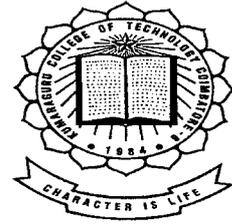
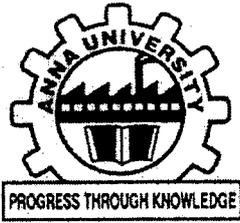


P-1407



DESIGN AND IMPLEMENTATION OF PLC AND DIGITAL AC DRIVE
FOR VMC-400

by

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for the award of the degree*

of

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IN

POWER ELECTRONICS & DRIVES

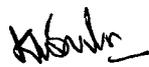
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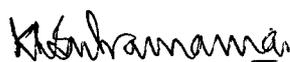
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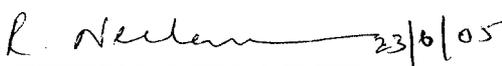
Certified that this project report titled “**DESIGN AND IMPLEMENTATION OF PLC AND DIGITAL AC DRIVE FOR VERTICAL MACHINING CENTER- 400**” is the bonafide work of **Mr. KASHOK KUMARAVELAN** who carried out the research under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.


PROJECT GUIDE


HEAD OF THE DEPARTMENT

The Candidate with University Register No: 71203415001 was
examined by us in the project Viva-Voce examination held on 23-6-05


INTERNAL EXAMINER

 23/6/05
EXTERNAL EXAMINER

ABSTRACT

This project deals with the addition of 4th axis in Vertical Machining Center which is a machine working under Computer Numeric Control. A rotary table is added as the fourth axis with the existing three axis operation of the machine ensuring multifaceted operation for the jobs. Using hardwired control panel, process will be a tedious one. So in this, Programmable Logic Controller is employed for logical decision making. PLC here contains 64 input modules and 32 output modules. PLC is implemented with statement List programming in the specially designed software siematic s5. Status of PLC and the operation of the machine will get displayed in panel viewer. In the design part of the driver circuit, Servomotor is used to operate the CNC machine, which provides wide range of torque, and posses' low moment of inertia. Digital AC servo drives was implemented for actuating and controlling the servomotor. In this Digital Drives, new Microprocessor based digital inverter provides control flexibility and fast dynamic response with its vector control concept. IGBT (Insulated Gate Bipolar Transistor) is used as the switching device for faster switching of the driver circuit

ACKNOWLEDGEMENT

First and foremost, I would like to extend my heart-felt gratitude and thanks to our beloved Principal of Kumaraguru College of Technology, **Dr.K.K.PADMANABHAN** without whom I would not have been studying in this institution.

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The constant guide and care showered upon me by my **PARENTS** is untold and immeasurable. Finally, it give me a great pleasure to express my sincere thanks to all my **FRIENDS** who have helped me during the course of this work.

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“DESIGN AND IMPLEMENTATION OF PLC SYSTEM AND DRIVE FOR ADDITION OF FOURTH AXIS IN VMC-400 CNC MACHINE”

The above project has done by him in the Maintenance and Service Department of BHEL, Trichy – 14, from 28-12-2004 to 28-03-2005 and found successful in his project work.

During this period he has shown keen interest in bearing various aspects of his project. The out come of this project is benefitable to our organization.

I wish him all success in future endeavors.

EXTERNAL GUIDE 5/4/05

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BHEL-PROFILE

BHARAT HEAVY ELECTRICAL LIMITED (BHEL), one of the Navaratnas is all to emerge a global plant. Endowed with distinctive competence in technology absorption product development and manufacturing technology, the company continues to play a vibrant role in the Indian Power Plant equipment market even after the liberalization and opening up of the economy.

AN EXPANDING PROFILE:

The Trichy complex of BHEL in Tamilnadu, comprising the high pressure boiler plant and the seamless steel tube plant, the boiler auxiliaries' plant at Ranipet and the industrial value a plant at Govindwal has been expanding its product and technology profiles over the last three decades. Setup initially with technology for its various products in the seventies with a serious of collaboration with leading equipment manufactures in the U.S, Germany, Sweden and Switzerland. The boiler unit rating has been steadily increased from 60MW to 110MW and 500MW within two decades. Company has so far bagged orders for total of 517 boilers. In Trichy BHEL, besides conventional steam generators for utility and industrial applications, the product profile of Trichy complex includes. HPLP by pass system under steam generating equipment of 259MW boilers using the design expertise and the operating knowledge base established over the years.

CUSTOMER SERVICES:

At BHEL Trichy, every system is turned towards servicing the customer. The entire project management required for timely execution of customer orders is handled through a computer network system. Planned of components in workshops as well as timely ordering on outside vendors is carried out to ensure dispatch of components matching construction schedule at the sites. This helps BHEL in maintaining product deliveries with shortest lead times. Services are provided during and after commissioning of equipment by field engineering services.

Supply of spares and service after sales are two other major components of BHEL, Trichy's service support. BHEL, Trichy ensures timely supply of spares for proper upkeep of equipment and maximization of equipment utilization. Techniques and methodology have been developed to assess the residual life of components, based on which selective replacement decision can be made to extend the productive life of the equipment.

THRUST AND MARKETING AND DIVERSIFICATION:

The international competitiveness of BHEL's products has been established by the fact that its boiler and auxiliaries have been exported to Libya. Following the modernization of the value manufacturing facilities, BHEL Trichy has given a major thrust to export at values. Export orders worth about Rs.6 crores were received during 1996-1997 from the company's erstwhile collaborations, to a value from BHEL-Trichy, for the international market. BHEL will continue to strengthen its efforts to increase its exports by direct participation in select export tenders. The company is also planning to work with other leading organizations in some of the export tenders. The global competitiveness of BHEL's boilers is also established by the company's generally not lost orders for boilers and auxiliaries in the seamless steel tubes, spiral fin weld tubes, fans, electrostatic precipitators, air pre-heaters, wind electric generators and desalination plants. It has a wide network of auxiliaries and subcontracting units to take care of fabrication and machining of certain identified components of the boiler. BHEL-Trichy has been steadily making investments to expand the manufacturing capacity for various products as well as for product introduction. Besides investing in three stages of expansion for boilers and auxiliaries, investment has been made to augment the capacity for other products like value steam generators and pipe fittings.

R&D FOR FURTURISTIC TECHNOLOGIES:

BHEL is constantly monitoring the worldwide development and formulating suitable R&D programs for developing appropriate technologies. All the plants of BHEL Trichy have obtained certification under ISO. The company has been accredited with NSME's, 'S', 'V', 'V2' and 'R' stamps. The superior product quality and reliability is borne out by the outstanding performance of BHEL boilers. A recent performance is the excellent performance recorded by the country's first set of two. 2500MW boilers supplied by BHEL, Trichy to BSMS for their World Bank Funded Dahanu Project in Maharashtra. After tow years of operation Unit-1 of the plant has recorded a plant load factor (PLF) of over 100 percent, which is much higher than the national average annual PLF. The plant has achieved the unique distinction of non-stop operation for over 200 days. The 250MW boilers at BSES Dahanu TPS incorporate several new design features aimed at optimizing performance and have received great customer acclaim. In line with the market trends, the company is poised to maintain international benchmarks in delivery performance. Intensive efforts have been taken for cycle time reduction in various operational areas. These will result in a substantial reduction has been achieved as a result of increased productivity and reduced rework and rejection, following implementation of the modernization scheme. The company has already started executing several new contracts such Bakreshwar and Rainchur to the reduced level of delivery cycle time.

CERTIFICATION:

BHEL is the first owned company to acquire ISO 9000 certification during 1993 for all its operations. This being successfully maintained through surveillance and recertification audits. BHEL is continuing its thrust on total quality management (TQM) as per Confederation of Indian Industries (CII) /European Foundation Quality Model (EFQM) of Business Excellence. As a commitment towards TQM, continues improvement action plans are implemented involving technique like Benchmarking, Business Process Re-engineering and Six Sigma etc. CII has conferred "CII-EXIM Commendation Certificate" on the High Pressure Boiler Plant for 'Commitment to TQM'. BHEL Trichy has been accredited to IO14001 and ISO9001 standard signifying its clear commitment to clean and pollution free environment.

GLOBAL LINKS:

The achievements have earned an international reputation for BHEL, Trichy. The plant has so far supplied for around 1350MW of power generation capacity to Malaysia, Libya, Iran, Egypt etc. BHEL's valves have been exported to Malta, Cyprus, Malaysia and Indonesia while pressure part equipment and spares have been exported to the USA. Boiler components have been supplied the China and Seamless Steel Tubes have been exported to Malaysia. BHEL, Trichy is the proud winner of successive productivity awards and 'Sword of Honor from the British Safety Council. The President of India has awarded the shield for the Best Employer of Physically Handicapped Persons to BHEL, Trichy. Vishwakarma National awards and Young Engineer awards have been won in successive years by the employees of BHEL, Trichy. BHEL, Trichy has won goodwill and sustained support for its employee welfare schemes. A township to ensure housing, the sir C.V. Raman Science Centre and other educational facilities from the core of these schemes. As a responsible corporate body, BHEL Trichy, India has adopted several neighboring villages to help them uplift their lot. BHEL Trichy stands for all that is cherished by every member of BHEL, where quality is company-wide commitment. Dedication to technical excellence, development of state-of the technology-suitable to customers specific needs and strict adherence to quality standards from the guiding principle while surges ahead confidently into the future.

