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Electrical Design and Development of I-Gantry Automation System

Bhavana S.
Industrial Automation and Robotics
The National Institute of Engineering
Mysuru, India

Dr. N. V. Raghavendra
Department of Mechanical Engineering
The National Institute of Engineering
Mysuru, India

Abstract:- Presently, the demand for automobiles is increasing and the automotive parts have to be produced proportionately. Automotive industries are therefore determined to meet the customer demands i.e. to attain a greater product quality and to increase the production rates. Automation solution is provided to these manufacturing industries. Automated manufacturing systems use computers and computer related technologies that are capable of operating without human intervention. This paper presents the electrical design and development of gantry automated system by implementing PLC and CNC. Electrical circuit design, PLC and NC programs are explained for the compressor housing manufacturing line. Testing and tryout is carried out for different part models.

Keywords:- *Gantry system, Programmable Logic Controller (PLC), Computer Numerical Control (CNC), EPLAN Electric.*

I. INTRODUCTION

Automation is a technique that involves the application of mechanical, electronic and computer-based systems to manufacture products with least human intervention. Gantry automation is one such platform for material handling systems. A gantry system consists of an overhead manipulator which is assisted to transfer the parts from one machine to another. Automobile is one of the industries that is implementing gantry automation solution to adapt to the numerous challenges in terms of product quality and productivity. A gantry system is designed based on customer requirements.

Electricity is the main source of power in automation systems. This power is used in the manufacturing processes as well as material transfer functions such as loading and unloading of work units and also for the control unit to actuate the control signals and electromechanical devices such as switches, relays motors etc. The actions performed by an automated process is defined by a program of instructions. The processing steps are specified in the work cycle programs known as part programs in numerical control. The program of instructions are executed by the control system. The commands provided in the program of instructions actuate the switches, motors and other devices which changes the state of the system. Further sensors are provided to obtain a feedback to make the required adjustments.

Control engineering has evolved with the development of a special form of microprocessor based controller called the Programmable Logic Controller (PLC) that stores the instructions to implement logical and sequential functions used to control machines, equipment and other processes. Ladder logic is the main programming method used for PLCs. Processes are controlled by the PLC using the inputs from the sensors to make decisions and drive the actuators to obtain outputs.

Numerical Control (NC) is a form of programmable automation in which the mechanical actions are performed on the machine tools and equipment by a set of programmed alphanumerical data known as part programs. A Computer Numerical Control (CNC) is an NC system based on a dedicated microcomputer. NC part programming involves planning and documenting the sequence of operations to be performed by the machine. The programs are entered directly into a computer equipped with NC part programming software where the programs are executed block-wise.

The automation system has to be prepared electrically and mechanically for installation. All the machines and equipment are interfaced according to the design constraints and customer requirements. This paper presents the electrical design and development of the I-gantry automation system for compressor housing component. The PLC and NC programs are explained for the operating sequence.

II. LITERATURE REVIEW

With the knowledge of PLC, CNC systems and the related concepts, it is possible to design a gantry system according to customer requirements. All the machines and equipment have to be prepared mechanically and electrically to provide gantry automation solution. Following are some of the related literature works in support for the paper.

A. Automation Component and Conditioning Monitoring Concept

An important step towards improved development process is an architecture which defines constraints on the control application structure. Conventional PLC based architectures are the standard for control engineering and applications. Reinhard Hametner et al. [1] have proposed a framework to develop the automation control systems. An automation component is defined as a collection of hardware, software and properties describing the interaction between the

different parts and specifying different software specific aspects for implementation and execution of the process engineering objects. An automation component can be divided into subcomponents each for automation aspects (logic, behavior and implementation), test aspects (unit tests, integration tests and factory acceptance tests), runtime fault analysis aspects (diagnosis), and runtime fault prediction aspects (condition monitoring and data analysis).

Condition monitoring is a management technique which uses the regular evaluation of the actual operating condition of plant equipment, production systems, and plant management function for optimizing the total plant operation. The main objective of condition monitoring is to identify and diagnose the faults of industrial processes.

Therefore, automation component model is a valuable approach for encapsulated and reusable components while condition monitoring helps to diagnose the faults of the system.

B. Embedded Web PLC

Programmable Logic Controllers (PLC) are widely used in industrial control systems. With the development of technologies, the application scope of PLCs has drastically increased. Basanta Mahato et al. [2] present a review on web PLC recently developed. Web-enabled PLCs can significantly change the way plants are run, reducing downtime, communicate proactively and increasing productivity. Web-PLC allows the manufacturer who built it to remotely monitor and even repair their machines, reducing response time and cost. A built-in Ethernet interface allows this information to be easily shared across the enterprises for faster decision making.

