CONTROL OF GANTRY SYSTEM IN PRODUCTION LINE

[1] Ravikiran BP, [2] Ravikumar beeranur, [3] k.r Prakash

Abstract- Automation is the muscle for the production industries; it can be applied to many manufacturing industries in order to improve productivity and production quality, and now new updates in automation creates provision for data monitoring system .

Gantry automation is one of the preferred techniques for automating the loading and unloading of machines in production lines, the gantry systems are configured in different ways. Here we discuss the different configuration of gantry automation system with electrical design aspect and CNC controller programming technique.

Keywords: CNC, PMC, IPC, OPC, gantry, production rate, safety

I. INTRODUCTION: The gantry systems are also called as Cartesian robots, where the motion of gantry system takes place in Cartesian coordinates.

Gantry system consists of horizontal beam supported by the vertical beam structure, the movable carriages are mounted on horizontal beam and loaders are fitted on the carriages.

The gantries are usually used to pick and place of heavy materials and they are also used to loading and unloading of production line for machining. Servo drives are used to control the axis movement in gantry system, because servo drive is a closed loop system which helps in précised control of axis movement.

In gantry automation the stations are distributed throughout the gantry length and these distributed stations should be provided with suitable power distribution circuit and safety circuit.

II. GANTRY CONFIGURATIONS: There are two major classification of gantry such as, area gantry and linear gantry. Different configurations of gantries are shown in the Fig2.1.

Area gantry has six degree of freedom in the Cartesian coordinates and linear movement will be possible in all three coordinate planes(x, y, &z). Linear gantry has less than six degree of freedom in Cartesian coordinates.

Fig2.1: Different configuration of gantry.

Depending upon the application and the machine, different Gantry loader configurations are used. They are I loader configuration and h loader configuration.

I loader configuration is used with double gripper and the space inside the machine permits two grippers, It has shown in Fig 2.2.

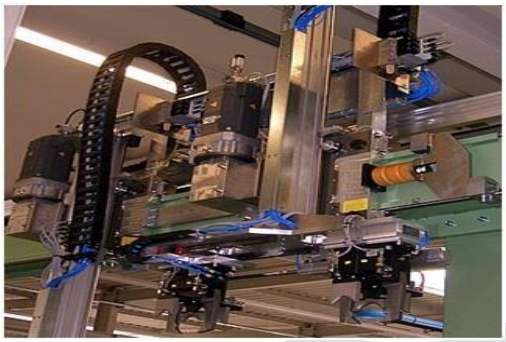

Fig 2.2: I loader

H loader configuration is used for bigger parts where the space inside machine does not allow two grippers, H Loader Configuration is shown in Fig 2.3.

The H-Loader has two independent arms with grippers arranged in parallel on one axis. The distance between the arms is fixed. This configuration is ideal for long shafts / crank shafts or cubical parts, where a swivel gripper cannot be used.

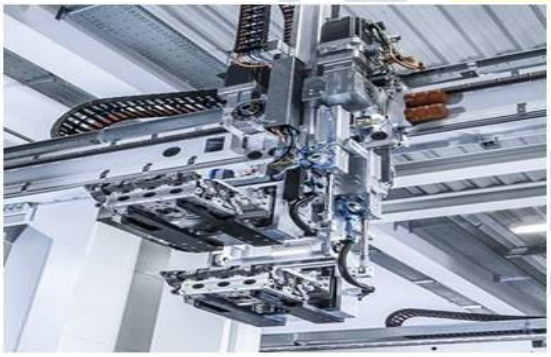

Fig 2.3: H loader

III. GANTRY AUTOMATION SYSTEM:

Gantry automation system is incorporated with many stations like IPC (input conveyor), OPC (output conveyor), tilting station etc. as shown in the fig 3.1.