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CHAPTER 1

INTRODUCTION

In industries, the main focus is to achieve the production target with good quality within their planned period. From that they can stabilize in this competitive market. The production volume depends upon the effort taken altogether by the workers but the quality is concerned with utilizing the developing technology and skill of the workers. Now a days in order to get better quality and automation of the industries, control systems (it can be mostly achieved with relays) play the vital role in manufactured products to ensure its performance and long life. In 1960's it was achieved with equipments which were larger in size, more circuits and more power requirements and above all investments were more. Even though we have spent more money in that, we cannot give assurance about the quality of the product. It is a very tedious process to ensure the quality.

When production requirements changed so did the control system. This becomes very expensive when the change is frequent. Since relays are mechanical devices, they also have a limited lifetime that required strict adherence to maintenance schedules. Troubleshooting was also quite tedious when so many relays are involved. Now, picture a machine control panel that included many, possibly hundreds or thousands, of individual relays. The size could be quite boggling.

Process control system is made up of a group of electronic devices and equipment that provide stability, accuracy and eliminate harmful transition states in production process.

At the start of industrial revolution, especially during 60's and 70's relays are used to operate automatic machines and they were interconnected using wires inside the control panel's hence the control becomes complex. To discover error in the system in the system much time was needed especially with more complex process control system and also the lifetime of the relay contacts was limited. So some relays have to be replaced frequently which resulted in stoppage of the machine for repair purposes and hence the loss in production occurred.

In the mid 70's the dominant PLC technologies were sequences state-machines and the bit-slice based CPU. The AMD2901 and 2903 were quite popular in modicon and A-B PLC's conventional microprocessor's lacked the power to quickly solve PLC logic in all but the smaller PLC's. as conventional microprocessor's evolved, larger and larger PLC's were being based upon them. The PLC could now communicate with other PLC's and they could be far away from the actual machine were controlling. They could also now be used to send and receive varying voltages to allow them to enter the analog world.

The 80's saw an attempt to standardize communications, with general motor's manufacturing automation protocol (MAP). It was also a time for reducing the size of the PLC and making them software programmable through symbolic programming on personal computers instead of dedicated programming terminals or hand held programmers.

The 90's have been a reduction in the introduction of new protocols, and the modernization of the physical layers of some of the more popular protocols that survived the 1980's. The latest standard (IOC 1131-3) has tried to merge PLC programming languages under one international standard. We now have PLC's that are programmable in function block diagrams, instruction lists, c and structured text all at the same.

Development of computer numerically controlled (CNC) machines is an outstanding contribution to the manufacturing industries. It has made possible the automation of the machining process with flexibility to handle small to medium batch quantities in part production.

Initially, the CNC technology was applied on basic metal cutting machines like lathes, milling machines etc. later, the increases the flexibility of the machines in handling a variety of components and to finish them in a single setup on the some machines were developed. It offers the following advantages in manufacturing.

- ❖ Higher flexibility
- ❖ Increased productivity
- ❖ Consistent quality
- ❖ Reduced man power
- ❖ Higher accuracy

CHAPTER 2

CNC SYSTEM DESCRIPTION

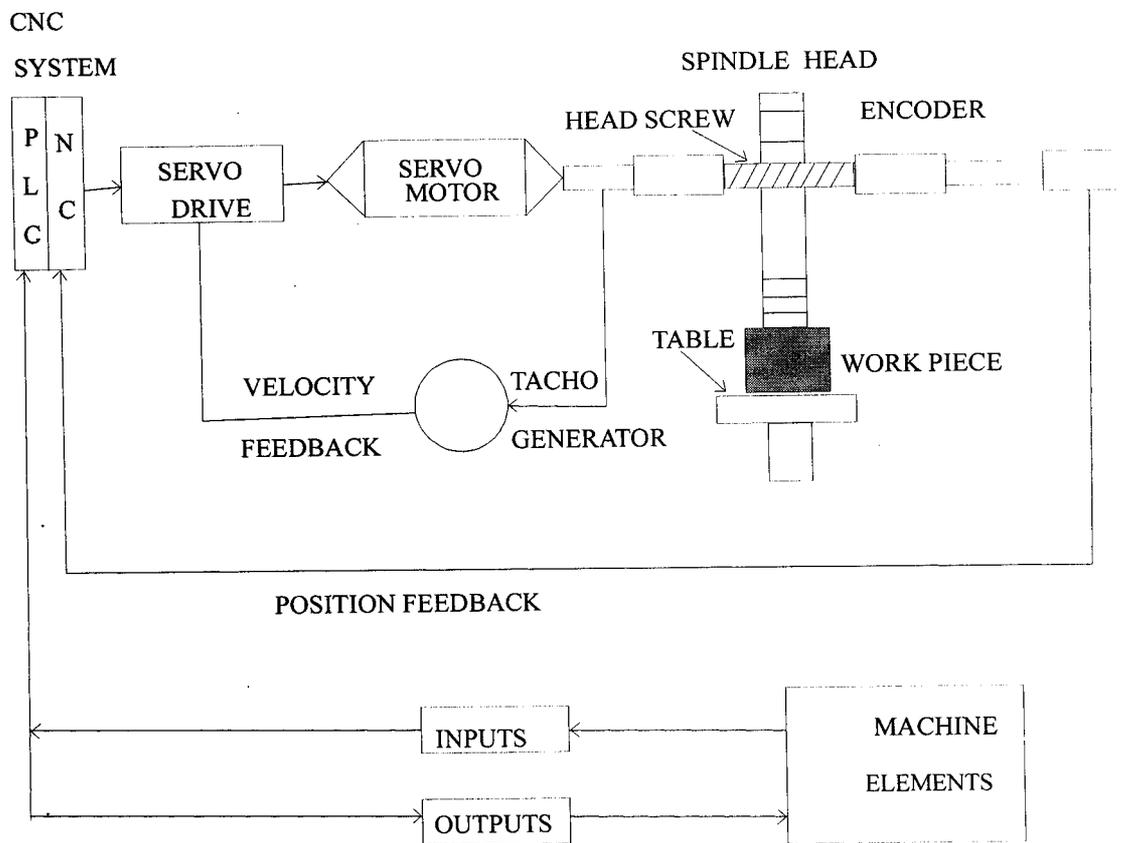
INTRODUCTION OF CNC SYSTEMS:

Numerical control (NC) is a method employed for controlling the motions of a machine tool slide and its auxiliary functions with an input in the form of numerical data. A Computer Numerical Control (CNC) is a microprocessor-based system to store and process the data for the control of slide motions and auxiliary functions of the machine tools. The CNC system is the heart and brain of a CNC machine which enables the operation of the various machine members such as slides, spindles, etc. as per the sequence programmed into it, depending on the machining operations.

The main advantage of CNC system are constructed with an NC unit integrated with a programmable Logic Controller (PLC) and sometimes with an additional external PLC (non-integrated). The NC controls the spindle movement and the speeds and feeds in machining. It calculates the traversing paths of the axes as defined by the inputs. The PLC controls the peripherals actuating elements of the enable the machine tool to operate automatically. Positioning and part accuracy depend on the CNC system's computer control algorithms, the system resolution and the basic mechanical machine inaccuracies. Control algorithms may cause errors while computing, which will reflect during contouring, but they are very negligible. Though this does not cause point-to-point positioning errors, but when mechanical machine inaccuracy is present, it will result in poorer part accuracy.

This chapter gives an overview of the configuration of the CNC system, interfacing and introduction to PLC programming. Annexure gives the general specifications of a CNC system and Annexure gives the basics of binary system, the numbering system with which all the computers work with.

BLOCK DIAGRAM OF A CNC SYSTEM



CHAPTER 3

VMC 400 SYSTEM DESCRIPTION

3.1 VERTICAL MACHINING CENTER:

Vertical machining center (VMC) is a machine, which involves in roughing boring, drilling facing and finishing of a job by means of Computer Numerical Control (CNC). VMC's operated in the three axis is capable to do operation of moving worktable and spindle to do vertical functioning over the job. VMC has several parts which includes AC servo motor, servo drive, feedback transducer, spindle etc.,

3.2 CONFIGURATION OF VMC (400):

- ❖ Central Processing Unit (CPU)
- ❖ Servo-Control Unit
- ❖ Servo-Drive
- ❖ Feedback Transducer
- ❖ Operator control panel
- ❖ Programmable logic controller

3.2.1 CENTRAL PROCESSING UNIT (CPU):

The CPU is the heart and brain of CNC system. It accepts the information stored in the memory as part program. This data is decoded and transformed into specific position control and velocity control and velocity control signals.

