

Implementation of PLC for CNC Flame cutting machine

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Abstract— In this modern era where everything is becoming automated, the business sector especially the manufacturing companies have gained so many benefits from using machines and technology to increase their profits and productivity rate. This paper presents Implementation of PLC logic for CNC flame cutting machine. And it involves the implementation of the hardware and software for CNC system i.e. development of PLC logic for CNC flame cutting machine and designing of circuit for interfacing of CNC System to the Flame cutting Machine. CNC Flame cutting Machines are automated that make Industrial components with less human interaction. Computer is used for processing of data and controlling various activities of the machine. PLC interfaces the Machine and the System. A great level of accuracy and speedier cycle times can be gained with the use of a CNC machine. Since this automation has a high repeatability, it can increase the consistency and yield.

Index Terms— Computerized Numerical Control (CNC), Distributed Numerical Control (DNC), Flame cutting machine, FAGOR CNC 8037, KeyCF, Numerical control (NC), Programmable Logic Controller (PLC),

1 INTRODUCTION

Modern precision manufacturing demands extreme dimensional accuracy and surface finish. Such performance is very difficult to achieve manually, even with expert operators. In cases where it is possible, it takes much higher time due to the need for frequent dimensional measurement to prevent overcutting. It is thus obvious that automated motion control would replace manual “hand wheel” control in modern manufacturing. Development of computer numerically controlled (CNC) machines has also made possible the automation of the machining processes with flexibility to handle production of small to medium batch of parts. [1]

In this paper, a new controlling system topology is proposed for Flame cutting machine. i.e., Computerized Numerical Control system is proposed for flame cutting machine. It involves the implementation of the hardware and software for CNC system i.e. development of PLC logic for CNC flame cutting machine and designing of circuit for interfacing of CNC System. The selected CNC system is FAGOR CNC 8037/Spain machine.

The CNC is prepared to be used in industrial environments, especially on milling machines, lathes, etc. The CNC can control machine movements and devices. The Computerized Numerical Control (CNC) machine makes use of computer for processing of data and controlling various activities of the flame cutting machines. This system the actions are controlled by the direct insertion of numerical data at some point. The system must automatically interpret portion of this data. The CNC system receives numerical data, interpret the data and then control the action accordingly.

Computerized Numerical Control (CNC) is a specialized and versatile form of soft automation and its applications cover many kinds, although it was initially developed to control the motion and operation of machine tools. Computerized Numerical Control may be considered to be means of operating a machine through the use of discrete numerical values fed

into the machine, where the required ‘input’ technical information is stored on a kind of input media such as hard disk, CD ROM, DVD, USB flash drive, or RAM card etc. The machine follows a predetermined sequence of machining operations at predetermined speeds necessary to produce a work piece of the right shape and size. [1],[2],[3],[7].

2 COMPUTERIZED NUMERICAL CONTROL SYSTEM (CNC)

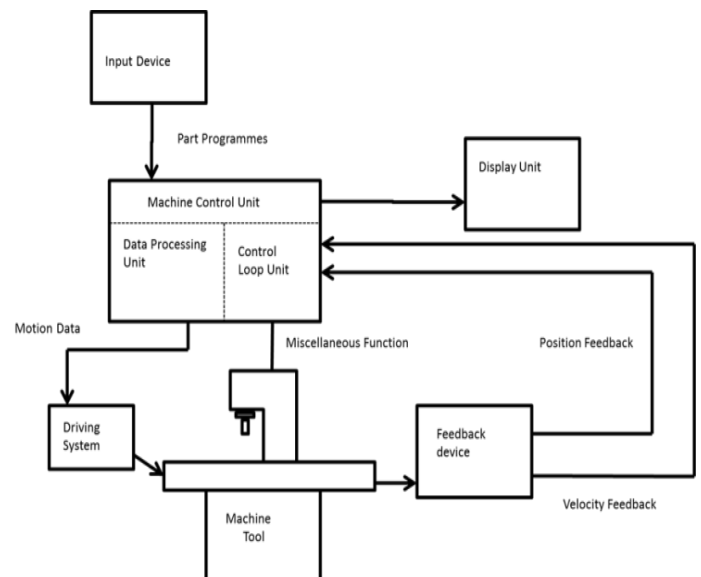


Fig.1 Basic block diagram of CNC machine

This includes brief explanation of the computerized Nu-

merical Control (CNC) system and its parts, with the help of a block diagram and required system specifications, technical specifications, and its parts. [fig.1]

CNC machine system consists of following sub systems:

2.1 Input Device:

The methods of loading the input to the system were as follows:

- **Manual Entry:** The program generated by the AutoCAD is taken and loaded into the CNC machines for the production of a work piece manually.
- **Serial port programming:** Loading of programs on the CNC machine is done using RS232 protocol and line driver through RS232 port.
- **External hard drives:** The programs can be copied from the DNC system to the CNC flame cutting machines using pen drives.

2.2 Feedback Devices:

In order to have a CNC machine operating accurately, the positional values and speed of the axes need to be constantly updated. Two types of feedback devices are normally used. They are positional feedback device and velocity feedback device.

- **Positional feedback devices:** There are two types of positional feedback devices i.e. A linear transducer, which is used for direct positional measurement and rotary encoder for angular (or indirect linear measurement).
- **Velocity feedback devices:** The actual speed of the motor can be measured in terms of voltage generated.

2.3 Display Unit (Monitor):

The Display Unit serves as an interactive device between the machine and the operator. When the machine is running, the display unit displays the present status such as the position of the machine slide, the feed rate, the part programs, etc. It also shows the graphics simulation of the tool path so that part programs can be verified before the actual machining.

