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Electrical System Design of Gantry system automation for Differential housing in machining Cells

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ABSTRACT: To meet the demand of growing industrial sector in processing or handling of operations the need of automation to be used is also growing, a motion centric system intended for multi-axis operation with an overhead bridge is called gantry system

This automation is designed to meet the customer requirements in processing few operations in production of a differential housing. Each part weighs around 3.5 –4 Kg's. The repetitive part handling humanly slows down the process. So as to step up the speed of material transfer gantry line is opted by the customer.

A differential is a system that transmits an engine's torque to the wheels. The differential takes the power from the engine and splits it, allowing the wheels to spin at different speeds.

The system design consists of Mechanical design and Electrical design of itself.

Electrical system design entails from project data or info page, cabinet design, Operator panel design, field connection overview, power distribution, safety relay Emergency looping, input connection, output connection, plug and socket connection and remote input output box connection.

Then project execution after assembly involved controller here NC configuration, programming, coordinate teaching, cycle testing and execution run verification.

Keywords: Gantry Automation, Differential Housing, Electrical system Design, eplan Electric P8

I. INTRODUCTION

1.1 Differential housing

A machine or a mechanism which is designed and used to control the energy shift from engine to left and right rotors, in particular the wheels to direct the way the automobile or machine travels in required direction.

They are machined from nodular cast iron and housing the vehicle differential gear assemblies, differential housings present difficulties in terms of interrupted cuts during roughing passes. Surface finishes and tolerances must be held to customer standards, and machining operations involve custom combination tooling such as turning heads, drills and reamers. To achieve it we face few manufacturing challenges

- Drilling numerous holes with minimal cost and time.
- Efficiently and securely turning the internal diameter and face.
- Ensuring high productivity during turning of the outer diameter and face.
- Drilling numerous holes with low cycle times, high quality and reliability.
- Reaming precise holes with perfect surface finishes.
- Productively turning the internal diameter and back facing.

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Fig 1.1: differential housing a product view

1 - Drilling numerous holes
2 - Turning the internal diameter and face
3 - Ensuring high productivity during turning of the outer diameter and face.
4 - Reaming precise holes

1.2 Electrical System Design

The electrical system design solves challenges which are related to design and development to ensure that they are economical, safe and reliable. The disadvantage of a poorly designed electrical system is that it will be destructive to the wellbeing of humans and property. Safety is the most important thing to any life. The job of an Electrical Engineer involves the design, development, simulation, prototyping, and testing of electrical equipment and systems. Engineering is based heavily on the use of various simulation software and programming skills. In this project process EPLAN Electric P8 Software is being used.

EPLAN Electric P8 automatically generates detailed evaluation for you as an integral component of the project documentation – either on ongoing basis or combined after project completion, as required. Downstream process steps then get all the necessary information from engineering: from integrated planning through to manufacturing, commissioning, maintenance and repair.

This software helps the engineers to have their required data of the designed projects from design of: Cabinet, Operator panels, Pulse generators, to Connection details with field devices.

II. LITERATURE SURVEY

i. **LuminitaPopa, BadeaLepadatescu "Collaborative Engineering in Product Development of Virtual Enterprises." Latest Advances in Information Science, Circuits and Systems 2013.**

The purpose of this paper is to introduce the application compatibility and some features of e-plan Electric P8. In this paper two different approach to product development is being studied i) Computer-Aided Product development in Virtual Enterprise Collaborative Product Development and ii) (CPD) of Virtual Enterprise. Later a case study about e-plan Mechatronic Integration (EMI) applications, Software integration and collaboration between members of different departments is being demonstrated where e-plan Electric P8 and AutoCAD inventor are used in collaboration in product development.

ii. **ChristofferAvela "EPLAN Electric P8 – parts database and pilot project - Development of component database for E-CAE tool and its implementation in project documentation" 2012.**

The purpose of this paper is to introduce the features of e-plan Electric P8. This paper work describes the process to have an established parts database for the electrical design tool Eplan P8, ready to be used at the Sales & Solution Support department. The source now covers the most common electrical components needed in Vacon cabinet drive systems. The result was also a complete documentation of a project to be used in future work tasks.

iii. **Shraddha Sonavale1, Prof. M.V. Kavade, AbhijitKavathekar. "Design and Development of Pick and Place Gantry System on Conveyor". International Research Journal of Engineering and Technology (IRJET) July 2020.**

The Purpose of this paper is to support advantages of gantry line automation system in industries in pick and place process optimization. This project has been effectively developed to handle required task. It can be identified colours of boxes and grab it and place it on required conveyor. By development of pick and place gantry system on

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conveyor reduces organisational worker effort and time for material handling as well as number of labours reduced by development of this system. It has future scopes like this system used for any product which have flat smooth surface.

iv. RavikumarBeeranur, K.R.Prakash, Ravikiran B.P. "Machine Logic Program Development and Electrical Design of H Gantry Automation System for Compressor Housing". International Journal of Recent Technology and Engineering (IJRTE) July 2020.

The Purpose of this paper is to support advantages of gantry line automation system in industries. This paper describes the machining and inspection line for different types of compressor housing. The objective of work is reduce the fatigue in handling heavier components for further processes in manufacturing production lines, in this an attempt has been made to design of gantry for transferring component of compressor housing in manufacturing and machining line of continuous discrete manufacturing industry, the results improved the production rate.

III. OBJECTIVE

The Purpose of this paper is to support advantages of gantry line automation system in industries. The design of different part handling system of automated gantry system used for differential housing is discussed in paper. The production industries always look for an increased productivity and high quality of its finished components. This can be achieved by incorporating a custom designed automated gantry system that suits the particular component which helps in automatic part handling that results in decreasing the overall cycle time and helps in eliminating the hurdles that affect the quality of the finished components.