It also oversees the movement of the control axis or spindle and whenever this does not match with the programmed values, corrective action is taken.

All the Compensation required for machine accuracies are calculated by the CPU depending upon the corresponding inputs made available to the system calculates all the compensation required for machine accuracies.

The same will be taken care of during the generation of control signals for the axis movement. Also, some basic safety checks and built into the system through this

unit and continuous necessary corrective actions will be provided by the CPU unit. Whenever the situation goes beyond control of the CPU, it takes the final action of shutting down the system and in turn the machine.

3.3.2 SPEED CONTROL UNIT:

This unit acts in unison with the CPU for the movement of the machine axes. The CPU sends the control signals generated for the movement of the servo-control unit and the servo-control unit converts these signals to a suitable digital or analog signal to be fed to a servo drive for machine tool axis movement. This also checks whether machine tool axis movement is at the same speed as directed by the CPU.

3.2.3 SERVO CONTROL UNIT:

The decoded position and velocity control signals generated by the CPU for the axis movement forms the input to the servo-control unit. This unit in turn generates suitable signals as command values. The command values are converted by the servo-drive units which are interfaced with the axes and the spindle motors convert the command values.

The servo-control unit receives the position feed back signals for the actual movement of the machine tool axes from the feed back devices. The velocity feed back are generally obtained through tachogenerators. The feed back signals are passed on to the CPU for further processing. Thus, the servo control unit performs the data communication between the machine tool and the CPU.

As explained earlier, the actual movement for the slides on the machine tool is achieved through servo drives. The amount of movement and the rate of movement are controlled by the CNC system depending upon the type of feed back system used i.e., closed loop or open loop system.

3.3 CLOSED LOOP SYSTEM:

The closed loop system is characterized by the presence of feedback. In this system, the CNC system sends out commands for movement and result is continuously monitored by the system through various feed back devices.

3.3.1 POSITION FEED BACK:

A closed-loop system regardless of the type of feed back device, will constantly try to achieve and maintain a given position by self-correcting. As the slide of the machine tool moves, its movement is feed back to the CNC system for determining the position of the slide to decide how much is yet to be traveled and also to decide whether the movement is as per the commanded rate. If the actual rate is not as per the required rate the system tries to correct it.

In case this is not possible, the system declares a fault and initiates action for disabling the drives and if necessary, switches off the machine.

3.3.2 VELOCITY FEED BACK:

In case no time constraint is put on the system to reach the final programmed position, then the system may not produce the required path or the surface finish accuracy. Hence, velocity feedback must be present along with the position feed back whenever CNC system are used for count comparator in order to produce correct interpolations and also specified acceleration and deceleration velocities. The tachogenerator used for velocity feed back is normally connected to the motor and it rotates whenever the motor rotates, thus giving an analog output proportional to the speed motor.

This analog voltage is taken as speed feed back by the servo-controller and swift action is taken by the controller to maintain the speed of the motor within the required limits.

3.4 OPEN LOOP SYSTEM:

This open-loop system lacks feedback. In this system, the CNC system sends out signals for movement but does not check whether actual movement is taking place or not. Stepper motor is used for actual movement and the electronics of these stepper motors is run on digital pulses from the CNC system. Since system controllers have no access to any real-time information about the system performance, they cannot counteract disturbances appearing during the operation. They can be utilized in point-point system, where loading torque on the axial motor is low and almost constant.

3.5 SERVO-DRIVES:

The servo-drive receives signals from the CNC system and transforms it into actual movement on the machine. The actual rate of movement and direction depend upon the command signal from the CNC system. There are various types of servo-drives, viz. dc drives, as drives and stepper motor drives. A servo-drive consists of two parts namely the motor and the electronics for driving the motor.

3.5.1 AXIS SERVO DRIVES:

This unit controls the speed loop of the control system. The speed reference to the drive unit comes from the CNC which is usually an analog signal varying from 0v to 10v for positive direction and 10v to 0v for negative direction.

The actual speed feed back comes from the tacho-generator mounted on the servo motor. Servo drives are of two types DC servo drives and AC servo drives.

DC servo drives controls to speed of the PMDC motors (permanent Magnet DC Motors)

AC servo drives controls the speed AC servo motors. Servo drives control the speed of the servo motors by controlling the armature voltage applied to them. The torque required is achieved by controlling the amount of current fed into the servo motor.

When the CNC commands a speed by issuing a analog signal, drive compares the current speed given by tacho with the commanded speed. If the speed does not match expected value drive varies the armature voltage to achieve the desired speed and maintains it till the analog input signal changes.

The main characteristic expected of any axis servo drive is its ability to deliver uniform torque over a speed range. Full torque of the motor must be available starting from zero speed to maximum speed for which the drive is turned.

The ability of servo drives to deliver uniform torque over a long range of speeds makes these drives most suitable for machine tool axis control applications.

3.5.2 SPINDLE DRIVES:

The drive is used to control the speed of machine tool spindles. There are two types of spindle drives. DC spindle drives and AC spindle drives.

DC spindle drive controls the speed of separately existed DC spindle motors. A drive takes the speed reference input from the CNC and feed back from tacho to achieve closed loop control of spindle drives.

The speed torque characteristic of DC spindle motors vary from the speed torque characteristic of servo drives.

In spindle drives, the power delivered by the motor is of more importance than the uniform torque.

In DC spindle motors the power available to the spindle shaft varies linearly from zero to motor base speed where speed control is achieved by varying the armature voltage.

For speed range above base speed the field current is decreased to achieve the desired speed. In this region the power available to the spindle is the rated power, but the available torque decreases due to decreased field current. The field current can be decreased up to maximum speed of the motor after which the motor stalls.

3.6 FEEDBACK TRANSDUCERS:

Transducers convert one form of energy to another form. In closed loop control systems, transducers are required to get actual feed back of the controlled parameters like speed, position etc. following are the major transducers used in the closed loop position control system.

3.6.1 TACHO GENERATOR:

This is used to obtain the actual speed feed back of the driver motor. This is a small generator mounted on the shaft of the motor and generates a voltage corresponding to the speed of the motor.

3.6.2 ENCODERS:

Encoders are used for position feed back. These are devices, which give a fixed number of pulses for every rotation of the encoder shaft. The encoder is mounted on the ball screw and encoder pulses are fed as position feed back into CNC.

CNC has a fixed resolution of one microns and counts to incoming number of pulses to calculate the distance covered.

If resolution other than one micron is required, a parameter in CNC called 'Scaling factor' can be adjusted. This setting is used by the CNC as a factor by which the incoming encoder pulses are multiplied. So, if this factor is set as say 0.5 total number of in every revolution of the encoder shaft.

3.7 OPERATOR CONTROL PANEL:

The operator control panel provides the user interface to facilitate a two-way communication between the users, CNC system and the machine tool. This consists of two parts

- ❖ Video display unit
- ❖ Keyboard

3.7.1 VIDEO DISPLAY UNIT:

The VDU displays the status of the various parameters of the CNC system and the machine tool. It displays all current information such as:

- Complete information on the block currently being executed.
- Actual position value, set or actual difference between current speed rate and spindle speed.
- Active G functions, miscellaneous function.
- Main program number, subroutine number.
- Display of all entered data, user program, user data, machine data etc. alarm message in plain text
- Soft key designations.

3.7.2 KEY BOARD:

Keyboard is provided for the following purposes.

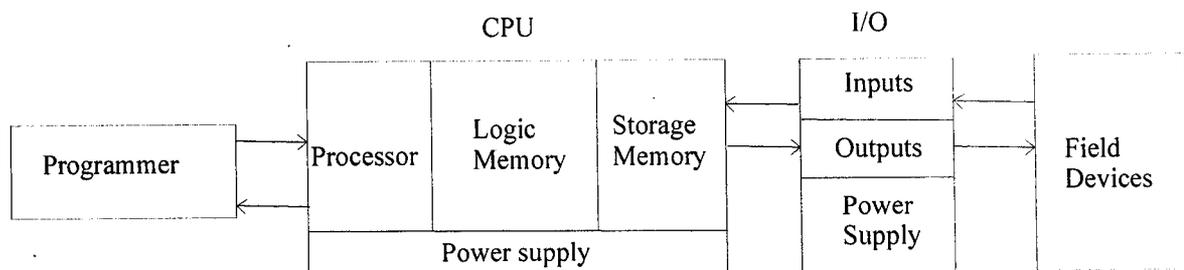
- ❖ Editing of part programs, tool data, machine parameters
- ❖ Selecting of different pages for viewing
- ❖ Selection of operating modes, e.g. manual data input, jog, etc
- ❖ Selection of feed rate override and spindle speed override
- ❖ Execution of part programs
- ❖ Execution of other tool functions

3.8 PROGRAMMABLE LOGIC CONTROLLERS:



A PLC matches the NC to the machine. PLCs were basically introduced as replacement for hard-wired relay control panels. They were developed to be re-programmed without hardware changes when requirements were altered and thus are re-usable. PLCs are now available with increased functions, more memory and larger input/output capabilities.