2.4 Machine Control Unit (MCU):

The machine control Unit is the heart of the CNC system.

There are two sub-units in the MCU: the Data Processing Unit (DPU) and the Control Loop Unit (CLU).

- **DPU :** receiving a part program, the DPU firstly interprets and encodes the part program into internal machine tools
- **CLU :** The data from the DPU are converted into electrical signals in the CLU to control the driving system to perform the required motions

2.5 Machine Tool:

This can be any type of machine tool or equipment, in order to obtain high accuracy and repeatability.

2.6 Driving System:

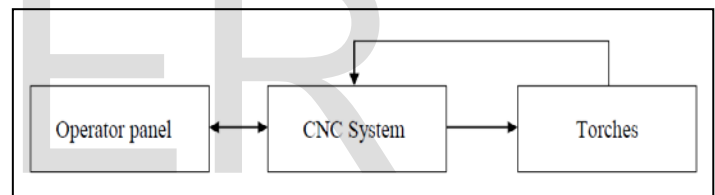
The driving system is an important component of a CNC machine as the accuracy and repeatability depend very much

on the characteristics and performance of the driving system. The requirement is that the driving system has to respond accurately according to the programmed instructions.

3 WORKING PRINCIPLE OF CNC FLAME CUTTING MACHINE

The input given to the system can be either through Manual Entry or programs can be loaded onto the CNC system. In order to have a CNC machine operate accurately, the positional values and speed of the axes feedbacks of the cutting machine are need to be constantly updated. The driving system has to response accurately according to the programmed instructions. The Display Unit acts as an interactive device between the machine and the operator. When the machine is running, the display unit displays the present status such as the position of the machine slide, feed rate, part programmes, etc. It also shows the graphics simulation of the tool path so that part programmes can be verified before the actual machining. The basic Block diagram depicting the working principle of the CNC Flame cutting Machine is shown in the fig 2.

Fig 2. Working Principle of CNC Flame Cutting Machine



4 BENEFITS OF CNC MACHINE

There are various valid reasons for the popularity of the CNC machines are;

1. CNC machines can be used continuously 24 hours a day, 365 days a year and only need to be switched off for occasional maintenance.
2. CNC machines are programmed with a design which can then be manufactured hundreds or even thousands of times. Each manufactured product will be exactly the same.
3. Less skilled/trained people can operate CNCs unlike manual flame cutting machines need skilled engineers.
4. CNC machines can be updated by improving the software used to drive the machines
5. Training in the use of CNCs is available through the use of „virtual software“. This is software that allows the operator to practice using the CNC machine on the screen of a computer.
6. CNC machines can be programmed by advanced design

software such as Pro/DESKTOP®, enabling the manufacture of products that cannot be made by manual machines, even those used by skilled designers / engineers.

7. Modern design software allows the designer to simulate the manufacture of his/her idea. There is no need to make a prototype or a model. This saves time and money.
8. One person can supervise many CNC machines as once they are programmed they can usually be left to work by themselves. Sometimes only the cutting tools need replacing occasionally.
9. A skilled engineer can make the same component many times. However, if each component is carefully studied, each one will vary slightly. A CNC machine will manufacture each component as an exact match.

5 PROGRAMMABLE LOGIC CONTROL (PLC)

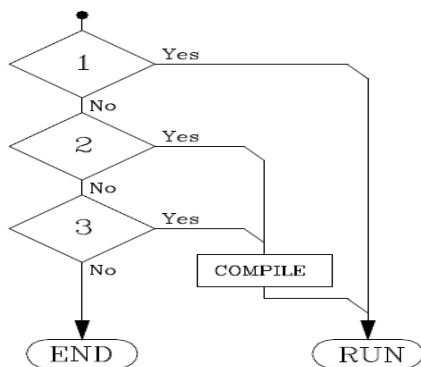
The PLC program (PLC_PRG) may be edited at the front panel or copied from the hard disk or from a peripheral device or PC.

The PLC program (PLC_PRG) is stored in the internal CNC memory with the part-programs and it is displayed in the program directory (utilities) together with the part-programs.

Before executing the PLC_PRG program, it must be compiled. Once it is done compiling, the CNC requests whether the PLC should be started or not.

To make the operator life easier and avoid new compilations, the source code generated at each compilation is stored in memory.

After power-up, the CNC acts as follows:



1. If there is an executable program stored in memory, it executes it (RUN).
2. If there is no executable program, but there is a PLC_PRG in memory, it compiles it (COMPILE) and executes it (RUN).
3. If there is no PLC_PRG in memory, it looks for it in the hard disk (KeyCF). If it is there, it compiles it (COMPILE) and executes it (RUN). If it is not there, it does nothing. Later on, when accessing the Jog mode, Execution mode, etc. the CNC will issue the corresponding error message.

Once the program has been compiled, it is not necessary to keep the source program (PLC_PRG) in memory because the PLC always executes the executable program.

The PLC has 512 inputs and 512 outputs. Some of them, depending on the CNC configuration, communicate with external devices.

There is an exchange of information between the CNC and the PLC which is done automatically and the system has a series of commands which allow the following to be done quickly and simply:

- The control of Logic CNC inputs and outputs by means of an exchange of information between both systems.
- The transfer from the CNC to the PLC of M, S and T auxiliary functions.
- To display a screen previously defined by the user, as well as generating messages and errors in the CNC.
- Read and modify internal CNC variables from the PLC.
- Access all PLC resources from any part-program.
- Monitor PLC resources on the CNC screen.
- Access to all PLC variables from a computer, via DNC and through the RS 232 C serial line. [5], [6].