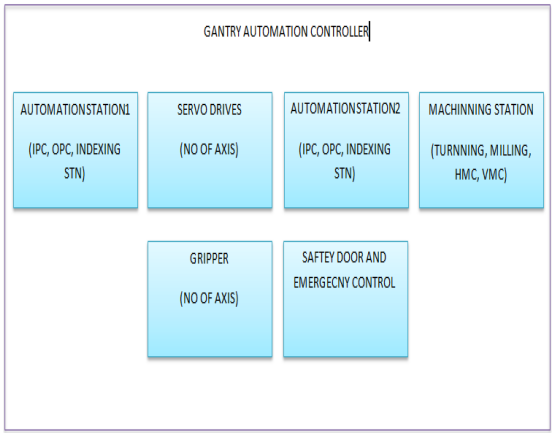

Fig3.1: gantry automation system block diagram

By taking feedback from each station, the servo axis position & operation of grippers are controlled.

In order to achieve this complex synchronise operation between servo axis and automated stations, CNC is used as a control unit for entire gantry automated system and it is shown in fig 3.2.

In NC programming, sequence of instruction is entered; this defines sequence of operation of the gantry system. The sequence of instructions also defines speed, interpolation and checks for logical interlocks.

PMC is used to build logic for machine operations. It uses the ladder language for logic development and there is continuous communication through PMC and NC control.

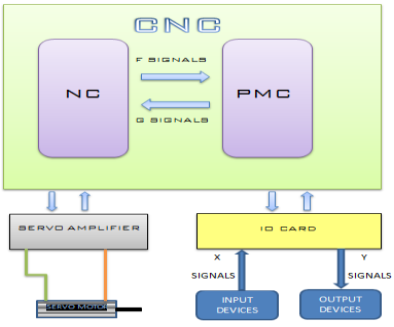

Fig 3.2: Schematic diagram of CNC controller.

Servo amplifier is the device which controls the servo drive with reference to feedback signal and it is a closed loop system.

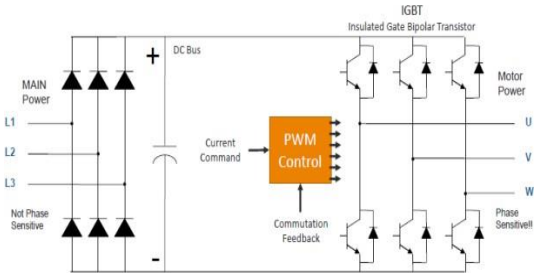

Fig3.3: servo amplifier circuit

The servo amplifier consists of combination of rectifier and inverter is shown in fig 3.3. The rectifier converts AC signal to DC signal, which is further converted into required frequency AC signal by inverter with the help of PWM (pulse width modulation) technique.

The PWM technique helps in precise frequency control which intern helps in precise position and speed control, the relations of N, F and P are given in the equation [1]. Whereas N is speed of motor F is frequency of supply & P is number of magnetic poles.

N=120F/P…… [1]

In the gantry system the servo drive is monitored through CNC controller, hence CNC is the master controller and servo drive or amplifier is slave controller.

Servo configuration in CNC: In gantry system there will be many servo axis, this servo axis should be configured in CNC by setting the speed, acceleration, torque, travel limit, axis position etc.

In order to achieve above configuration in CNC there will be certain pre-defined parameter numbers, this parameter number change as per the model & manufacturer.

The example of Fanuc oi-tf model CNC and its parameters are shown in table 2.1.

Table1: Parameter number and description.

Description	Parameter
Total no of Axis	987
Set the path Number to which axis belongs	981
Axis Type 0: Linear 1: rotary	1006
Control Axis Name	1020
Plane Selection	1022
Sequence of servo Axis	1023
Enable servo setting screen display	3111
Enable Spindle setting screen Display	3111
H/W Over travel Bypass	3004
Servo Loop Gain	1825
In Position width	1826
Position Deviation at running	1828
Position Deviation at stop	1829
Dry run Federate	1410
Maximum Rapid rate in Program	1420
Maximum Feed limit in all axis	1422
Maximum feed Rate at cutting	1430
Maximum Feed rate in Jog	1423
Maximum Rapid rate in Jog	1424
Reference return feed rate	1425
Rapid Acc/Dec time constant	1620
Feed Acc/Dec time constant	1622
Jog Feed Acc/Dec time constant	1624
ZERO REFERENCING	1815
Axis Interlock Disable	3003
Axis Interlock Disable	3003

Axis Int	
DFS	14476
DGP	2000

power circuit, power distribution circuits, power modulation circuit, drive circuit, safety circuit, and control circuit.