In the CPU, all the decisions are made relative to controlling a machine or a process. The CPU receives input data, performs logical decisions based upon stored programs and drives the outputs. Connections to a computer for hierarchical control are done via the CPU.



The I/O structure of PLCs is one of their major strengths. The inputs can be push buttons, limit switches, relay contacts, analog sensors, selector switches, thumb wheel switches, proximity sensors, pressure switches, float switches, etc. the output

can be motor starters, solenoid valves, position valves, relay coils, indicator lights, LED displays, etc.

The field devices are typically selected, supplied and installed by the machine tool builder or the end user. The type of I/O is thus normally determined by the voltage level of the field devices. So, power to actuate these devices must also be supplied external to the PLC. The PLC power supply is designated and rated only to operate the internal portions of the I/O structures, and not the field devices. A wide variety of voltages, current capacities and types of I/O modules are usually available.

3.9 CNC PROGRAMMING:

A set of coded information translated in to a language that can be read by the system of machine in a defined sequence of operation of a machine process of a CNC machine.

The information required to perform to desired operations are

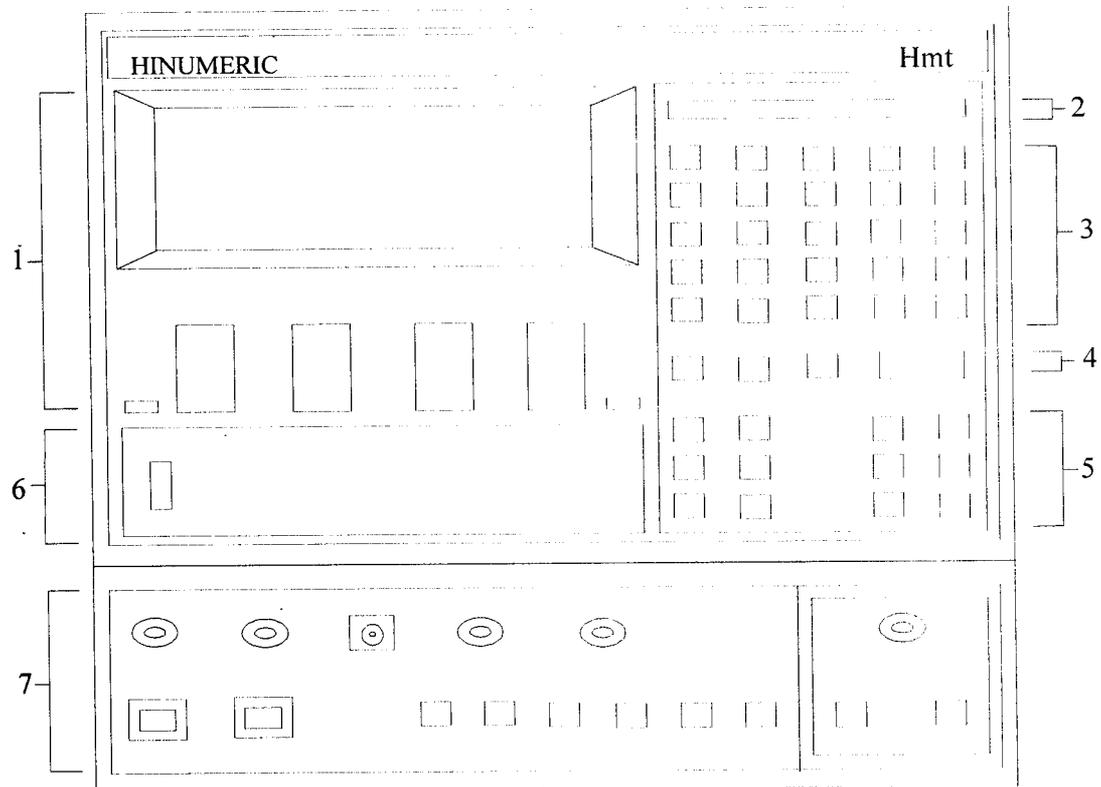
- ❖ Work piece dimensions
- ❖ Travel of tool and axis slides
- ❖ Machine sequence
- ❖ Tool selection
- ❖ Rotational speeds
- ❖ Feed rates

3.9.1 PANEL VIEWER:

The **Hinumerik 2000 (HM 2000)** is a microprocessor – controlled compact machine tool. In order to save space when mounting the control on the machine and to avoid problems when linking together various control components, the Hinumerik 2000 was designed as a compact unit where the numerical control (NC), programmable logic controller (PLC), control keyboard and monitor are integrated into a single housing.

The HM 2000 is used primarily to control machining defects and abnormal operations. The programming of this viewer can be either computer aided or manual operations.

It consists of soft keys for selecting different CRT display functions, 9" graphics screen, address/numerical keyboard and function keys, Screen displays provide information about current operating modes, set point/actual values, NC and PLC alarms etc in plain text.



Panel viewer

1. CRT DISPLAY
2. DISPLAY PANEL
3. ADDRESS/NUMERICAL KEYS
4. EDITING AND INPUT KEYS
5. CONTROL KEYS
6. BLANK PANEL WITH CONNECTOR
7. EXTERNAL MACHINE CONTROL

CHAPTER 4

PLC SYSTEM DESCRIPTION:

4.1 DEFINITION:

Programmable Logic Controller (PLC) is defined as a digital electronic device that uses programmable memory to store instruction and to implement function such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes. This is a replacement for hard-wired relay and timer logic control system. The advantage of PLC is that control system can be modified without rewiring the connections in the input/output and is achieved by changing program instruction. PLCs are similar to computer but have certain features.

- They are rugged in design to withstand vibrations, temperature and noise.
- Interfacing for inputs and outputs are inside the controller.
- They can be easily programmed in an easily understood language.

The programmable Controller offers solid – state reliability, lower power consumption and ease of expandability.

Overall a Programmable Logic Controller is a mini computer specifically designed for industrial and other applications.

4.2 SEQUENTIAL LOGIC CONTROL SYSTEM:

In a sequential logic control system, the control point is automatically adjusted to follow a predetermined pattern with respect to time and process conditions. In this system, a PLC is used to automate adjustments of analogue set points, as well as the check and inhibit actions of interlock logic. The synchronized starts and stops of process equipment are also completely automated. This system bridges the gap between mechanical programmers and process computers.

The sequential logic control program is designed with an easily understood ladder logic language. The logic operations is created by pushbuttons, without wiring and stored in the memory of a PLC. This PLC is capable of operating several completely independent process units at the same time.

In addition to start-ups and shutdowns of continuous processes, batch processes are also controlled by PLC,s. a stored program is used to repeat all the events in an operation step by step, throughout a production cycle. The program elements consist of on/off relay logic, time delay and elapsed-time periods, predetermined counts of pulses and pulsed outputs for set point control.

To ensure that all data received by the PLC is correct, various checks are continuously executed and a failure of any of these will cause the PLC to trip.

Sequential logic control systems are best suited to improve a variety of applications including process control, material handling, energy management, machine monitoring and data gathering and reporting.

4.3 PLC ARCHITECTURE:

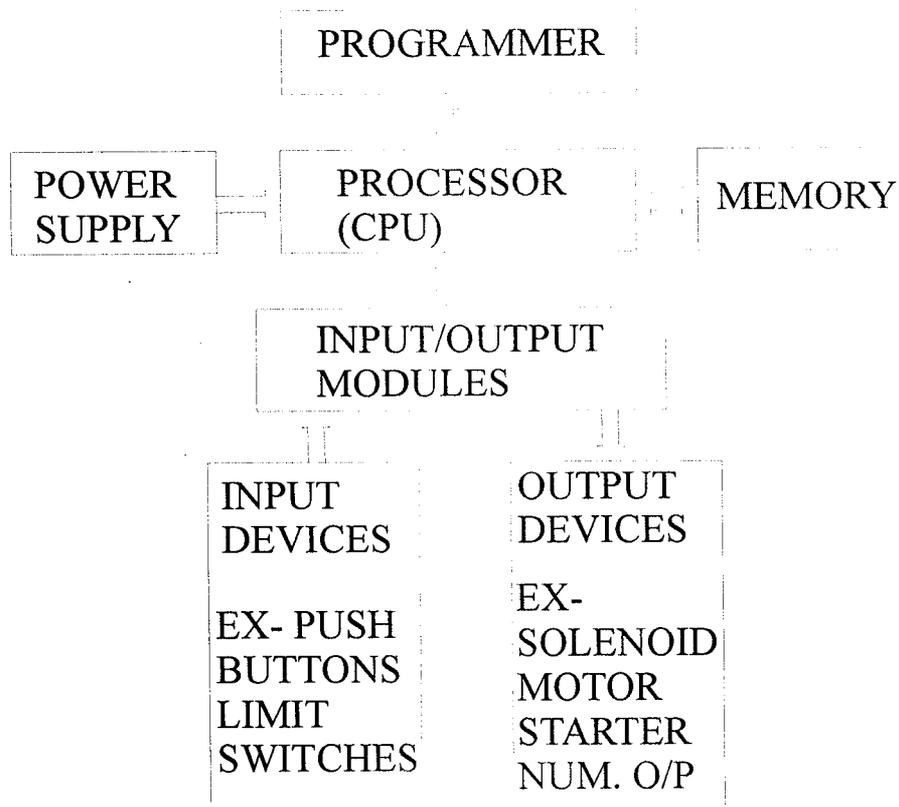
Generally PLC's are manufactured by different manufacturers have various levels of capabilities and complexities. Architecture of a typical PLC system shown in Fig. It essentially consists of memory, a processor, a programmer, a power supply, input/output modules and input/output devices.