6 PLC RESOURCES

- 6.1 **Inputs (I):** They are elements that provide information to the PLC on the signals they receive from the outside world. They are represented by the letter I and there are 512 inputs available.
- 6.2 **Outputs (O):** They are elements that let the PLC activate or deactivate the various devices of the electrical cabinet. These are represented by the letter O and there are 512 outputs available.
- 6.3 **Marks (M):** These are elements capable of memorizing in one bit (as if it were an internal relay) the status of the different internal variables of the CNC (information of the logic outputs received in the Communication between the CNC and the PLC of the CNC) and the status of the different variables of the PLC, whether these are internal or established by the user. They are represented by the letter M, and there are 3999 user marks and other special marks.
- 6.4 **Registers (R):** These are elements which allow a numerical value to be stored in 32 bits or facilitate CNC-PLC communication with the Logic CNC inputs and outputs. They are represented by the letter R and there are 256 user registers and other special registers.
- 6.5 **Timers (T):** These are elements which, once activated, alter the status of their output for a specific time (time constant). They are represented by the letter T, and there are 512 timers.
- 6.6 **Counters (C):** They are elements capable of counting up or down a preset amount of events. They are represented by the letter C and there are 256 counters.

7 PLC PROGRAM EXECUTION

The PLC executes the user program cyclically. In other words, once it executes the complete program, it restarts running this program from the first instruction. [Fig 3]

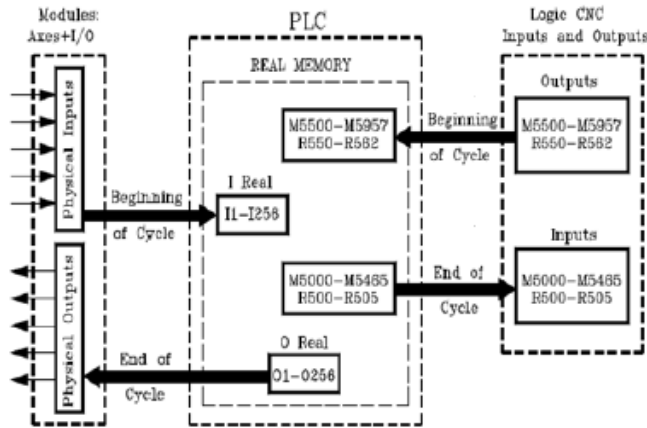


Fig. 3 PLC program execution

This cyclic processing of the program is done as follows:

- 1) At the beginning of the cycle, PLC's "I" resources are assigned the current values of the physical inputs (connectors). For example, if the physical input I10 is at 24V, the PLC sets the I10 resource to "1".
- 2) It allocates the current values of the logic CNC outputs (CNCREADY, START, FHOUT, etc.) to PLC resources M5500 thru M5957 and R550 thru R562.
- 3) It runs the program cycle. The following sections indicate how the PLC program is structured and which are its execution modules.
- 4) After executing the cycle, it updates the Logic CNC inputs (/EMERGEN, /STOP, /FEEDHOL, etc.) with the current values of PLC resources M5000 thru M5465 and R500 thru R505.
- 5) It assigns the current values of the PLC's "O" resources to the physical outputs (connectors). For example, if the "O5" resource is at "1", the PLC sets physical output O5 (connector) to 24V.
- 6) The cycle ends and is ready for the next scan. Bear in mind that all the actions of the program executed by the PLC alter the status of its resources.

Example: I10 AND I20 = O5

When this condition is met [resource I10 is "1" and I20 is also "1"], the PLC sets resource "O5" to "1". If this condition is not met, the PLC sets resource "O5" to "0".

Therefore, the status of a resource may change during the execution of the PLC program.

Example, assuming that the initial status of resource M100 is "0":

M100 AND I7 = O3

Resource M100 = "0"

I10 = M100

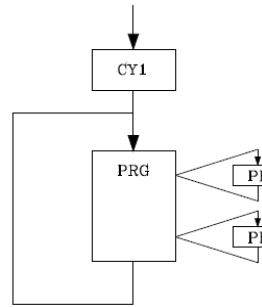
M100 takes the value of resource I10

M100 AND I8 = M101

The value of M100 depends on the previous instruction.

8 MODULAR STRUCTURE OF THE PROGRAM

The program to be executed by the PLC consists of a series of modules which are appropriately defined by means of directing instructions.



The modules which can make up the program are:

- a) Main module (PRG)
- b) Periodic execution module (PE)
- c) First cycle module (CY1)

Each module must begin with the directing instruction which defines it (PRG, PE, CY1) and end with the directing instruction END. Should the main program contain the main module only it is not necessary to place the instructions PRG and END.

8.1 First cycle module (CY1):

This module is optional and will only be executed when the PLC is turned on. It is used to initialize the different resources and variables with their initial values, before proceeding to execute the rest of the program.

This module operates by default with the real values of resources I, O, M. It is not necessary for this to be at the beginning of the program, but must always be preceded by the instruction CY1.

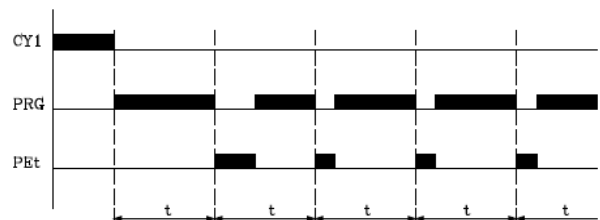
8.2 Main module (PRG):

This module contains the user program. It will be executed cyclically and will be given the task of analysing and modifying CNC inputs and outputs. This module operates by default with the image values of resources I, O, M. There can only be one main program and this must be preceded by the instruction PRG. It is not necessary to define it if it starts on the first line.