By having studied few research theses the electrical system design for gantry line automation in processing few processes in manufacturing a differential housing is selected for the project. So as to actuate the requirement few processes are need to be followed:

a) The requirement is to automate cell 1 with 1 No OP 10 Turning Machine, 1 No OP 20 Turning Machines, 1 No OP 20 Auto Gauge, 1 No OP 30 Turning Machines, 1 No OP 30 Auto Gauge, 1 No. Dot Peen Marking Station. Prove out for part 40182981.
b) Part to be indexed by 180 degrees from OP 10 to OP 20
c) Part to be indexed by 180 degrees from OP 20 to OP 30
d) OP 10 Operation needs a shuttle to take part out for manual inspection
e) Small Segment Output conveyor to be provided to take part to the operator for inspection /subsequent washing
f) NOK Chute to be provided after OP 20 Auto Gauge and OP 30 Auto Gauge – i) No Each
ii) 2 parts buffer to be provided after OP 10 Machining and OP 20 Machining
g) Air Blow station to be provided before OP 20 Auto Gauging and before OP 30 Auto Gauging

Maximum weight of incoming part is 4.5 Kg's. Machined part weight is 3.1 Kg's for part 40182981

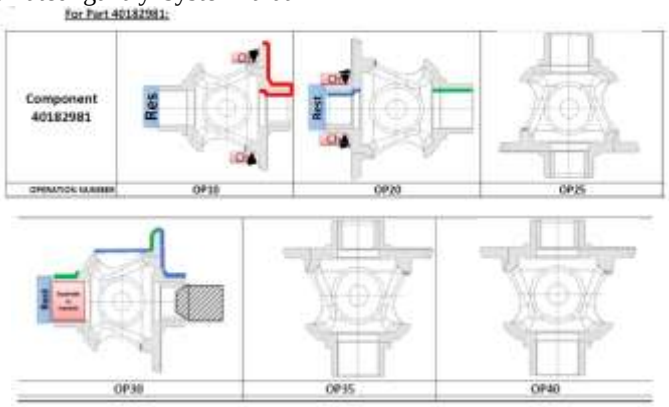

Fig 3.1: Operation Chart

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IV. SCOPE:

The machines to be automated have to be prepared (mechanical and electrical) for automatic loading. The interface needs specific signals for automatic, manual and setup handling. Also, specific emergency stop signals are required.
Customer/machine supplier, to provide these signals with appropriate programme for running their machine with the gantry loading system.

i. Door needs to be automatic actuated by pneumatic cylinder with limit switch confirmation for Open / close (Felsomat recommend separate top shutter)
ii. During auto unload / load cycle the front door remains open (In case top shutter is not provided). Customer to plan a separate guard in front of the machine which is not in scope of automation supplier
iii. 12 Inputs / 12 outputs are required in the machine for interfacing with Gantry. These I/O's must be wired internally via potential free relays and terminated at the machined cabinet sides by Customer / Machine supplier in quick connectors (both male and female connectors to be provided). Gantry interface cable loose ends will be wired by us to the quick connector provided by Customer / Machine supplier on the side of the machine cabinet.
iv. Machine logic to be modified for making the machine ready for interface with gantry.
v. Machine to have auto / manual selector switch.
vi. Gantry interface with machines is by hard wiring.
vii. Machine Fixture & Work rest are to be designed suitable for loading / unloading by Felsomat Automation gripper arrangement.
viii. Oriented spindle stop required in each machine. It should be possible to have one spindle orientation for loading and another spindle orientation for unloading if required to suit various process requirements.
ix. Sensors required at Machine fixture to give part present / not present feedback to Automation & the same has to be provided by Customer / Machine supplier
x. Necessary Air Blow arrangements to be made to blow out chips / swarf from chuck area.
xi. If required, Seat check arrangement in fixtures must be provided to know correct butting / resting of parts on machine chuck.
xii. Chip conveyor of all machines to be on the back side.
xiii. Marking and Re-arranging the machines as per automation layout has to be carried out by customer.
xiv. Machines need to be grouted in position after alignment and running with gantry. The same has to be carried out by customer.
xv. Lifting facilities for gantry installation has to be provided by customer free of cost.
xvi. Power and pneumatic supply up to gantry cabinet and FRL respectively is in customer scope. Air Supply required at 6 Bar. Power supply to be provided as per Felsomat Specification.

Unloading the delivered material and bringing it close to installation site has to be done by customer. Clearing the packing debris is in scope of customer.

For any project to be designed or carried out the floor plan or layout plan is a must. This is the first process in the implementation of any project so as to enable any engineer related to project to understand and further work on it, the engineer need to have a clear image of how the project in future must look like.

Fig 4.1: Layout plan

4.1 Methodology

1. 3 Axes CNC Gantry with Longitudinal beam length of 23 m (Dual Vertical axis – H Loader) i.e., this project has a gantry line which is controlled and monitored by a CNc in total of 3 Axis's. The gantry is of type H and 23m long in dimension.
2. Each vertical axis is provided with a maximum vertical stroke of 1200 mm.

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3. 6 No's columns are provided to support gantry beam on cell bed.
4. At the end of each vertical axis, Gripper arrangement is provided
5. Gripper arrangement consists of 1 no 2 jaw parallel gripper on a 0-90 gripper index unit. The 0-90
6. Gripper index unit makes the part orientation suitable for loading at machine / at the conveyors.

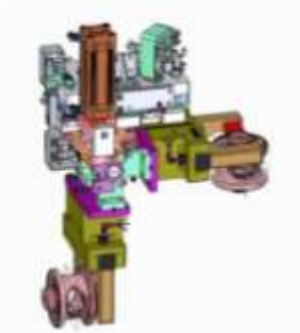

Fig 4.2: Design of Gripper Assembly

Gripper Assembly as the name suggests it is a part which handles the transfer operation in gantry from machine to line or line to machine to facilitate the process in accordance to required flow.

Make: Schunk

They are controlled via PLC/NC/PC controllers. In this project NC controller is the giving it commands while ensuring their conditions from the respective gripper feedback.

7. Between the gripper and the 0-90 Index Unit a spring loaded arrangement with butting
8. confirmation sensor is provided to ensure positive butting in the fixture
9. 1 No indexing chain type input conveyor is provided to store input parts having 40 parts storage capacity.

Conveyers are of various type belt, chain, trolley, bucket, magnetic etc., in this project the Input conveyer is of chain type with part holding fixtures to hold parts in allocated place so as to ease the gantry teaching points.

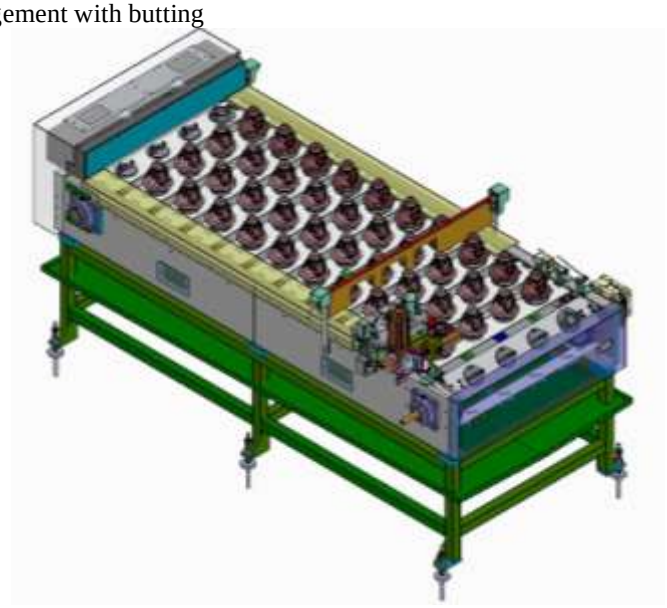

Fig 4.3 : Input Conveyer Design

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10. 1 No Indexing Belt type output conveyor is provided to store machined parts having 7 parts storage