4.3.1 Memory:

Memory of a PLC is the storage area, which is used to hold the program to be executed by the processor. It stores information until it is needed. It is passive in that it merely receives data, stores it and gives it on demand. A memory device must be extremely immune to noise, versatile and economical. The size of PLC's memory is function of inputs and outputs to be controlled.

The basic unit of storage within memory is called a word. Memory sizes are usually expressed as multiples of 1024 words, for example 1k, 2k 4k and so on, where k equals 1024. The memory capacity required in a PLC should be carefully selected after evaluating present and future needs. Some PLC's use a portion of the memory for 'executive program', which reduces the available memory for the control program. The number of words of memory used per contract varies in different models of PLC of different manufacturers. This should be checked before selecting a particular memory size.

An important concept in the operation of a PLC is 'memory scan'. The time from solving any individual network on one scan until that network is again solved on the next scan is defined as the scan time of the memory. It depends upon the complexity of the programmed logic and memory size.



Some manufacturers offer 'scratch pad' or 'trial' read/write memories in addition to main memory in their PLC's. These enable the programmer to make changes, add or delete from the program. Debug the program and then transfer it to the main memory. An additional feature of some PLC's is 'memory protect', where a key interlock is provided to prevent unauthorized tampering with the stored program.

Digital data is passed around through buses. The buses were originally 4 parallel lines but as technology progressed this became 8, then 16 and now 32. The buses are connected to memory chips. In a memory chip, digital numbers are stored in locations. The number is the data and the locations by either writing it or reading. The lines labeled Read and Write are a signal line that makes the CPU read or write.

A REGISTER is a temporary memory location where data is put to be manipulated and then taken away. The CLOCK line is pulsed at a regular rate to synchronize the operations. Currently this has reached a rate measure in Giga Hertz (1000 million times a second).

The Reset line when activated resets the program counter to zero. The operations are carried out to a set of instruction (the program) and these are decoded in the ID (instruction Decoder).

4.3.2 Processor or CPU:

The processor is the heart of a PLC. It receives instructions from the memory and generates commands to the output modules. Input commands, device status and instructions are converted to logic signals. These logic signals are then processed by the processor. Available PLC's are based on various microprocessor chips, which are preprogrammed with a main 'executive program'. The executive program enables the processor to understand input command instructions and status signals, besides providing logic processing capability. These capabilities include simple AND, OR, Logic, Timing, Sequencing, Routing, Counting, Arithmetic functions, Decision marking, Manipulation and Structuring of data in arrays.

The signals generated by the processor are used either to turn on/of heaters, solenoid valves, motors and other loads, lights of communication displays or to adjust set points of analogue controllers. The processor solves each network of interconnected logic elements in their numerical sequence in the order in which these are programmed. The first network is scanned from the time the power is applied, first from top left to bottom left, and then continuing to the next vertical column to right. Within a network, the logic elements are solved during the scan and then the coils are appropriately energized or de-energized to complete the scan. Since the scanning rate is of the order of a few milliseconds, all logic appears to get solved simultaneously. The result of each network scan is then available to all subsequent networks. Thus, all inputs and outputs are updated once per scan. To communicate these inputs and output signals, storage registers act as bridges between the signals at field levels and the high speed circuit of the processor.

The information stored in the memory relates to the way the input and output data should be processed.

The complexity of the control plan determines the amount of memory required. Most PLC memories are expandable in fixed increments.

Memory elements store individual pieces of information called bits. These elements are mounted on printed circuit boards.

PLC memory capacity may vary from less than 100 bits to over 48k bits.

The actual control program is held within electronic memory storage components such as RAM and E2PROM.

The most popular ROM used in PLC's today is ultra violet programmable read only memory.

The most common R/W memory used in PLC's magnetic core. The main advantages of the core memory is that it can be easily altered which is especially useful when program variables such as set points must be changed several times a work shift, day or week.

4.3.3 Programmer:

The programmer transforms the control scheme into useful PLC logic. The logic program is then stored in memory, where it is made available to the processor for logic operations.

Various types of programmers are available from PLC manufacturers. LCD and CRT programmers are very popular. Programs can also be stored on cassette tape and loaded into the PLC through a special interface unit. A PLC can also be hooked up to a central computer for programming. Some PLC manufacturers offer factory written programs, which can be loaded into the PLC via a telephone interface.

4.3.3.1 LCD Programmer:

It is compact and light weight for convenience in testing and for maintenance. It has the following functions: (i) programming, adding, deleting and altering; (ii) supervising; (iii) readout; (iv) simulation; (v) debugging; (vi) storing and readout of program; and (vii) recording, loading and verifying the program.

4.3.3.2 CRT Programmer:

Many sophisticated programmers based on a portable CRT console have been developed for PLC's. A CRT programmer has the following; (i) programming, adding, deleting and altering; (ii) monitoring; (iii) simulation; (iv) search; (v) fault diagnosis; (vi) program printout; (vii) off-line programming; and (viii) loading, dumping and verification of the program.

Special back lighted keys with contact coil and engraved branch symbols make program entry straightforward. With these programmers, one or more rung can be displayed at a time, providing the designer with the picture of the ladder diagram off-line programming allows the designer to make corrections to the program without turning off the PLC.

4.3.4 Power Supply:

Power supply is one of the most important factors in determining the long term reliability of the PLC. For safe and reliable operation of a PLC, uninterrupted power virtually free of frequency excursions and voltage dips, surges and transients is essential. Failure of power supply can have effects varying from inconvenience to catastrophic breakdown of equipment. Excessively large voltage impulses or noise burs and inadequate filtering may result in component voltage overstress or in the premature triggering of control circuit elements.

Power supply is an integral part of the PLC and is generally mounted in the mainframe enclosure. Line power at 230v, 50Hz or 115v, 50Hz is converted to the appropriate DC voltages required by the solid-state circuitry and memory. It is designed to operate both the processor and the basic number of inputs and output. For expanded inputs/output, an additional heavy-duty power supply is usually required.

The power supply is generally designed for a controlled 'power down' sequence in case line power is lost. In this case the processor stops solving logic and retains the status of all coils, inputs, outputs and registers. The outputs are all turned off. This eliminates the possibility of failure in an undetermined mode. In the 'power-up' sequence, the stored inputs, outputs, status of coils and registers are checked and only then the memory scan sequence is started. The over-rated types tend to be extravagant in the use of high current rated semiconductors.