8.3 Periodic execution module (PE t):

This module is optional and will be executed every period of time t indicated in the directing instruction defining the module. This module may be used to process certain critical inputs and outputs which cannot be checked or updated properly in the body of the main program due to its extended execution time.

Another application for this module is for those cases where specific tasks need not be evaluated at every PLC program cycle. Those tasks would be programmed in the periodic module and they would be executed with the frequency established by the execution time assigned to this module



Every time the PLC program is started (command RUN) the first module to be executed is the first cycle module (CY1).

Once execution has been completed, it will continue with the main module (PRG).The main module will be executed cyclically until the execution of the PLC has stopped (command STOP). [5], [6].The periodic module will be executed every time the time indicated in the directing instruction "PET" elapses. This count starts when the execution of the main module (the first time) begins.

The periodic module is processed as follows:

1. The PLC takes into account the current values, as just before executing the PE module, of the local physical inputs (connectors of the central unit).
2. Executes the periodic module.
3. It assigns the current values of the PLC's "O" resources to the local physical outputs (connectors of the central unit).
4. It ends the execution of the Periodic Module and resumes the execution of the main module.

9 HARDWARE AND SOFTWARE DESCRIPTION

9.1 CNC monitor, keyboard and operating panel

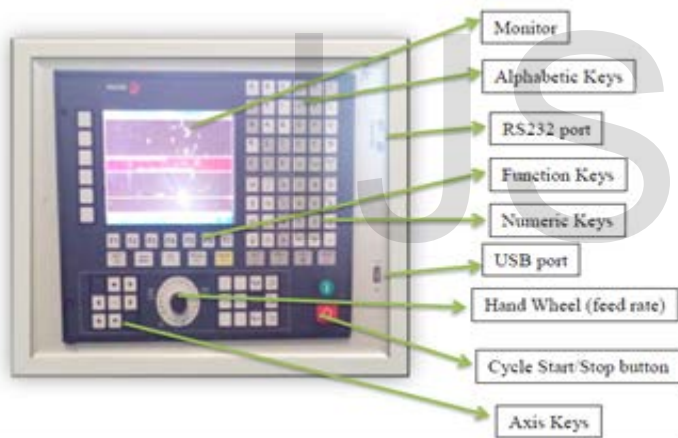


Fig 4 CNC Monitor and Keyboard

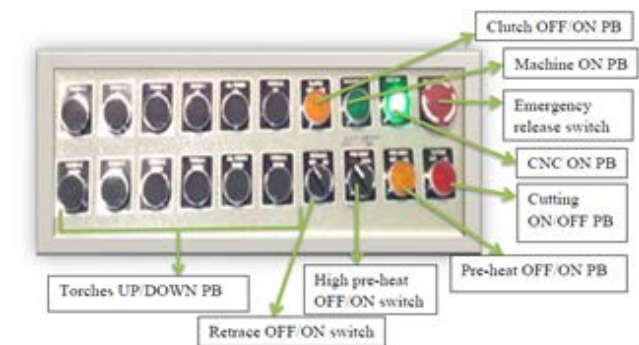


Fig 5 Operating panel

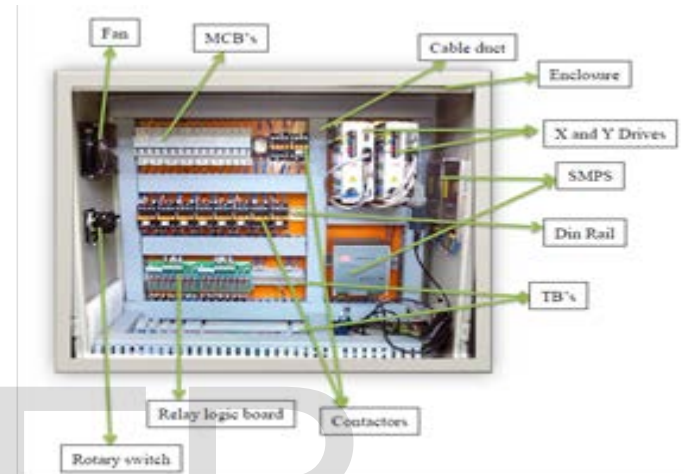
The schematic monitor, keyboard and operating panel is shown in fig 4 and 5. The CNC The central unit is located on the rear of the monitor. Operating panel contains few switches for torch movement and for manually controlling the flame

cutting operation. The Knob (hand wheel) is used to adjust the feed rate which is nothing but the adjustment of the motor speed. To the left of the knob we can see few switches which are used to manipulate the X and Y axis movements. Cycle start/Stop button is used to start/stop the movement of machine.

9.2 Control panel

Fig 6. Control panel with Accessories

The schematic of control panel is shown in fig 6. Ratings of



all components are shown in table 1;

Table 1: Components ratings

SI No.	Component	Rating
1.	AC brushless servomotor (X-motor)	510W, 2.38A, 4000rpm, 300V
2.	AC brushless servomotor (Y-motor)	510W, 2.38A, 4000rpm, 300V
3.	Digital AC servo drive (X-drive)	510W
4.	Digital AC servo drive (Y-drive)	510W
5.	Inductive relay	24V DC coil, 5A
6.	Contactors	230 V, 10A
7.	MCB	240V/415V, 10A
8.	SMPS	24V DC
9.	Encoder with halls	2500 PPR

9.3 Hardware Circuit Interface

The hardware circuit connection of CNC flame cutting machine is shown in figure 7. Its hardware and software requirements are as follows;

Hardware Required

- CNC system
- RS232 cables
- Velocity Feedback units
- Positional Feedback units
- Power Supply unit
- Measuring Board
- Command Board
- I/O Boards
- Flame cutting torches
- Rail structures.