C. Distributive NC System based on Fieldbus

Today, numerical control (NC) technology develops greatly in integration design, open architectures and intelligence. Distributive architecture and distributive control technology theory can be applied to design NC system. In the process of research and design, the maturing filed-bus technology is adopted to communicate and transfer data among different system nodes which are discrete. So Tao Wang et al. [3] proposed a research framework on distributive NC system based on fieldbus. NC system is often connected with local network in the enterprise or internet in order to implement network and information management and manufacturing in the entire corporation and network diagnosing of NC system devices. NCK is the main control node which is responsible for creating and allocating all the tasks of NC system. HMI node displays friendly human-machine intercommunication interface, deals with keyboard input, displays various data and machining information. I/O module mainly deal with some electric signals related to machine devices.

III. ELECTRICAL DESIGN OF THE I-GANTRY SYSTEM

The plans and designs of the electrical circuits, interface of hardware and software devices are implemented to run the gantry line. PLC and CNC logics are programmed to conduct test runs. This paper provides gantry automation solution to I-gantry system of a compressor housing manufacturing line. The floor plan designs and details of the machines and equipment that are used in the system are obtained from the mechanical team. Figure 1 shows the layout of I-gantry cell. The major requirement is to automate all the machines and equipment in the manufacturing line. To do so, the gantry system has to be prepared mechanically and electrically. Mechanically the system is assembled according to the mechanical designs. Electrically the circuit designing, PLC and NC programming are done to run the gantry line.

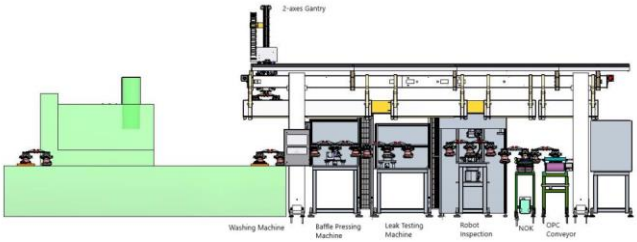

Figure 1: I-Gantry Automation Cell

The gantry system consists of manipulators known as a loaders that can transfer parts from one machine to another. This system uses a single loader that can travel in 2 axes (longitudinal and vertical), and hence the system is referred as an I-gantry system.

To begin with, the electrical circuit designing is done using the EPLAN Electric P8 software. It is a simulation software dedicated for circuit designing. It allows the user to create electrical circuits and label them easily. The major circuits that are drawn using EPLAN are the power distribution circuits in which the main power is distributed to the electrical cabinet consisting of relays, contactors, drivers, SMPS and transformers and also to the conveyor motors in the system. Figure 2 shows the main power terminal details of the motors.

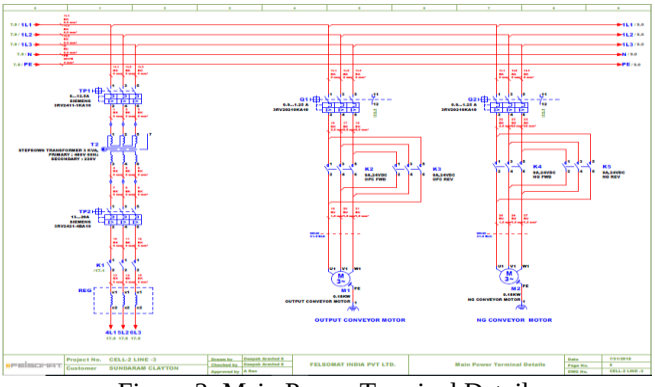

Figure 2: Main Power Terminal Details

Further figure 3 shows an emergency stop circuit designed using safety. Emergency stop circuits are designed

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to avoid the mishaps that might occur due to faults and isolate the system from the fault.

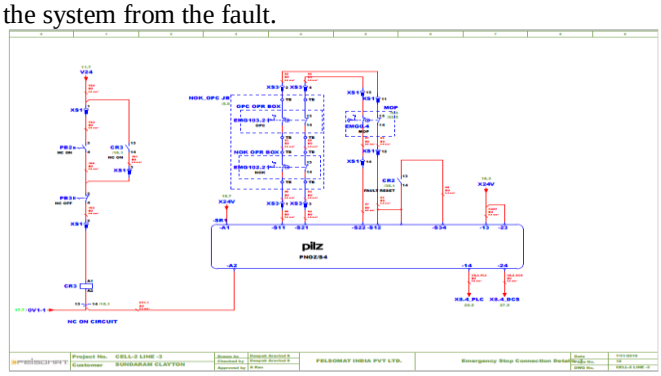

Figure 3: Emergency Stop Circuit

Other important circuits that are drawn using EPLAN are the remote IO connections which indicate the connection of sensors, switches, relays and lamps with the PLC module. These devices are controlled by the PLC through digital signals to change the state of the system. Figure 4 shows the remote input connections and figure 5 shows the remote output connections.