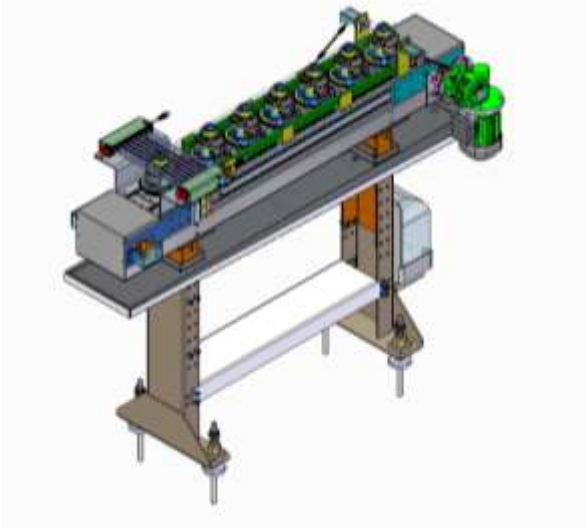

Fig 4.4: Output Conveyer design

In this project the Output conveyer is of belt type which can support smooth flow of processed parts for next line or process.

11. Capacity. Conveyor takes the part to operator for inspection / for subsequent washing

12. 1 No 0-180° Index Station 1 is provided between OP 10 and OP 20 machine

13. 1 No 0-180° Index Station 2 is provided between OP 20 and OP 30 machine

14. 1 No 0-180° Index Station 2 is provided between OP 30 and OP 30 gauging machine.

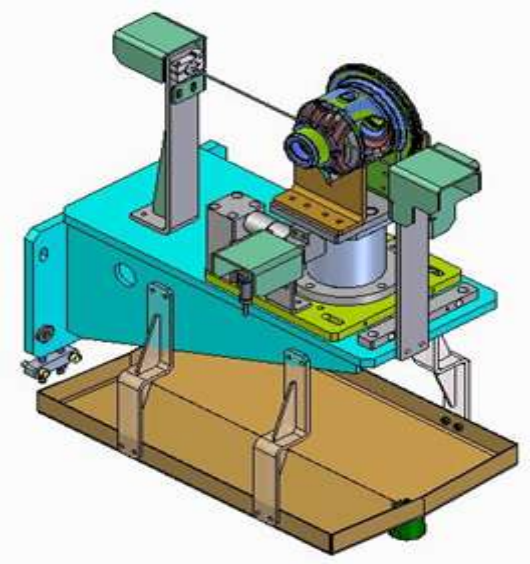

Fig 4.5 : Indexing station Design

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The indexing stations are generally used to ease the process of pick and place automation lines by helping the grippers to transfer the part to consecutive processes in required orientation for maching or processing.

15. 1 No Manual Inspection Shuttle is provided after OP 10

The inspection shuttles or special part chute(SPC) are part of all automation lines where many processes are made to go through to have access to any products or parts processed to be accessible to be inspected by humans to confirm the process authenticity.

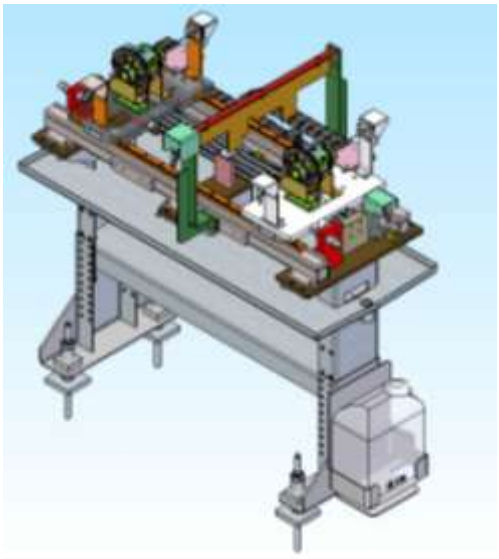

Fig 4.6: SPC shuttle design

16. 1 No Gravity chute for storage of OP 20 Auto Gauge rejection Part – 2 parts storage capacity
17. 1 No Gravity chute for storage of OP 30 Auto Gauge rejection Part – 2 parts storage capacity

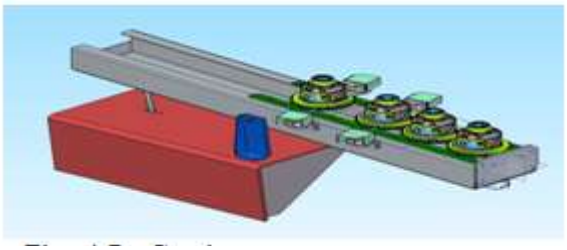

Fig 4.7: Gravity NOK chute design

Gravity chutes are also part of inspection mechanisms of many automation lines where gravity is used as a medium of testing i.e, the part weight plays a major role in categorising the process or part fault.

18. 1 No 2 part buffer is provided after OP 10 Machining
19. 1 No 2 part buffer is provided after OP 20 Machining

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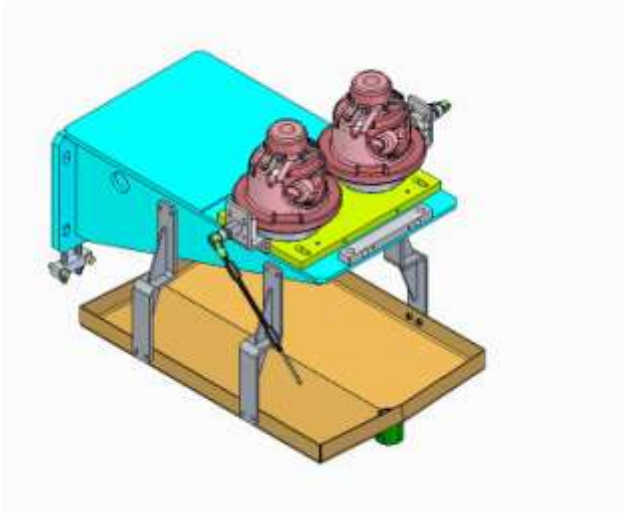

Fig 4.8: Part buffer Design

Automation processes are continuous but sometimes there exist times where the parts are in waiting after certain processes to get to next process but there also exist process waiting for parts in other sections so to facilitate the seamless flow buffer place to have small stock inventory in line. Buffer station mentioned is designed and implemented for the same in multiple places in the automation line here with inventory limit of 2 pieces.

20. 1 No air blow station is provided before OP 20 post gauging.

To clean the parts after processes the need to be passes through cleaning stations in accordance to the part condition. In here the air blow of certain pressure and direction is made to do the work of the cleaning stations. Since the air blow does the work they are named air blow stations.