Software Required

- Operating System
- PLC
- CNC net.exe
- Auto CAD-2010
- MOST 2D
- BEML CAM
- Win DNC

9.4 System Configuration

Hardware Configuration:

- Configuration of the CNC 8037
- Power supply
- CPU-CNC power PC module
- Axes 2
- Digital video
- CNC resources
- RAM memory (kb)
 - User 1024
 - System 1024
- SDRAM PPC (Mb) 64
- PLC resources
- PLC integrated in CPU-CNC
- Local: 56 I, 32 O

Software Configuration:

- Maximum number of axes-3

9.5 CNC-PLC Communication

With the data exchange between the CNC and the PLC, it is possible to:

1. The control of logic inputs and outputs from the CNC by means of an exchange of information between both systems, which is done periodically and by means of specific PLC Marks and Registers.
2. The transfer from the CNC to the PLC of M, S and T auxiliary functions.
3. Display screens which have been defined previously by the user, as well as generating messages and errors in the CNC, by means of specific PLC Marks.
4. Read and modify internal CNC variables from the PLC.
5. Access all PLC resources from any part-program.
6. Monitor PLC resources on the CNC screen.
7. Access to all PLC variables from a computer, via DNC through the RS 232 C serial line.

10 PROCESS AUTOMATION

10.1 PLC logic flowchart

A graphical representation of an algorithm is often used in design phase of programming to work out the logical flow of a program. The logic is divided into various

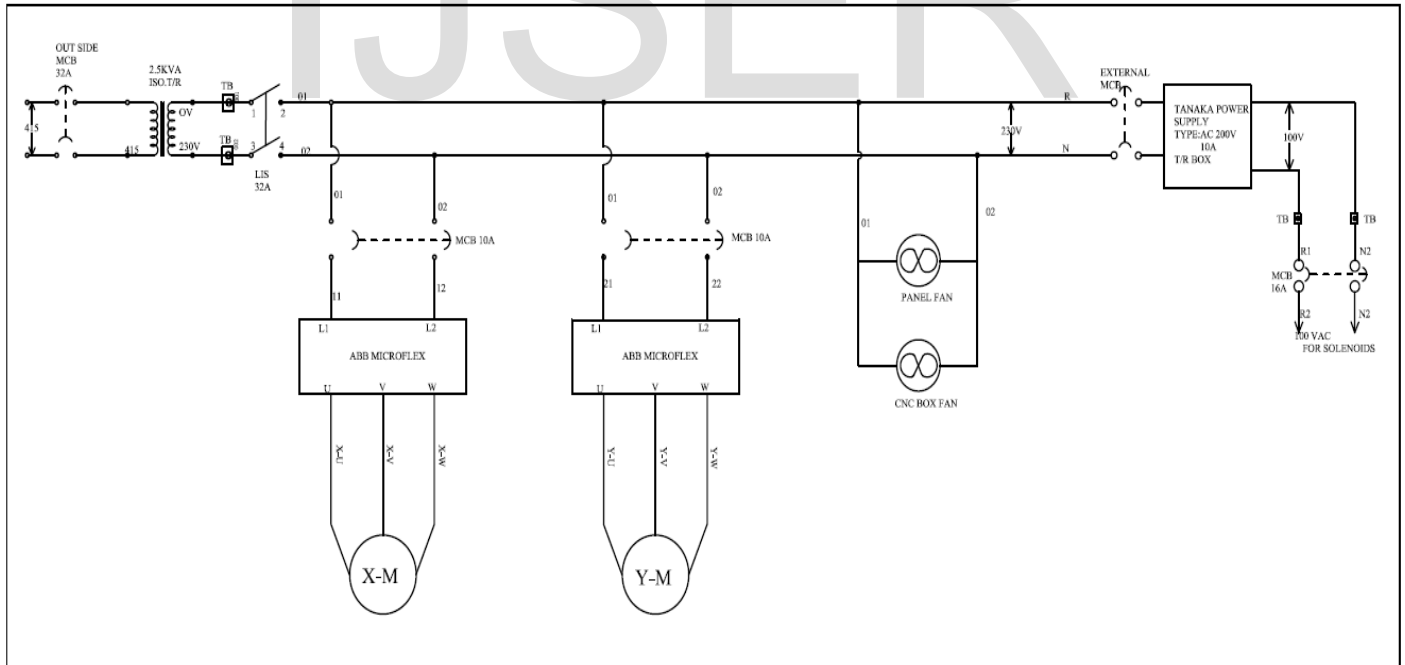


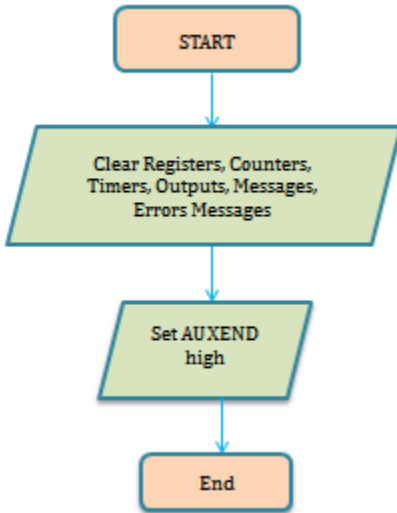
Fig 7. Circuit interface diagram of CNC flame cutting ma-