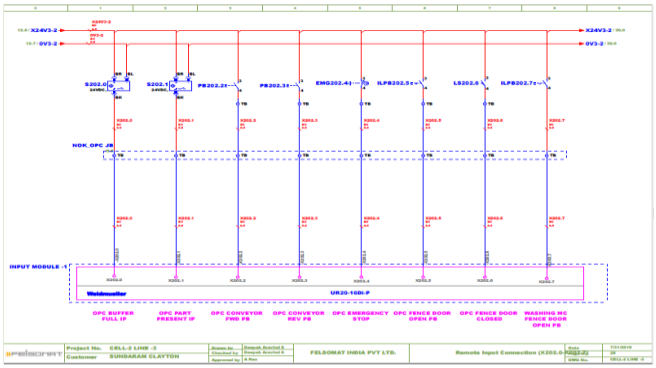

Figure 4: Remote Input Connections

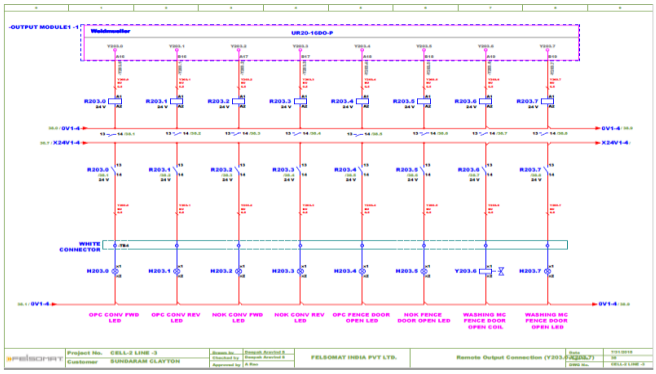

Figure 5: Remote Output Connections

IV. PROGRAMMING THE I-GANTRY SYSTEM

The gantry system programming involves both PLC and CNC programming. PLC programs are written in ladder language. Programmable Machine Control (PMC) is a tool provided by FANUC. PMC uses an internal CPU and is programmed using FANUC Ladder-III programming software. The PMC system is the interface between FANUC CNC and machine tool. Figure 6 shows the flowchart of logic analysis for end-of-arm tool and figure 7 shows the PLC ladder logic of the same.

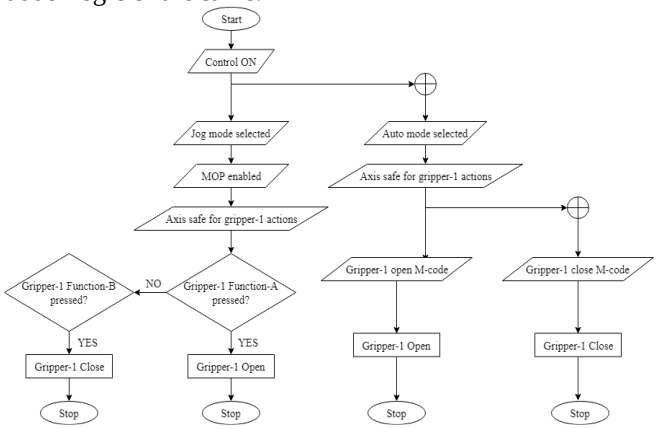

Figure 6: Flowchart for end-of-arm tool actions

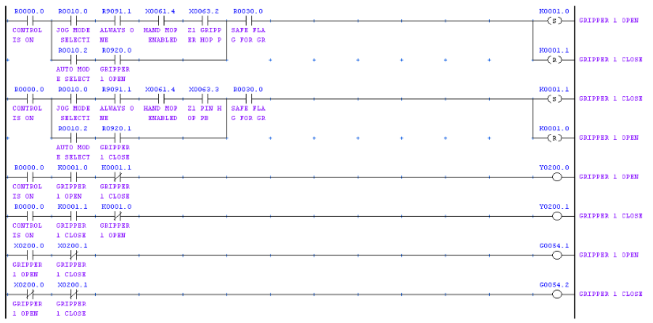

Figure 7: Ladder Logic of end-of-arm tool

The PMC accepts inputs from the CNC as well as from external devices (including the machine tool). These inputs are called F-signals and X-signals, respectively. Similarly, it sends outputs to the CNC (G-signals) as well as to the external devices (Y-signals). The X and Y-signals are also called DI (data in) and DO (data out) signals, respectively. Figure 8 shows the ladder logic for machine loading/unloading using G-signals.