4.3.5 Input/Output Interface:

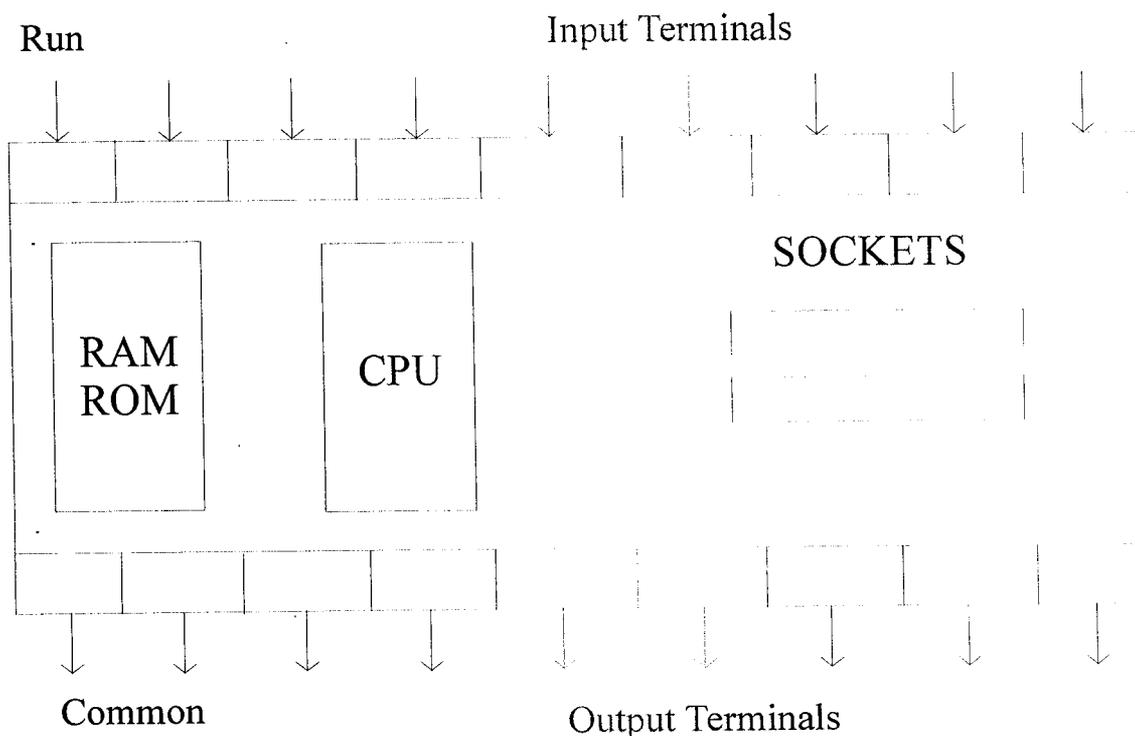
The input module performs four tasks electronically. First, it senses the presence or absence of an input signal at each of its input terminals. The input signal tells what switch, sensor or other signal is on or off in the process being controlled.

Second, it converts the input signal from a high to a DC level usable by the module's electronic circuit. For a low or off input signal, no signal is converted indicating off.

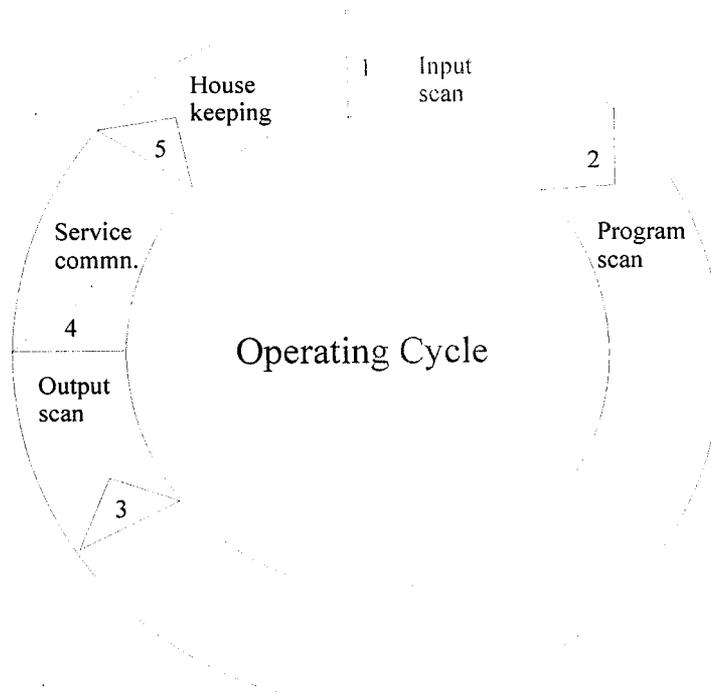
Third, the input module carries out electronic isolation by electronically isolating the input module output from its input.

Finally, its electronic circuit must produce an output to be sensed by the PLC CPU.

A typical input module has 4, 6, 8, 12, 16, 32 terminals, plus common and safely ground terminals are shown in the fig.



4.4 OPERATING CYCLE:



INPUT SCAN – The time required for the controller to scan and read all input data; typically accomplished within microseconds.

PROGRAM SCAN – The time required for the processor to execute the instructions in the program. The program scan time varies depending on the instructions used and each instruction's status during the scan time.

SERVICE COMMUNICATIONS – The part of the operating cycle in which communication takes place with other devices, such as an HHP or personal computer.

HOUSEKEEPING AND OVERHEAD – Time spent on memory management and updating timers and internal registers.

You enter a logic program into the controller using a programming device. The logic program is based on your electrical relay print diagrams. It contains instructions that direct of your application.

4.4.1 OPERATION OF PLC:

Microprocessor is a term that has become common in our everybody life. The programmable controller is all controlled by one or more internal Microprocessor. Although a microprocessor can be very complex devices, the fundamentals needed to program. Operates, and troubleshoot a PLC based system are easy to understand.

Using PLC is very similar. There is a microprocessor in the form of a integrated circuit chip, and other supporting chips mounted on a printed circuit board. These chips make up the CPU. The microprocessor and its supporting chips make this is a digital computer. By changing the program, we can instruct the PLC to make a different product. This is very similar to playing a different video game by simply changing a cartridge.

Basic of a PLC function is continual scanning of a program. The scanning process involves three basic steps.

Step 1:

Testing input status: First the PLC checks each of its input to see which one has status on or off. In other words, it checks whether a switch or a sensor etc., is activated or not. The information that the processor thus obtains through this step is stored in memory in order to be used in the following steps.

Step 2:

Programming execution: Here a PLC executes a program instruction by instruction based on the program and based on the status of the input has obtained in the preceding step, and appropriate action is taken. The action might be activation of certain outputs and the results can be put off and stored in memory to be retrieved later in the following step.

Step 3:

Check up and Correction of the output status: Finally, a PLC checks up output signals and adjust it has needed. Changes are performed based on the input status that had been read during the first step, and based on the result of the program execution in step 2. Following execution of step 3 PLC returns a beginning of the cycle and continually repeats these steps.

Scanning time = Time for performing step 1 + Time for performing step 2 + Time for performing step 3.

CHAPTER 5

SOFTWARE DESCRIPTION

5.1 INTRODUCTION TO PLC PROGRAMMING:

The principle of operation of a PLC is determined essentially by the PLC program memory, processor, input and outputs. The program that determines PLC operation is stored in the internal PLC program memory. The PLC operates cyclically i.e., when a complete program has been scanned it starts again at the beginning of the program. At the beginning of each cycle, the processor examines the signal status at all inputs as well as the external timers and counters are stored.

To execute the program, the processor fetches one statement after another from the program memory and executes it. The results are constantly stored during the cycle. At the end of a scanning cycle, i.e. program completion, the processor transfers the content of the process image output to the output modules and to the external timers and counters. The processor then begins a new program scan.

The PLC can be programmed by means of direct logic and step 5. In our application we are using step 5 programming.

Step 5 programming language is used for writing user programs for Siematic S5 programmable controllers. The meaning for the obscure notation S5 is nothing but design of a program in five steps. The steps involved are:

- S1** : The process elements are represented schematically.
- S2** : The input/output signals are listed and given symbolic names.
- S3** : The control sequence with its conditions and action is represented.
- S4** : The data block is set up.
- S5** : The blocks of the program are programmed in STL.

This Step 5 programming language can be represented in three ways:

- Ladder diagram (LAD)
- Control System Flow Chart (CSF)
- Statement List (STL)

5.1.1 LADDER DIAGRAM (LAD):

Features:

A number of relays can be grouped together to form a register, which can provide storage area for a series sequence of individual bits .

A function, which is often provided with PLCs, is the conditional jump function. The function enables programs to be designed so that if a certain condition exists then a section of the program is jumped.

Besides, PLC can be used for data movement, data comparison, and arithmetic operation and code conversion.

The following are the factors to be considered in selection of PLC.

- Number of inputs & outputs.
- Type of inputs-signal conditioning required or not.
- Size of memory required.
- Speed of CPU required.
- Power required program steps required.
- Any other special feature.

5.1.2 CONTROL SYSTEM FLOW CHART (CSF)

The control system flow chart is a graphical representation of the automation task.

5.1.3 STATEMENT LIST (STL)

The statement list describes the automation task by means of mnemonic function designation. In the statement list (STL) method of representation , a statement is typed in per line in either absolute or symbolic form .The format to be followed in STL is operations should be in the followed by operands .The command line is optional but it will be useful during troubleshooting.

Reasons behind using statement list is,

- It is easier to understand since it is in list form
- It requires small amount of memory space in PLC than other types
- User Friendly Instruction Sets
- Viewing of more number of lines in a single screen is possible with STL but not in other types. It will be immensely useful during troubleshooting

5.2 Latching :

There are often situations, where it is necessary to hold the coil energized even when in that energizes it ceases .The phenomenon is called latching .The circuit used for latching.

In this case, initially output is energized by energizing input. However when there is an output, asset of contacts associated with output is energized and closed .Even if input contact is open output will continue to get supply for another set of contacts. The output can be brought to normal function but opening normally closed contact. (input 2)

5.3 Sequencing:

In situations where sequence of outputs is required, switch from one output motive controls motion to other output. For example, consider a hydraulic shaper, where the tam is subjected forward and reverse stroke actuated by forward and reverse motion of hydraulic cylinder.