- Tool radius compensation
- DNC
- Retrace
- Setup assistance
- Ethernet

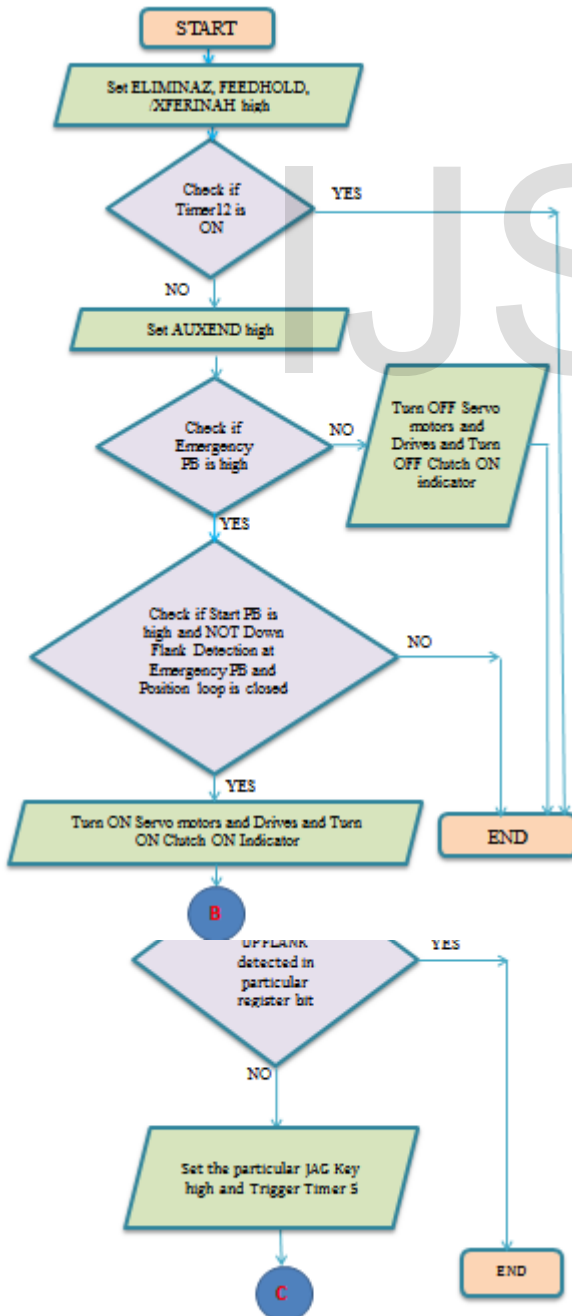
subsections that are intended to perform a particular task.

The flowcharts are written as per ladder program.

