the RSLogix™ 5000.It is quite hard to beat the simplicity and usefulness of ladder diagram programming when it is used to replace timers, counters and relays. It is, therefore, a graphical programming technique that came from electrical circuit diagrams. The logic in ladder diagrams flows from left to right where the diagram can be divided into subdivisions called rungs. With an input of instructions, which lead to single output instruction are every rung containing function block instructions which are complicated. In other words, the programming method is vertical which means that the user can visualize what the program does. The vertical line on the left stands on the positive side of the power source while the vertical line on the right side represents the negative side of the power source. If at any case the two lines that are vertical are connected, there is a closed circuit. Rohner, P. (1996).

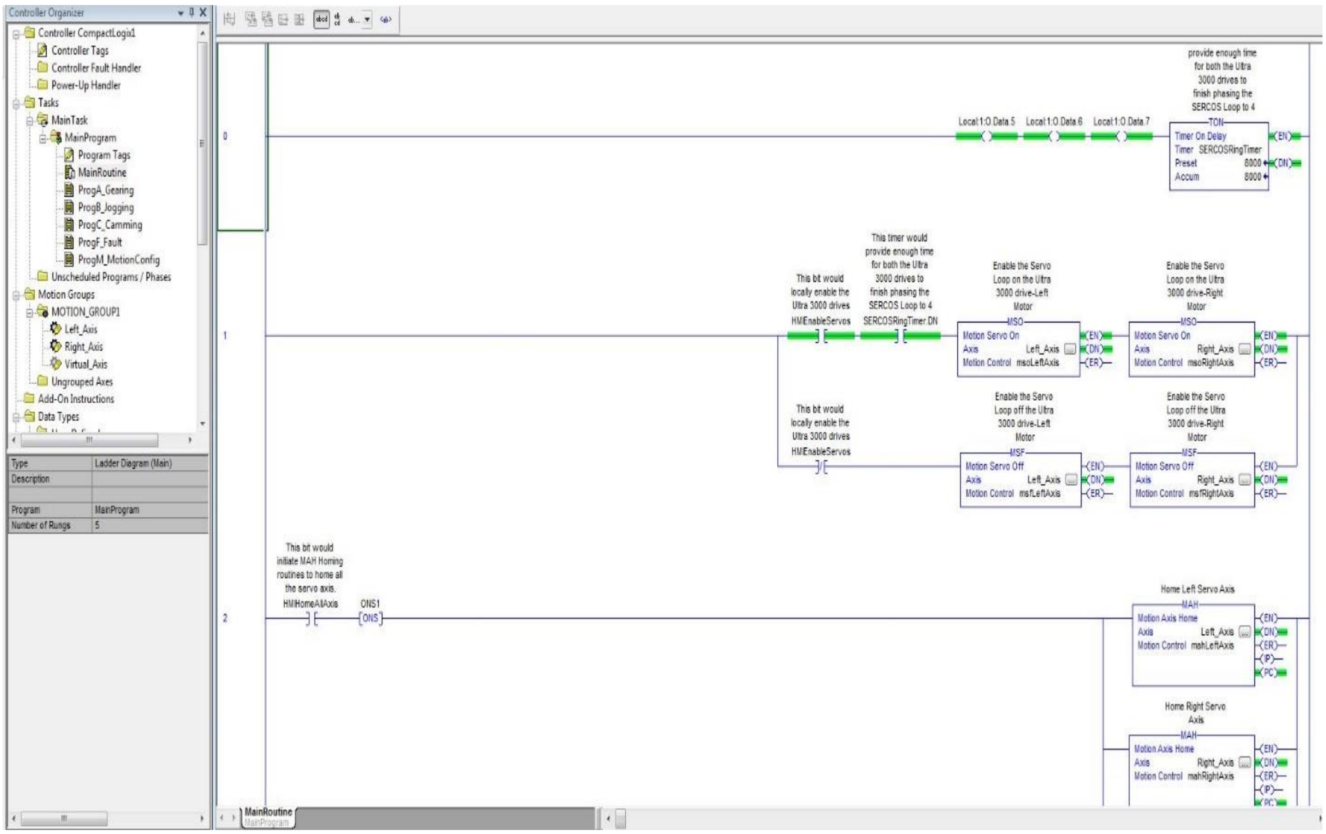

Figure 5: Ladder Diagram from RSLogix™ 5000

Discussion of Results:

This research outcome gives many opportunity to the people who are interested in Automation industries, Graduate students can do a lot of research work regarding control systems and there process of operation. Technicians can also get exposure about the trending technology in the field of the Control Engineering. This also provides Undergraduate students a strong motivation to pursue their carrier in Automation sector.

Summary

PLC training module which is equipped with a robot arm, conveyor belt and wired to a controller can be able to perform a task or a project excellently. PLC has made the mode of communication and technology easier as it has its' application areas which to be covered here. PLC has become an important element of automation engineering as it integrates safety engineering, technology, and communication. This trainer Panel can help student to learn about the configuration of servo motor, ladder logic Programming, configuration OF Vision checking system etc. more importantly student can get the idea of the real time control system which will be helpful for their future career. This PLC Laboratory setup replicas the industrial environment that will help the system of education to reduce the transition gap across the theoretical knowledge provided and to the industrial Equipment. By including the process of Design, assembly and Programming in the Laboratory Experiments and getting Hands on with the setup will result in an exposure where the student can involve in the process of PLC Design for the requirements by including this into the curriculum. This training module can act as a platform to the students so as to have their ladder logic downloaded into the PLC and observe the operation of the servo motors, conveyors and integrate the sensors to their logic. The data given about the comparison of Industrial Operation before and after PLC installation will show how the expertise in this technology will help the industries in a way to have an economical production. So by having the students knowledgeable enough in this field will reflect in the results much better than to present days.

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