This consists a direction control solenoid valve which has solenoids A+ & B+ to control direction of motion of pistons of cylinder. For example, by actuation of solenoid A+ the piston moves in the direction of A and by solenoid B+, it moves in opposite direction B .The solenoids can be made actuated by limit switches A & B located at the end of stroke

Timers :

A timer circuit is specified by stating the interval to be timed and the conditions or events that are to start and/of stop the timer. These timers are relays with coils, which are energized, resulting in opening or closing of input contacts after per-set time. Timers can be linked to form effects of cascading, ON, OFF or delay OFF.

Internal Relays:

Internal relays built-up inside PLC are not actual relays but simulations by the software of PLC. These internal relays are used when there are programs with multiple input conditions.

Counters:

Counters are use when there is a need to count a specified number of contact operations as in number of boxes passing through a conveyer at a time interval. Counter as down counter i.e. Starts counting are descending order from a preset value.

5.4 PLC PROGRAMMING:**5.4.1 Structured Programming:**

The user program can be made more manageable and straight forward if it is broken down into related sections. Various software block types are available for construction the user program.

Program blocks (PB) contain the user program broken down into technologically or functionally related sections (e.g., program block for transportation, monitoring, etc.) Further blocks, such as program blocks or function blocks can be called from a PB.

In addition, special OBs can be programmed by the user to react to interruptions during cyclic program processing. Such an interrupt can be triggered by a monitoring function if one or several monitored events occur.

Function blocks (FB) are blocks with programs for recurrent and usually complex functions. In addition to the basic operations, the user has an extended operation set at his disposal for developing function blocks. The program in a function block is usually not written with absolute operands but with symbolic operands. This enables a function block to be used several times over with different absolute operands.

For even more complex functions, standard function blocks are available from a program library. Such FBs are available, e.g., for individual controls, sequence controls, messages, arithmetic functions, two-step control loops, operator communication, listing etc, these standard FBs for complex functions can be linked into the user program just like user-written FBs simply by means of a call along with the relevant parameters.

The Sequence blocks (SB) contain the step-enabling conditions, monitoring times and output conditions for the current step in a sequence cascade. Sequence blocks are employed, for example, to organize the sequence cascade in communication with a standard FB.

5.4.2 Interrupt Driven Program Processing:

When certain input signal changes occur, cyclic processing is interrupted at the next block boundary and an OB assigned to this event is started. The user can formulate his response program to this interrupt in the OB. The cyclic program execution is then resumed from the point at which it was interrupted.

Time Controlled Program Execution:

Certain OBs are executed at predetermined time intervals (e.g., over 100ms, 200ms, 500ms, 1s, 2s or 5s). For this purpose, cyclic program execution is interrupted at a block boundary and resumed again at this point, once the relevant OB has been executed. The organization and execution of a structured use program.

5.5 Steps to Write a PLC Program:

Before attempting to write a PLC program, first go through the instruction set of the particular language used for the equipment and understand the meaning of each instruction. Then study how to use these instructions in the program (through illustration examples given in the manual). Once the familiarization task is over and then starts writing the program.

Follow the following steps to write a PLC program.

- List down each individual element (field device) on the machine as Input/Output.
- Indicate against each element the respective address as identified during electrical interfacing of these elements with the PLC.
- Break down the complete machine auxiliary functions which are controlled by the PLC into individual, self contained functions.
 - Identity each individual function as separate block (PBxx/FBxx).
 - Once the PBs/FBs for each function are identified, take them one by one for writing the programs.
 - List down the preconditions required for the particular function separately.
 - List down the respective elements available on the machine.
 - Note down the address of the listed elements.
 - Write down the flow chart for the function.
 - Translate the flow chart into PLC program using the instructions already familiarized.
 - Complete the program translation of all individual functions in similar lines.
 - Check the individual blocks independently and correct the program to get the required results.
 - Organize all the program blocks in the organization block depending upon the sequence in which they are supposed to be executed as per the main machine function flow chart.

5.6 PROGRAMMING MODEL:

The VIKING CNC provides Inputs, Outputs, Miscellaneous functions, Markers, Special functions (Window markers), Counters and Timers for PLC execution. The instructions have a specified range of operation. The inputs, outputs markers, M-functions and Special functions have a bit area in the range 0-123. The timers and counters are represented in 16-bit words. Some of the special functions are updated by the CNC, so care to be taken in using the above functions.

➤ Digital Inputs

- The CNC supports 128 inputs in the system for PLC execution. The provision can be accommodated in 4 output cards of 32 outputs each.
- The CNC supports 4 jog inputs (used only with ANC keyboard).

➤ Digital Outputs

- The CNC supports 128 inputs in the system for PLC execution. The provision can be accommodated in 4 output cards of 32 outputs each. The details are provided in CNC output data.

➤ Markers

- The markers are used by PLC for storing intermediate results. The CNC supports 512 markers.

➤ Miscellaneous Functions

- The M-functions 00-99 used by the CNC are decoded and stored in the M-function area of PLC.

➤ **Special Functions**

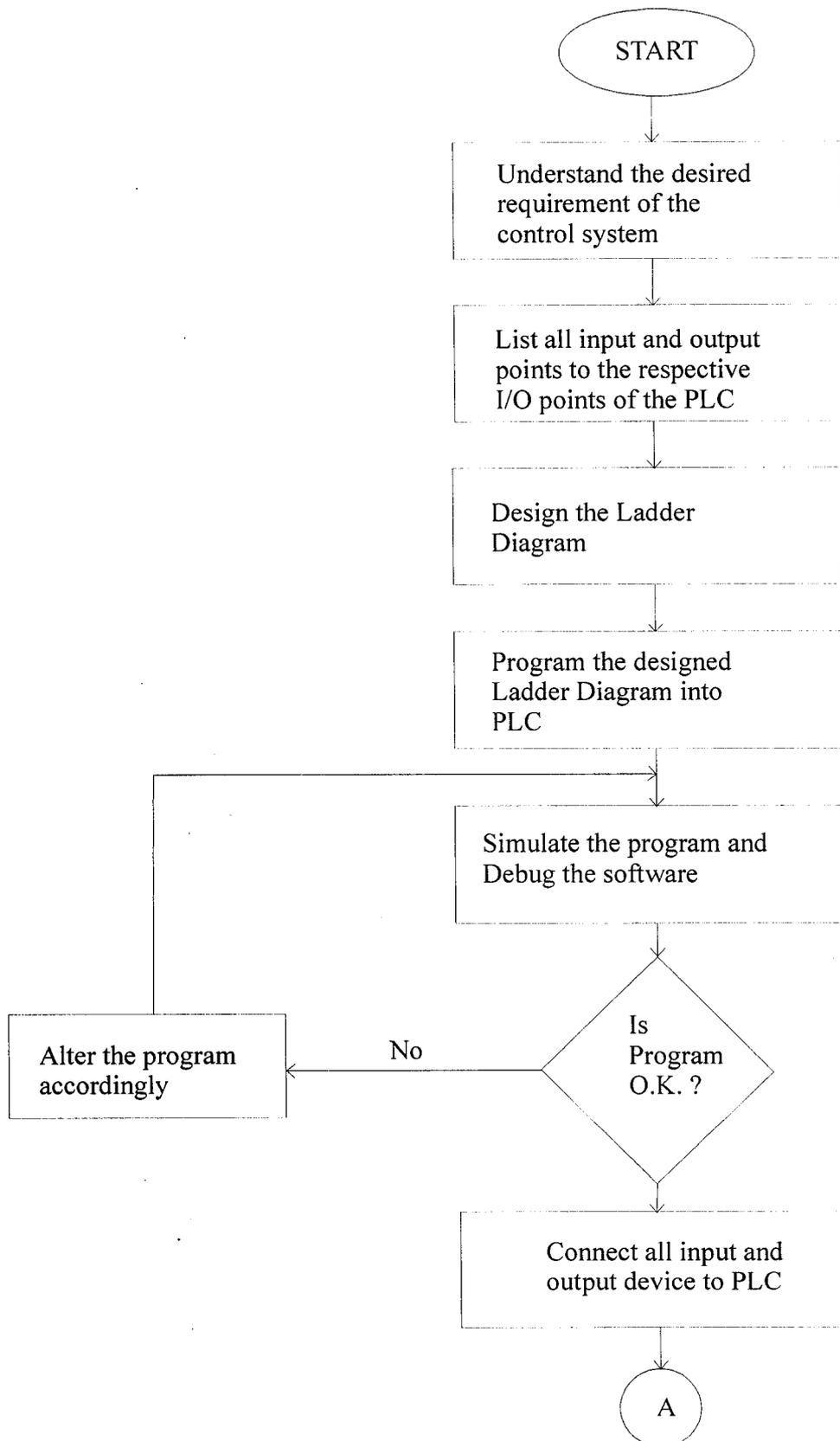
- The special function bits are the window markers (CNC=>PLC or PLC=>CNC). The special function bits are either updated by CNC to be used in PLC or they are updated in the PLC and CNC checks for the bits during the execution. Each special function bit has been assigned with a function of its own which can be used by PLC for the configuration of CNC execution. The function bits with the PLC address are listed below.