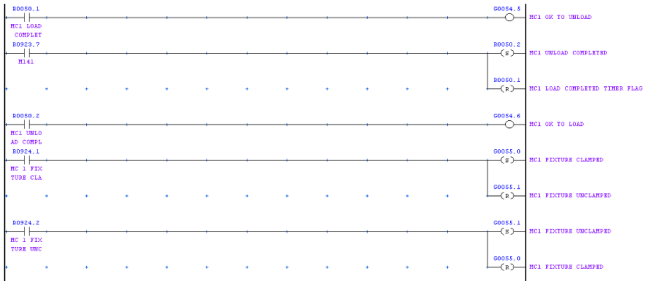

Figure 8: Ladder Logic for Machine Loading/unloading

V.IMPLEMENTATION OF I-GANTRY AUTOMATION SYSTEM

New trends in industrial automation deals with latest control devices and communication protocols to control field devices like control valves and other final control elements. Industrial automation fulfills the aim of the company by allowing the company to run a manufacturing plant for 24 hours in a day 7 days in a week and 365 days a year. This

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leads to a significant improvement in the productivity of the company.

Gantry automation solution is provided and the automated system is tested for various conditions as per customer requirements. Software solution is provided through PLC and CNC programming. The programs are altered with reference to the test runs since the programmed commands may differ in reality due to physical constraints. Figure 9 shows the assembly of I-gantry cell.

The gantry is initially made to run only in the longitudinal axis (Y-axis) at different speeds to verify the feedrate and check for the vibrations when it is made to run at full speed. Lubrication, pneumatic supply, electrical supply, alarms and buzzer are checked before running the actual auto cycle. The logic sequences are verified manually one after the other. First the axes movements and gripper actuations are checked manually for all conditions as per the PLC-CNC programs. The conveyors are manually run with the push buttons to check the motor direction. All the emergency circuits are checked for their operation. The auto cycle is run and tested for various part models.

Figure 9: I-Gantry Automation Cell

FANUC Oi-F series CNC is implemented for providing the gantry automation solution to the compressor housing machining line. Parameters required for interfacing and communicating with machines and equipment are manually entered through this CNC. General data about the axes, feedrate, CNC programs etc. are made visible on the custom screen for the operator as shown in figure 10. Basic PMC Configuration screen is shown in figure 11.

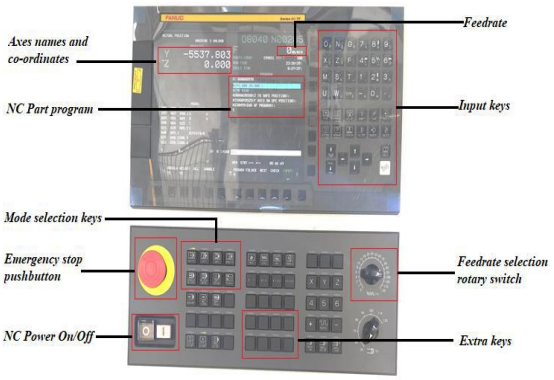

Figure 10: FANUC Oi-F Series CNC

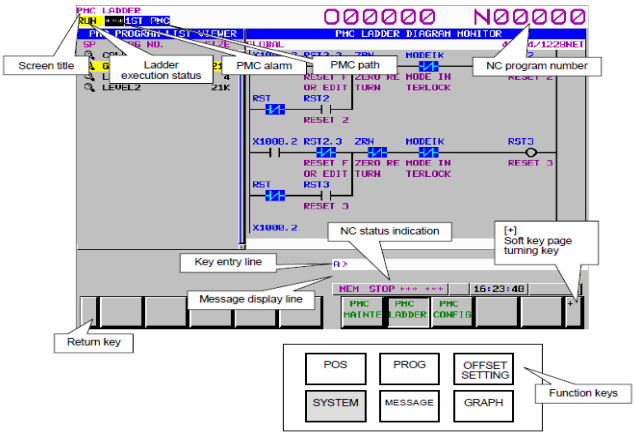

Figure 11: Basic PMC Configuration Screen

VI. CONCLUSIONS AND FUTURE SCOPE

The main aim of manufacturing industries is to achieve increased productivity and high quality of the products. This can be achieved by automating the machines and equipment in the manufacturing line. The gantry automation system to manufacture the compressor housing component is designed and fabricated as per customer requirements.

Implementation of PLC and CNC has led to improved material handling. The hardware interfacing is provided through PROFIBUS network.

The system can be improved by providing machine remote diagnosis solution. In the remote diagnosis process, the system can be connected to a network (internet) and configured to a PC. This helps the operator/programmer to view and diagnose the gantry operations remotely without physically being present at the gantry location.

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