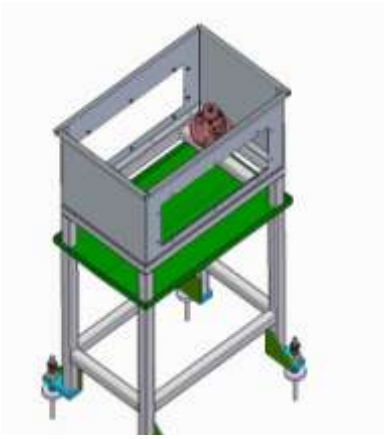

Fig 4.9: ID Air blow station design

Since the processes here are both regarding the inner diameter and outer diameter the directions of air blow need to be in accordance. After the inside diameter related machining process ID or inside air blow is made to carry in ID air blow station.

After the outside diameter related machining process OD or outside air blow is made to carry in OD air blow station.

21. 1 No air blow station is provided before OP 30 post gauging (Note: OD in area of gripping cannot be air blown)

Fig 4.10: OD Air blow station design

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22. Centralised Lubrication system for gantry is provided
23. Safety fence with access doors are provided at gantry unloading & loading position for operator
24. safety at the conveyors, auto gauge stations, 180° Index Stations and the inspection shuttle as
25. shown in the layout
26. Oil tray is provided for the full length of the gantry
27. Gantry is controlled by a Mitsubishi controller with 1 path and 3 NC axes. Control Cabinet is provided with Panel Cooler
28. Bare interface cables with loose ends to machines are included
29. Prove out for 1 model of differential housing Part 40182981

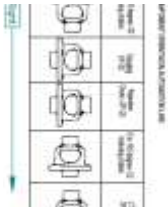

Fig 4.11: Flow Chart Diagram of the project

For Part 40182981 in 23 m Gantry:

Table 4.1: Takt Time

SI. No.	Description	Machining Time in sec's	Door Open + Door Close time in Sec's	Gantry Unload / load incl. chuck clamp / chuck unclamp in Sec's	Machine Wait time (Sec's)	Total cycle time in in Sec's	Gantry Operation Time in Sec's	Gantry Wait time in Sec's	Time per part from the cell in Sec's
1	OP 10 M/C	80	6	14	8	108	212	0	108
2	OP 20 M/C	88	6	14	0	108		2	
3	OP 30 M/C	190	6	14	6	216		0	
4	Marking Machine	25	No Door	10	73	108		0	

If in Any cycle any 1 operation Auto gauging is considered for unload / load, the Takt time will be 122.2 Sec's
Customer: Mahindra CIE, Urse

V. IMPLEMENTATION

Any project to be designed has the respective information of type of project, customer, and engineer in charge, Engineering Company, date of creation, and many more if needed in the project info page or the project cover page for future/customer/creator reference.

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Fig 5.1: Project info page in electrical design software used

An electrical enclosure is cabinet for electrical or electronic equipment to mount switches, knobs and displays and to prevent electrical shock to equipment users and protect the contents from the environment. The enclosure is the only part of the equipment which is seen by users.

An electrical enclosure is housing for electrical or electronic equipment. Its purpose is to protect that equipment from the environment (especially in the case of external electrical enclosures) and also to protect people from the equipment (e.g. to prevent electric shock or the propagation of an explosion).

Table 5.1: Sheet of materials listed to assist in design and purchase of requirements

Cabinet Assembly		
SL NO	COMPONENTS	QUANTITY
1	CABINET LAMP 11WATTS	1
2	Electrical Cabinet 800MM(W)X2000MM(H)X500MM(D)	1
3	3 PIN SOCKET	1
4	R-PHASE INDICATOR LAMP	1
5	Y-PHASE INDICATOR LAMP	1
6	B-PHASE INDICATOR LAMP	1
7	Push button labels	3
8	Cabinet Name Plate	1
9	FUSE TB	3
10	3 PH ISOLATOR SWITCH 32A	1
12	MCB OF1(2A) 1P for Cabinet lamp	1
13	MCB OF1(6A) 1P for domestic socket	1
14	MCB F1(6A) 1P for cabinet ac	1
15	16 sq.TB for mains entry	4
16	16sq.mm earthing terminal for mains entry	1
17	16Sq.mm End Plate	2
18	MPCB 0.63A-1A for IPC-1 and opc-1	2
19	MPCB AUXILARY CONTACT BLOCK	2
20	CONTACTORS IPC/OPC 24VDC, 9A	3
21	MCB 3P 10A (Transformer Primary)	1
22	MCB 3P 16A(Secondary)	1
23	Transformer 5 KVA	1
23	Transformer Box of Having size 470MM(L)X300MM(W)X480MM(H)	1

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	for 8KVA ,12KVA Transformer	
24	CONTACTORS C5 ,24V DC, 32A for Drive	1
25	10 sq.mm TB for transformer primary	3
26	10 sq.mm TB for transformer secondary	3
27	10sw.mm end plate	4
28	10sq.mm earth terminal	2
29	10sq.mm terminal for 3 ph. 200v lopping for servo drives	12
30	10sq.mm end plate	3
31	PG16 Conduit Gland (2 at cabinet side and 2 at transform side)	4
32	PG16 Flexible Conduit (5 Mtr for primary and 5 mtr for secondary)	10mtr
33	MCB F4 (6A)2P for power supply-1 (All motor brakes)	1
34	MCB F5 (6A)2P for power supply-2 (Group-1 RIO Boxes)	1
35	MCB 6A 2P for power supply-3 (For Group-2 RIO Boxes)	1
36	MCB 6A 2P for power supply-4(for CNC and IO cards supply)	1
36	SMPS G1(TO FIELD DEVICE) Schneider 10A	4
37	MCB F6 (10A)1P	1
38	MCB F7 (10A)1P	1
39	MCB (10A)1P	1
39	MCB (10A)1P	1
40	sttb 2.5sq.mm terminal	50
41	sttb2.5 earth terminal	20
42	sttb 2.5 sq.mm end plate	10
43	end clamp	60
45	2 change over relay K1 24V DC/AC WITH CONNECTOR BASE for Control on	1
46	2 change over relay base	1
	2 change over relay K1 24V DC/AC WITH CONNECTOR BASE for Tube light and AC on	1
	2 change over relay base	1
47	4 change over relay for all motor brakes	2
48	4 changeover relay base	2
49	2 change over relay for Drive contactor C5 on	1
50	2 changeover relay base	1
51	RELAY BOARD (8 SWITCHES)	6
56	CABLE DUCT 30 X 80	3
57	CABLE DUCT 40 X 80	5
58	Cabinet AC; advance make	1
59	cable duct 60x80	2
60	din rail	5
61	Safety relay Phoenix	1
62	Panel Door Limit switch	1
68	1.5 SQMM black CABLE	100