Flowchart – 1: First cycle module

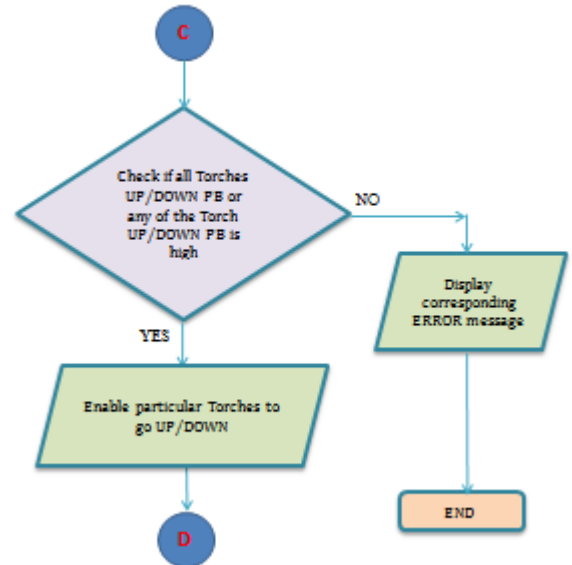


Flowchart – 2: Main PLC program



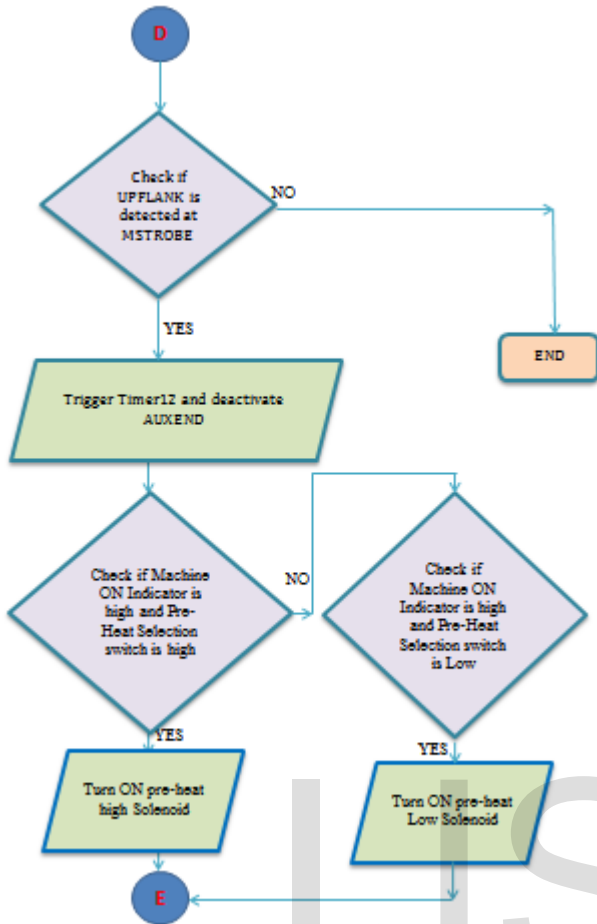
Flowchart – 3: Axis Jag keys

Flowchart – 4: Torches UP/DOWN

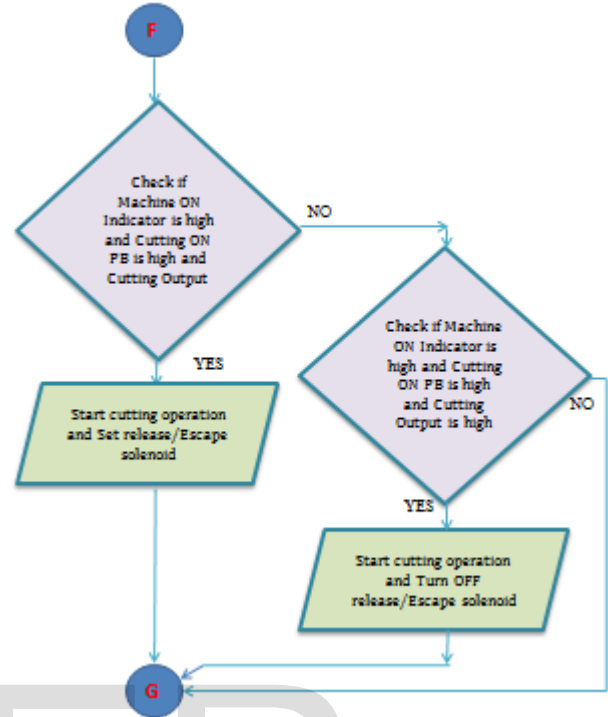


Flowchart – 5: Valve operation M codes

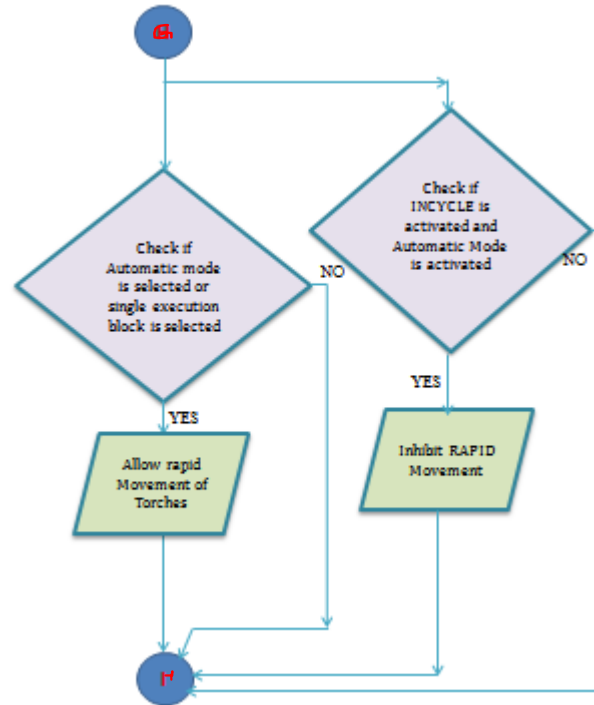
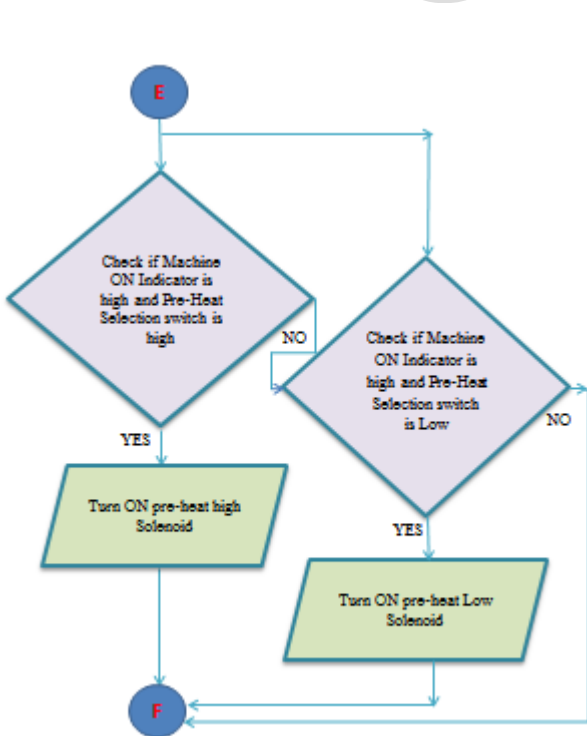
Flowchart –7: Manual pre-heat OFF/ON