IV. IO SIGNAL DISTRIBUTION: In gantry automation system servo axis need to control along with some integrated automated station, the integrated automation stations are conveyor, tilting station, turning machine, milling machine etc. which are distributed throughout the gantry length, and CNC controller will be in placed on the cabinet.

So in order communicate distributed IO signals between CNC controllers, there are many ways like using plug and socket with IO card or duct routing etc. but these are costlier and complex due to requirement of lots of cable & supporting structure. In order to overcome this profibus connection can be used shown in fig 3.1. In profibus protocol a single cable can be used for IO communication.

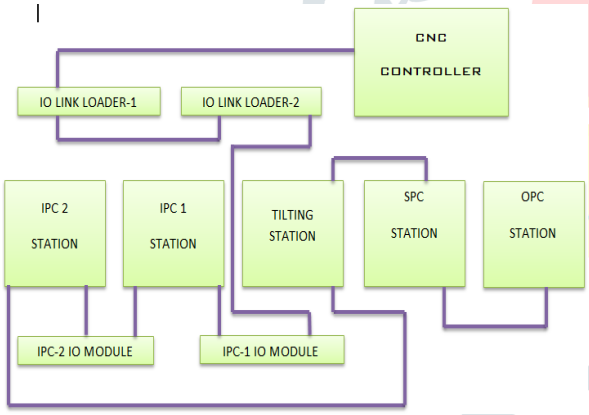

Fig 3.1: IO signal distribution by profibus.

V. ELECTRICAL DESGIN: Electrical panel is the system which provides power to the entire system, in electrical panel power is modulated as per requirement of electrical peripheral like drives, CNC controller, sensors, sensor module and motors etc.

While designing electrical panel the circuit is divided into

In each division of circuit design the safety of the circuit is considered by using different protection devices such as MCB, MCCB, phase monitor device etc. along with considering the safety there is also need of consideration for ease of connection, which in turn helps in maintenance.

Power Modulation Circuit: In electrical panel different electrical peripherals require different voltage or current, in order to get this different power rating, SMPS (switch mode power supply) are used as power modulator. The number of SMPS is decided by load current and voltage level.

Drive Circuit: The drive circuit is designed as per the number of servo axis along with their configuration, an isolation transformer is provided for the servo supply circuit. The isolation transformer for servo axis's are calculated for the 60% of total load current of servo configuration. In gantry system at a time only one servo axis will be driving. Servo brakes release coil will be energized only if servo is healthy and ready.

Power Circuit: Power circuit supplies power to the entire system, and there will be provision provided for isolation of power from the system for maintenance. And while designing power circuit we should also consider cabinet cooling circuit and cabinet lighting circuit.

VI. GANTRY SYSTEM PROGRAMMING: The programming of gantry takes place in two sections, one is PMC programming and NC programming.

PMC Programming: PMC programming uses ladder logic to build machine logic, in PMC programming there are some special signals along with Io signals, they are g signals and f signals, which are used as signal exchanger between NC and PMC, which intern creates provision for building interlock between NC and PMC.

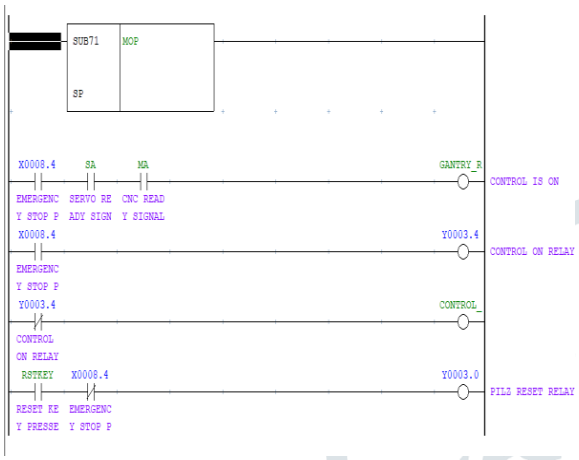

Fig 5.1: ladder logic.

Let's discuss the special bits used in PMC ladder signals.

*M codes***:** M codes are called miscellaneous codes, these are used to activate external hardware signals. *G signals:* G signals are used to activate system outputs of control on, m finish, mode selection and feed override, this signals are having dedicated address for dedicated function.