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69	1 SQMM red Cable	100
71	6 sq,mm black	100
72	1.5sq.mm blue	100
73	0.5sq.mm blue cable	1000
74	Pin Type LUGS 0.5 SQMM	5000
75	Pin LUGS 1.5 SQMM	1000
76	Pin Type Twin Lugs 0.5Sq.mm	1000
77	30 MTR Ethernet Cable	30mtr
78	Servo Motor Power Cable 4 GX1.5(Z1-33,Z2-33,Y-34M)	100 MTR
79	Servo Motor Encoder Cable (5x0.5 + 2x0.25)(Y-34,Z1-33)	100 MTR
80	SERVO MOTOR Brake Cable 3GX0.75	100 MTR
82	MCB 1 Pole 2A	6
	CC-Link IE Header Module	1
	CC-Link IE Input Module	8
	CC-Link IE Output Module	6

Table 5.2: Transformer Selection criteria:

DESIGN CALCULATION SHEET				
SR.NO	**FANUC CAT NO**	**MOTOR**	**MOTOR RATING IN KW**	**TOTAL KW*0.7**
1	HG104BS-A48	3\3000	1	0.7
2	HG104BS-A48	3\3000	1	0.7
3	HG104BS-A48	3\3000	1	0.7
			total KW	**2.1**
			total KW*1.3	**2.73**
	Transformer KVA(total KW\0.8)			**3.4125**
	(0.8 is the power factor)			
			Total KVA 1.3 Higher	**4.43625**

i.e., ~4.5 KVA. From our supplier the Transformer we can get for calculated power rating is 5KVA which is being selected and used.

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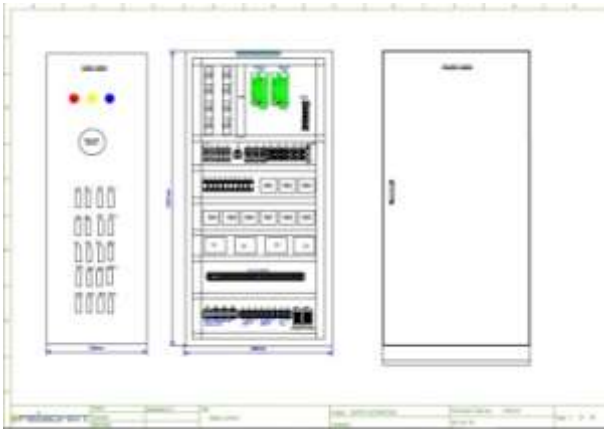

Fig 7.2: Electrical cabinet designed to requirement

The above image is software page screenshot of cabinet design with arrangement of various devices are in accordance with available cabinet and device dimensions.

The Operator Panel enables interaction between humans and machines and makes the Human Machine Interface (HMI).The panels usually include LCD display with an attached touch display, which replaces old fashioned HMIs with bulky push-buttons, levers, analog indicators, etc.

The used CNc package details are-
Make: Mitsubishi
Model: E80B
HMI: 8.4 inches
To create any connection diagram and design of panels or cabinets it requires basic step of organized data model of all the components used in the required creation.

Table 5.3: Main operator model components list

Main operator panel	Quantity
Key switch for NC ON\OFF	1
control on(Green)	1
Reset loader red ILPB	1
emg stop PB(Red Mushroom)	1
NC BLOCK	2
single block (green)	1
lamp check(yellow)	1
edit key(key selector switch)	1
Lubrication inch(Green)	1
cycle start loadr(green)	1
cycle stop (Red)	1
Mode selection Rotary Switch	1
Feed Override Switch	1
MOP Name plate	1
Empty Cycle(Green)	1
Operator box key holder	1
Boot for Push Buttons	10
Blind Plug	5
STTB2.5 terminals	30
STTb2.5 earth terminals	2
end clamp	5
Sttb 2.5 sq.mm End plate	5
Service socket	1
Cable 4Gx1.5	30
24 Pin plug and socket	1
PG21 cable gland	2

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16 pin Plug and socket	1
PG21 cable gland	1
TSD 40 PIN	3
TSD 40 pin round Cable of 2Mtr	3

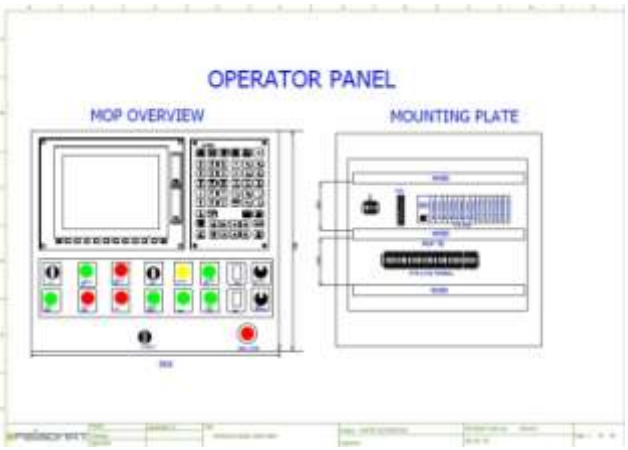

Fig 5.3: Main Operator panel designed

The above image is software page screenshot of Operator panel design with arrangement of various devices are in accordance with available operator panel and device dimensions.

Operator panels play an important role in the field of industrial automation and can be found on every factory floor. Besides the industrial automation, the operator panels can be found in other industrial sectors as well. They are gaining popularity in building automation and are inescapable parts of diverse vending machines, information kiosks, etc.

The project details also consist of respective field connection layout to facilitate engineer or the customer to have overview of the project at any point of time to easily access the wiring or connections for any need.