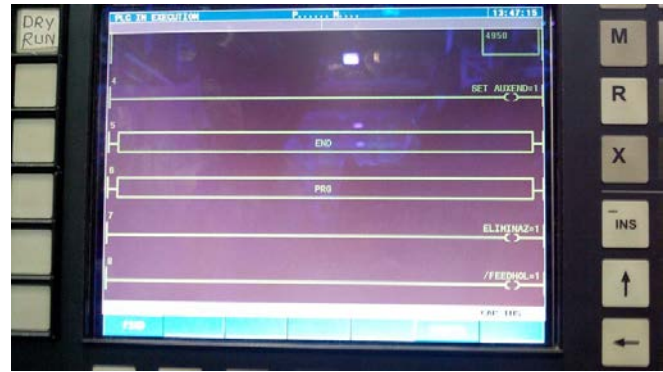
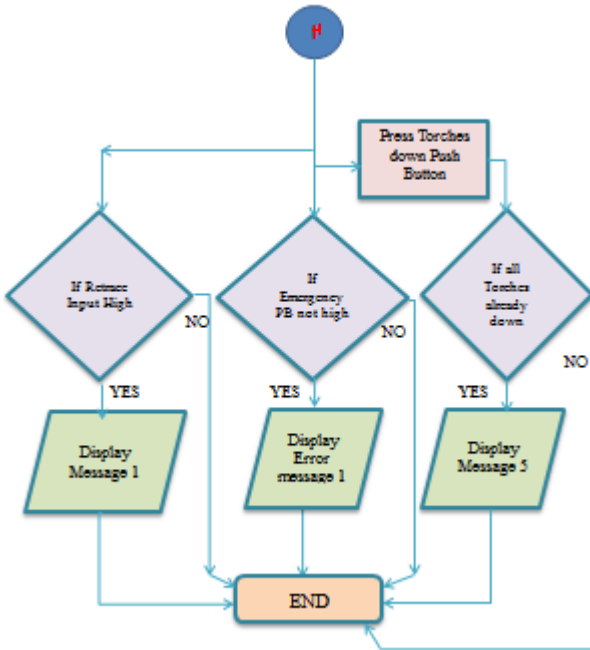
Flowchart – 6: Manual high pre-heat OFF/ON



Flowchart –8: Cutting Oxygen ON/OFF



Flowchart –9: PLC errors and messages



11 RESULTS

Control object needed for CNC flame cutting machine is achieved by Programmable logic controller. Structure text logics written for the process is working satisfactorily.

Torch - 1 up operation:

Validation of ladder logic done is shown in

Table NO. 1

INPUTS TO PLC	STATUS	OUTPUT
Main supply	ON (high)	PLC is giving output to Torch-1 UP
Emergency PB	Released (Low)	
CNC ON PB	High (System will boot up)	CONT 1 (i.e., Output O42) if and only if all these status are achieved.
Clutch ON PB	High (Enables axes movement)	
Machine ON PB	Yes (high)	
Torch - 1 UP PB or All torch UP PB	Yes (high)	
Torch - 1 DOWN PB or All torch DOWN PB	NO (low)	(checked individually and found satisfactory result)

Table NO 1. Result

Similarly, the PLC is giving output for all other operations of the CNC flame cutting machine.

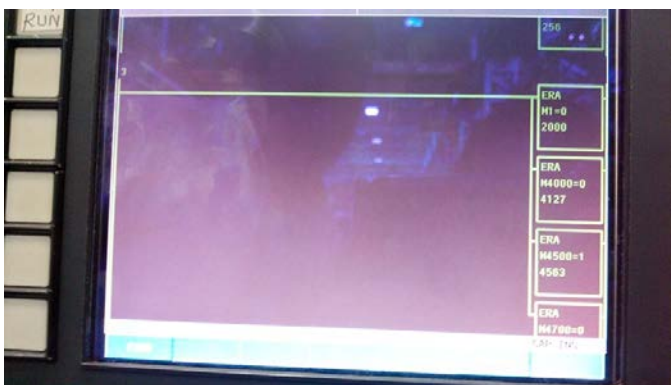
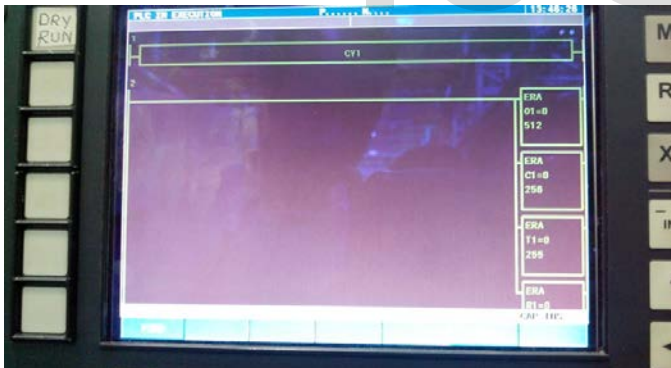
The required part Program is either directly entered through the operator panel or retrieved via DNC Connection in the form of a CAD Drawing.

The metal work pieces of required dimensions are drawn using CAD Tool. Then the drawing is converted in to part program using BEML KAM software. These converted part programmes are then transferred to CNC system via DNC connection.

The program is selected on the CNC system and it is executed. Thus, the Metal plate is cut accurately with required dimensions. Thus, the PLC which is integrated with in the CNC System helps in moving the torches more accurately and the dimension of the obtained metal work piece is accurate.

10.2 PLC programming example

The first cycle module ladder program is shown below.



12 CONCLUSION

This paper presents, one of the advanced system controller for CNC flame cutting machine and designing of circuit for interfacing of CNC System to the Flame cutting Machine. Compared to other conventional Numerical Control system, CNC is an advanced system and it makes the Industrial components with less human interactions. Computer system is used for processing of data and controlling various activities of the machine. The proposed system is FAGOR 8037/SPAIN.

The user enters the part program manually through the Operator panel or select and edit a part program which is already present in CNC Memory. The CNC System processes the machine parameters and sends the required input to the PLC. Thus the PLC controls the movement of the torches and other machining operations with the help of the feedback devices. There are two feedback devices used, one is the positional Feedback which is obtained from the motors to the Axis drives regarding the position of the Motors and direction of Motion. The other one is the Velocity Feedback which is feed back to CNC System which gives the current velocity of the Motors which is maintained by controlling the pulses generated from an encoder.

The main features of the system are as follows:

- 1) CNC machine can be used continuously, only need to be switched off for maintenance.
- 2) Each manufactured product will be exactly the same.
- 3) Less skilled or trained people can operate
- 4) Can be updated by improving software
- 5) Virtual software is available

13 REFERENCE

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