Position switches: In Fanuc CNC system there is pre-defined 16 position switches per channel of CNC, this position switches are used to read servo position over 16 position ranges which helps in interlocking of axis in particular position.

VII. NC PROGRAMMING: NC program is a technique where the sequence of operation is entered, NC controller is major sequence controller but in order to execute NC program, logical condition to satisfied in PMC ladder logic.

In numerical program the sequence is divided into fragments m1 loading and m2 unloading etc. Then this fragmented sub programs are call in sequence of main program, this calling of sub program will only execute only if pre-defined conditions is satisfied.

There are also be some special sub programs home recovery program, empty cycle program, teach value programs.

The G-codes are function define dwell, rapid transverse, linear interpolation etc.

N-codes Gives an identifying number for each block of information. It is generally good practice to increment each block number by 5 or 10 to allow additional blocks to be inserted in order to future changes.

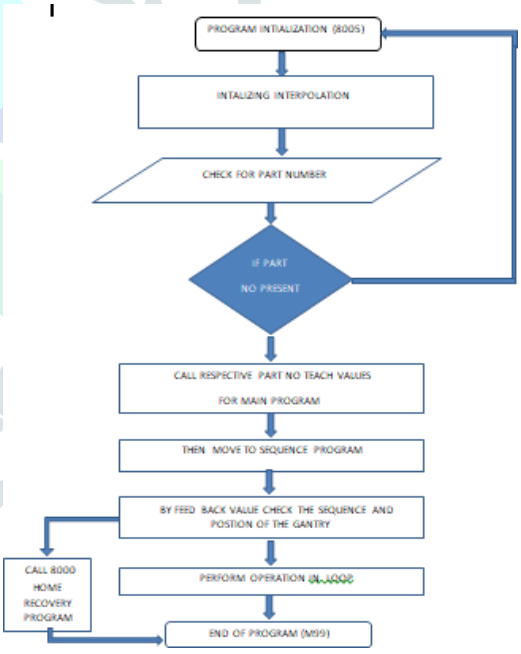

Fig6.1: NC sequence flow chart

Macro is simple technique used to store data of value which can be used in the program for different purposes like speed variation, travel distance, part selection or memory of the program, the macros are represented by using # symbol in front of the numbers but while creating we should not use the numbers which are already pre-defined address which are parameter numbers.

VIII. CONCLUSION: The customized design of gantry automation system will improve productivity and production quality, but in order to develop customized gantry system there are many challenges, human machine safety intervention, synchronize control action between servo axis and machining station.

This lead to major complex control action, this type of complex control action can be achieved systematically by CNC controller with suitable electrical design.

IX. Acknowledgement: The authors would like to acknowledge Felsomat India Pvt Ltd for giving opportunity to undergo this project and this work was jointly supported by guide Ravikumar beeranur, K.R. Prakash, mechanical engineering department, NIE Mysore.

References

[1] Michael S.morse “Designing for Electrical Safety that can withstand Legal Scrutiny” ieee,2009.

[2] Kittipong Ekkachai , Udom Komin "Design and development of an open architecture CNC controller for milling machine retrofitting," *2009 ICCAS-SICE*, Fukuoka, 2009, pp. 5629-5632.

[3] G. Gabor, C. Pintilie, C. Dumitrescu, N. Costica and A. T. Plesca, "Application of Industrial PROFIBUS-DP Protocol," *2018 International Conference and Exposition on Electrical and Power Engineering (EPE)*, Iasi, 2018, pp. 0614- 0617

[4] T. Ernst, "Application of multi-function motor protection relays to variable frequency drive connected motors," *2015 61st IEEE Pulp and Paper Industry Conference (PPIC)*, Milwaukee, WI, 2015, pp. 1-6.
doi: 10.1109/PPIC.2015.7165855

[5] Kyung Chang Lee, and Suk Lee, “Implementation of Networked Control System using a Profibus-DP Network”, International Journal of the Korean Society
of Precision Engineering Vol. 3, No. 3, July 2002.

[6] Rajendra Rajput1, Dr. Ajay Kumar Sarathe2, “Study of CNC Controllers used in CNC Milling Machine”, American Journal Of Engineering Research (AJER) volume-5, issue-4, pp-54-62.