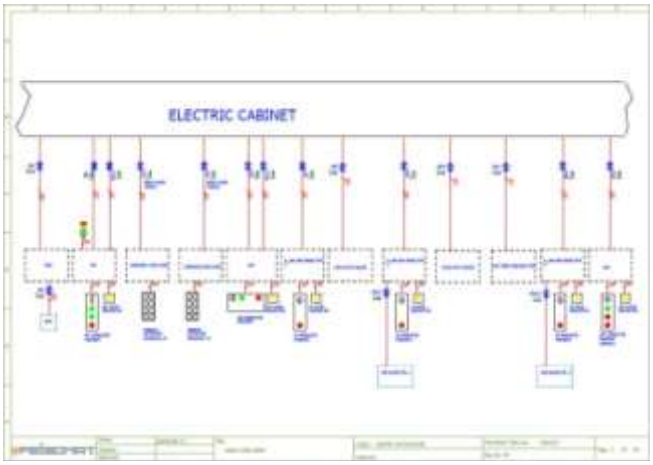

Fig 5.4: Cabinet to Field devices wiring plan -01

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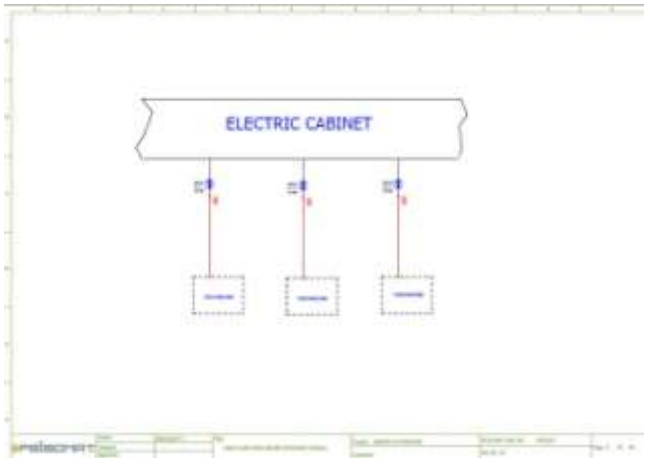

Fig 5.5: Cabinet to Field devices wiring plan -02

The Automaton lines are also in need of safety measures to keep the process, part, and humans safe while operating the processes or servicing or installation of parts. This requires having safety relay and circuit so as to enable the user or any person to stop the process by cutting the flow of current.

This is possible only when the automation line has series connection if circuit breaking switches the emergency switches which can be handled from multiple positions of the same line so as to be accessible and less time consuming in time of need.

The following is the designed and implemented safety emergency loop.

Safety relay make: Phoenix Contacts

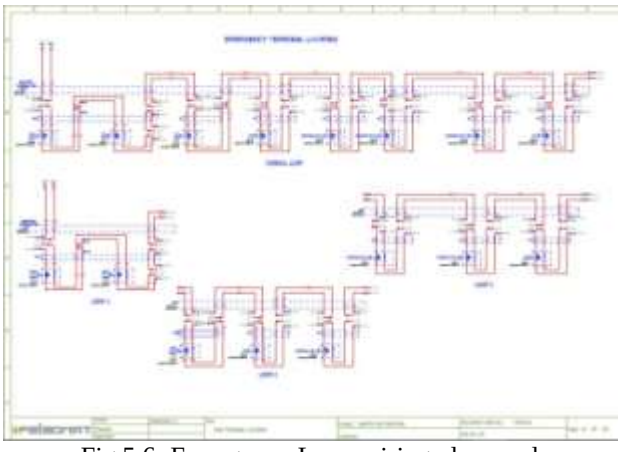

Fig 5.6: Emergency Loop wiring plan used

A motor driver acts as an interface between the motors and the control circuits. Motor require high amount of current whereas the controller circuit works on low current signals. So the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor.

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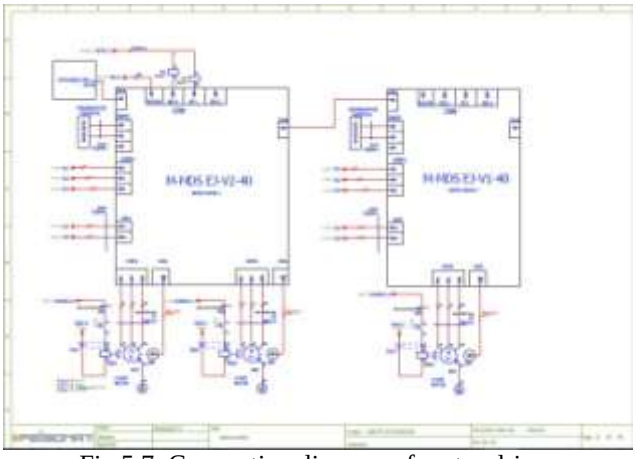

Fig 5.7: Connection diagram of motor drives

The drive model: MDS-EJ-V1-40 and MDS-EJ-V2-40 (servo motor only)
Make: Mitsubishi make
Voltage rating: 200V-240V,
Peak current rating: 40A
Operational current rating: 5A.
The V2 series supports 2 motor while V1 series supports 1 motor. The selection is as due to the required is only 3 axis control in gantry automation control.

The Remote Input Output box is an extended enclosure for few connected system. They provide the interface to the field devices and the main control unit also safety for the circuit from any hazards and rough environmental conditions if any.

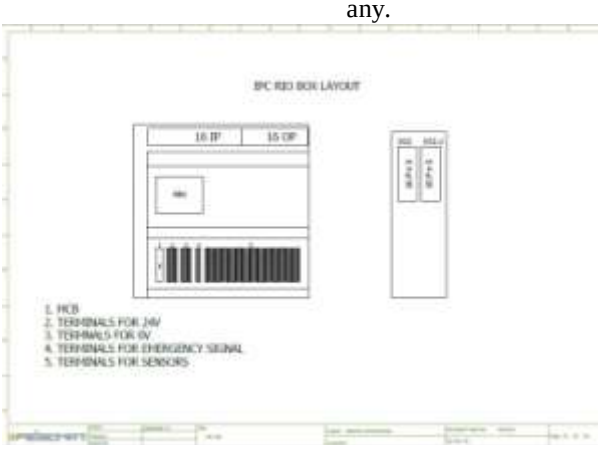

Fig 5.8: Remote Input Output (RIO) Box design

Electrical system design core is all about the input and output connections throughout the system. In this project the input and output connections is of about 62 pages. Since explaining them in detail is a lengthy process and consists of many repetitive types of components and connection type few pages as example is explained here in the report.

Input connection is mostly consisting of connections where the controller gets input from various devices to facilitate required processes. The page also houses the input card address along with signal/connection address, the voltage and distribution tag, type of cables at different stages of connection, plug and socket numbering and many more.

In following image it depicts the input connections from Main operator panel to controller to run few actions in accordance to described action pushbuttons and switches of different types and colours as per requirements.

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Table 5.4: Page connection details

SL.NO	DESCRIPTION	INPUT ADDRESS
MOP		
1	CYCLE START	X200
2	CYCLE STOP	X201
3	RESET	X202
4	MODE SEL BIT 0	X203
5	MODE SEL BIT 1	X204
6	FEED OVERIDE BIT 0	X205
7	FEED OVERIDE BIT 1	X206
8	FEED OVERIDE BIT 2	X207
9	FEED OVERIDE BIT 3	X208

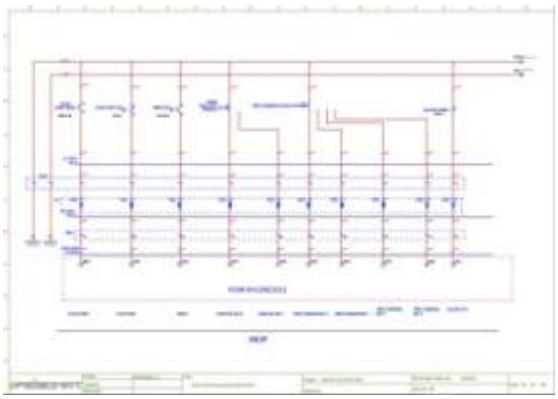

Fig 5.9: Input Connection example page -01

In following image it depicts the input connections from Gantry Z axis to controller to run few actions in accordance to described action sensors of different types and ranges as per requirements.

Table 5.5: Page connection details

H LOADER GANTRY		
S.NO	DESCRIPTION	INPUT ADDRESS
1	U(Z1) AXIS GRIPPER OPEN SENSOR	X340
2	U(Z1) AXIS GRIPPER CLOSE SENSOR	X341
3	U(Z1) SLIDE LOCK SENSOR	X342
4	U(Z1) SLIDE UNLOCK SENSOR	X343
5	U(Z1) SLIDE FLOAT PRESENT SENSOR	X344
6	U(Z1) TILTING UNIT@ 0DEG SENSOR	X345
7	U(Z1) TILTING UNIT@ 90DEG SENSOR	X346
8	V(Z2) AXIS GRIPPER OPEN SENSOR	X347

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Fig 5.10: Input Connection example page -02

In following image it depicts the output connections to Main operator panel from controller to run few actions in accordance to described action lamps and indicators of different types and colours as per requirements.

Table 5.6: Page connection details

SL.NO	DESCRIPTION	OUTPUT ADDRESS
MOP		
1	CYCLE START LAMP	Y200
2	LUBE INCH LED	Y201
3	EMPTY CYCLE LED	Y202
4	SINGLE BLOCK PB LED	Y203
5	SPARE	Y204
6	SPARE	Y205
7	SPARE	Y206
8	SPARE	Y207

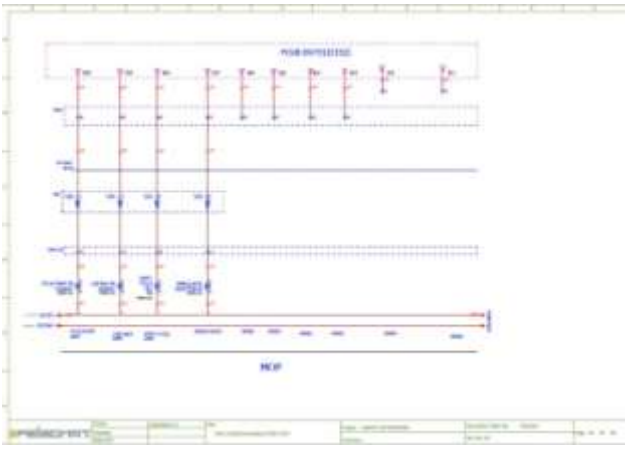

Fig 5.11: Output connection example page -01

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In following image it depicts the output connections to gantry Z1 axis from controller to run few actions in accordance to described action solenoids of different range as per requirements.

Table 5.7: Page connection details

H LOADER GANTRY		
S.NO	DESCRIPTION	OUTPUT ADDRESS
1	U(Z1) AXIS GRIPPER OPEN SOLENOID	Y360
2	U(Z1) AXIS GRIPPER CLOSE SOLENOID	Y361
3	U(Z1) SLIDE LOCK SOLENOID	Y362
4	U(Z1) SLIDE UNLOCK SOLENOID	Y363
5		Y364
6	U(Z1) TILTING UNIT@ 0DEG SOLENOID	Y365
7	U(Z1) TILTING UNIT@ 90DEG SOLENOID	Y366
8	V(Z2) AXIS GRIPPER OPEN SOLENOID	Y367

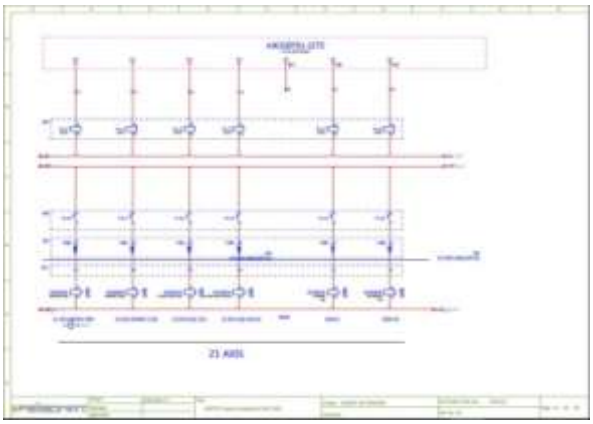

Fig 5.12: Output connection example page -02

Plug and socket is the interface which connects the field wires to hat of its corresponding cabinet or enclosure wires.

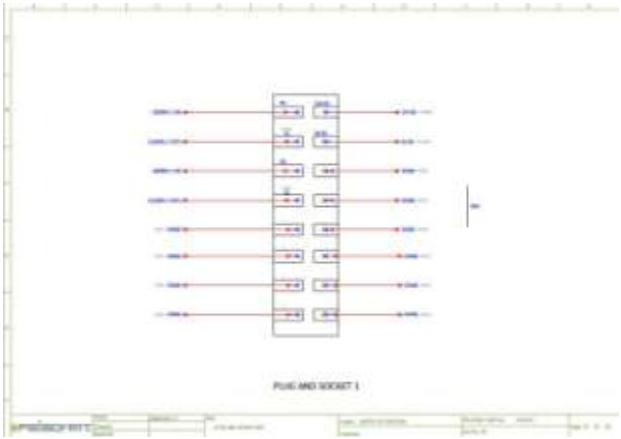

Fig 5.13: Plug and Socket Connection plan design

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NC Programming:

NC program is a technique where the sequence of operation is to be entered.

It involves:

i. Setting of parameters
ii. Defining and establishing connection addresses
iii. Programming actions
iv. Defining custom messages and feedbacks
v. Teaching positions
vi. Designing Screen
vii. Assigning and interlocking addresses
viii. Testing and corrections if needed

The following image depicts a part of the NC program loaded to teach part coordinates at different process locations.

```
1001 - Notepad
File  Edit  Format  View  Help

(PART_DEFINE_PRG-1.SPF)
(********IPC PICK TEACH POINTS*******)
N0001#500=-216.896(Y AXIS ON IPC CONVEYOR POS-1)
N0005#501=-422.195(Y AXIS ON IPC CONVEYOR POS-2)
N0010#502=-626.195(Y AXIS ON IPC CONVEYOR POS-3)
N0015#503=-832.395(Y AXIS ON IPC CONVEYOR POS-4)
N0020#504=-1200.700(U AXIS ON IPC CONVEYOR FOR PART PICK)
(********OP10 MC UNLOAD WITH V AXIS TEACH POINTS*******)
N0025#510=-2737.885(Y AXIS POS IN OP10 MC FOR PART UNLOAD WITH V AXIS)
N0020#511=[#510-150](Y AXIS SAFE POS IN OP10 MC FOR V AXIS PART UNLOAD)
N0025#512=-1023.559(V AXIS DOWN IN OP10 MACHINE FOR PART UNLOAD)
(********OP10 MC LOAD WITH U AXIS TEACH POINTS*******)
N0030#515=-3396.000(Y AXIS POS IN OP10 MC FOR PART LOAD WITH U AXIS)
N0035#516=[#515-150](Y AXIS SAFE POS IN OP10 MC FOR U AXIS PART LOAD)
N0040#517=-1021.864(U AXIS DOWN IN OP10 MACHINE FOR PART LOAD)
(********SPC LOAD/UNLOAD WITH V AXIS TEACH POINTS*******)
N0045#520=-4925.885(Y AXIS POS ON SPC STN FOR LOAD/UNLOAD WITH V AXIS)
N0050#521=-1001.559(V AXIS DOWN AT SPC STATION FOR PART LOAD/UNLOAD)
(********OPC LOAD WITH V AXIS TEACH POINTS*******)
N0045#522=-21362.026(Y AXIS POS ON OPC FOR PART LOAD WITH V AXIS)
N0050#523=-1192.209(V AXIS DOWN AT OPC FOR PART LOAD)
(********INDEXING STATION-1 UNLOAD WITH V AXIS TEACH POINTS*******)
N0030#525=-5421.715(Y AXIS POS ON IND STN-1 FOR PART UNLOAD WITH U AXIS)
```

Fig 5.14: NC program example page 01

The following image depicts a part of the NC program loaded to define actions and the flow descriptions

```
1500 - Notepad
File  Edit  Format  View  Help
(H_LOADER_HOME_RECOVERY_PRG.SPF)
N0005G00G90
N0015IF[[#5022GE[#570-5]]AND[#5022LE[#570+5]]]GOTO30
N0020G04X00.3(DWELL TIME OF 30 MILLISEC)
N0025GOTO40(GOTO LINE N40)
N0030IF[[#5023GE[#571-5]]AND[#5023LE[#571+5]]]GOTO5000
N0035G04X00.2(DWELL TIME OF 20 MILLISEC)
N0040IF[#150EQ1]GOTO100(IPC_PICK_HOME_RECOVERY)
N0041IF[#150EQ2]GOTO200(OP10_PART_UNLOAD_HOME_RECOVERY)
N0042IF[#150EQ3]GOTO400(OP10_PART_LOAD_HOME_RECOVERY)
N0043IF[#150EQ4]GOTO600(SPC_STN_PART_UNLOAD_HOME_RECOVERY)
N0044IF[#150EQ5]GOTO700(SPC_STN_PART_LOAD_HOME_RECOVERY)
N0045IF[#150EQ6]GOTO800(IND_STN_UNLOAD_HOME_RECOVERY)
N0046IF[#150EQ7]GOTO900(IND_STN_LOAD_HOME_RECOVERY)
N0047IF[#150EQ8]GOTO1400(OP10_BUFFER_STN_PART_UNLOAD_HOME_RECOVERY)
N0048IF[#150EQ9]GOTO1500(OP10_BUFFER_STN_PART_LOAD_HOME_RECOVERY)
N0049IF[#150EQ10]GOTO1000(OP20_PART_UNLOAD_BY_U AXIS_HOME_RECOVERY)
N0050IF[#150EQ11]GOTO1200(OP20_PART_LOAD_BY_V_AXIS_HOME_RECOVERY)
N0051IF[#150EQ12]GOTO2200(ID_AIR_BLOW_HOME_RECOVERY)
N0052IF[#150EQ13]GOTO
N0053IF[#150EQ14]GOTO
N0054IF[#150EQ15]GOTO
N0055IF[#150EQ16]GOTO
N0056IF[#150EQ17]GOTO
```

Fig 5.15: NC program example page 02

The following image depicts status screen while developing which is being loaded to NC screen at Main operator panel.

LEADWELL MACHINE-3 TO GANTRY

S.NO	DESCRIPTION	INPUT	STATUS	S.NO	DESCRIPTION	INPUT	STATUS
1	RDY FOR AUTO WITH GANTRY	X38		13	M/C TOP DOOR IS FULLY CLSED	X44	
2	OP10/3 REQUEST FOR LOAD	X39		14	M/C FRONT & SIDE DRS CLSED	X45	
3	OP10/3 REQUEST FOR UNLOAD	X3A		15	OP10/3 CHUCK CLAMP	X46	
4	M/C IN SAFE FOR GANTRY	X3B		16	OP10/3 CHUCK UNCLAMP	X47	
5	PART TYPE SELECTION BIT 0	X3C		17	OP20/3 CHUCK CLAMP	X48	
6	PART TYPE SELECTION BIT 1	X3D		18	OP20/3 CHUCK UNCLAMP	X49	
7	PART TYPE SELECTION BIT 2	X3E		19	OP10/3 SLIDE TOWARDS GRPR	X4A	
8	MC-3 PART PRE-REQUEST	X3F		20	OP10/3 SLIDE AWAY FRM GRPR	X4B	
9	MC-3 GANTRY ENABLE	X40		21	OP20/3 SLIDE TOWARDS GRPR	X4C	
10	MC-3 SEAT CHECK OK	X41		22	OP20/3 SLIDE AWAY FROM GRPR	X4D	
11	MC-3 SEAT CHECK NOT OK	X42		23			
12	M/C TOP DOOR IS FULLY OPNED	X43		24			

Fig 5.16: NC Screen example page

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The NC screen follows the program line by highlighting the executing action corresponding code

VI. CONCLUSION:

The Gantry automation system for automatic loading and unloading of differential housing to the processing machine is designed and implemented as per the requirements of customer considering the specifications provided by them. The Gantry automation system developed is capable of performing the intended tasks automatically in a pre-determined sequence and orientation.

The automated gantry system is tested and it is found that system meets the customer needs successfully and runs without intervention of human being.

The system is made simple to install in customer place. The aluminium frames are made easy to assemble with gusset and t-nuts. The system is made reliable since it can be stopped in any intermediate position.

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[12] "https://dl.mitsubishielectric.com/dl/fa/document/manual/school_text/sh081376eng/sh081376enga.pdf . To understand various features of CC-link.

[13] "https://dl.mitsubishielectric.com/dl/fa/document/manual/plc/sh080895eng/sh080895enge.pdf". L-series CC-Link Module User Manual.