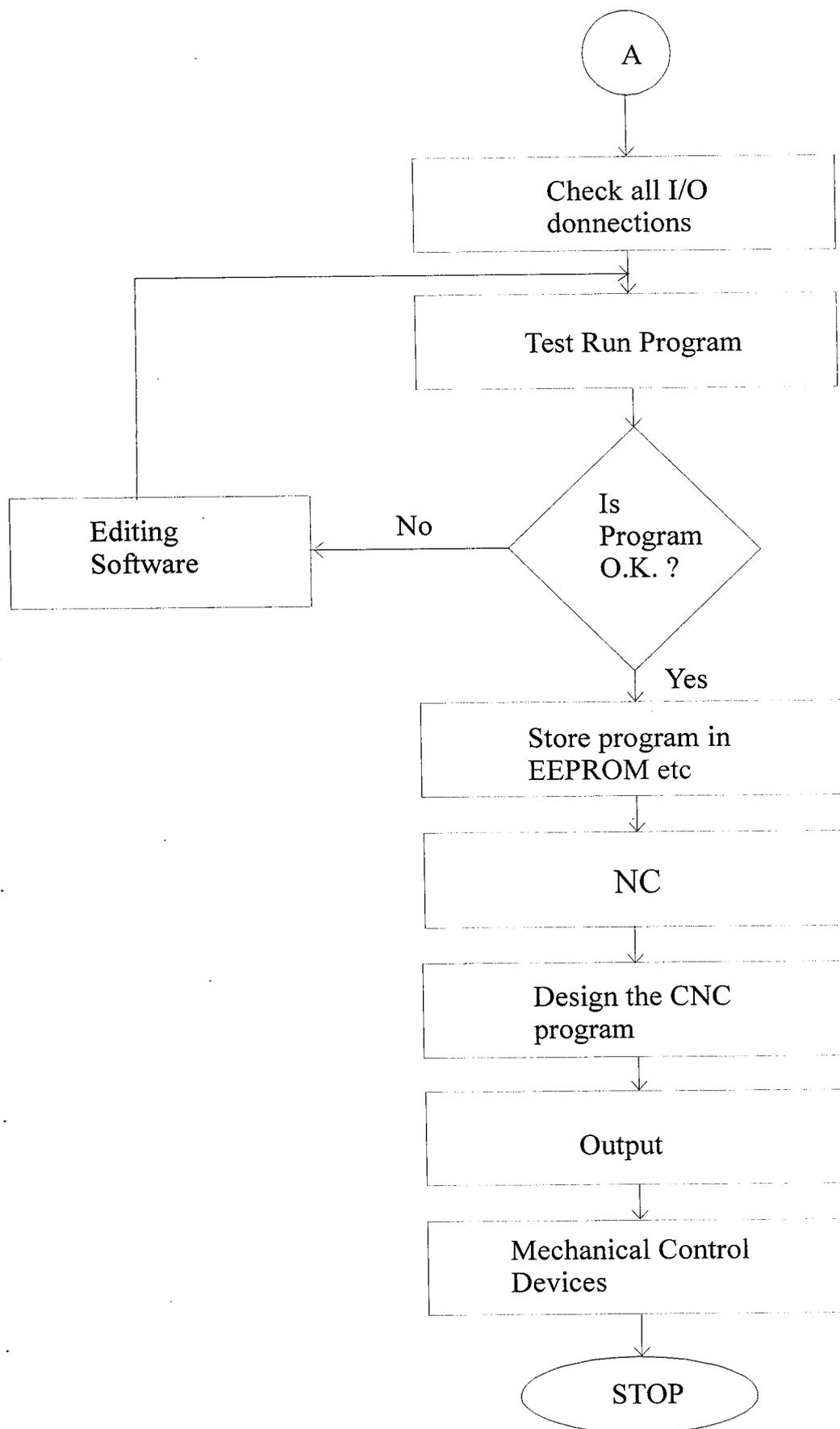
➤ **Counters**

- The CNC supports to software counters for the PLC execution. Each counter is a 16 bits word and the range is 0-65535. The counters can be loaded, decremented and compared using PLC instruction. The counters can be useful in counting the No. of times an operation is to be executed.

➤ **Timers**

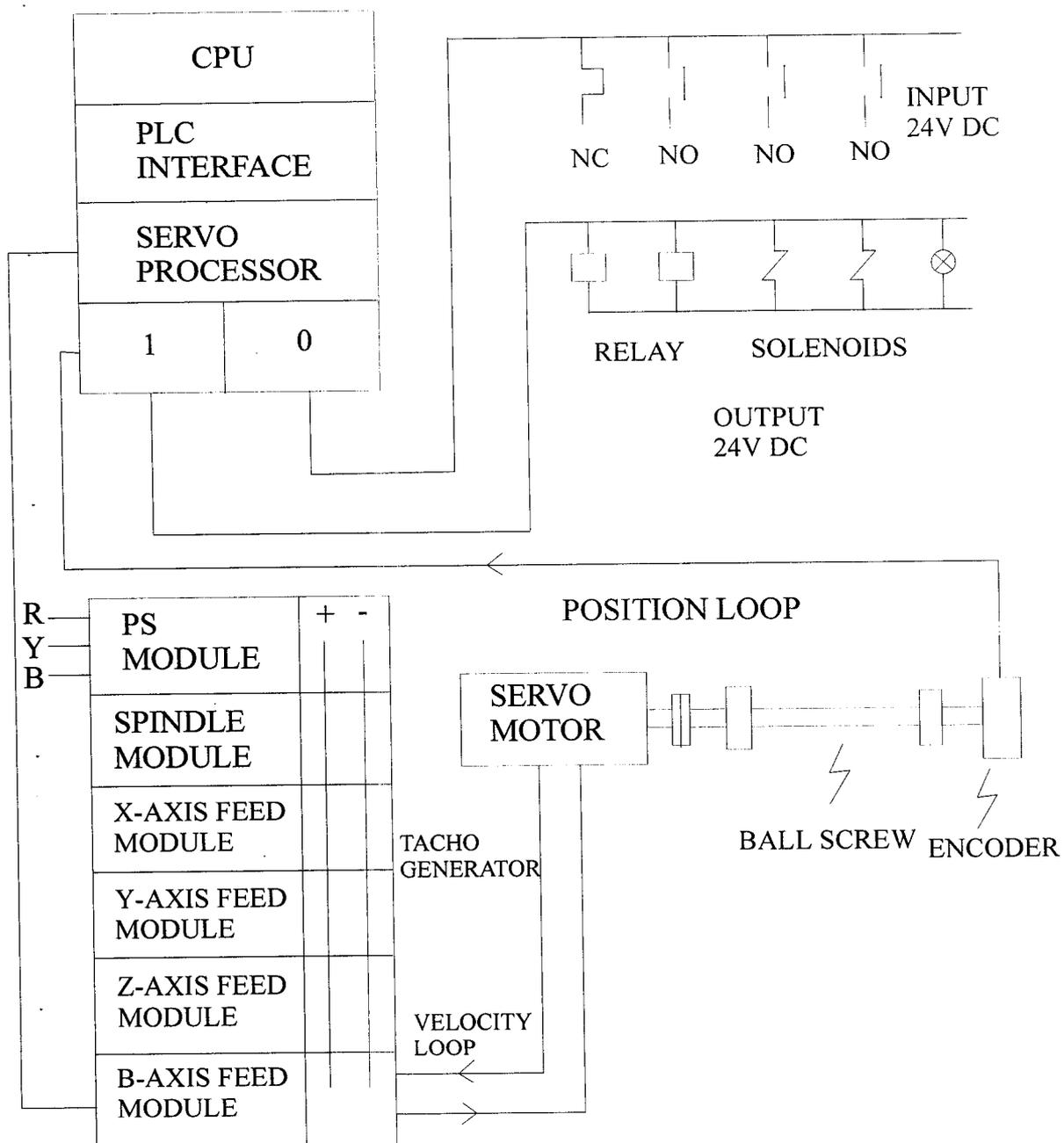
- The CNC supports 64 software timers for the PLC execution. The least, count of the timer is equipment to 10 ms, and the timer has a range of 0-65535 so the maximum time that can be programmed is 655-35 seconds. Using the timers in cascade by a suitable PLC logic the range can be increased to any level. The timers can be loaded and test for zero using PLC instructions. The timers are extensively used in the operation of tool magazine control.

5.7 SYSTEMATIC APPROACH TO PLC FLOW CHART DESIGN FOR CNC



CHAPTER 6

6.1 ADDITION OF FOURTH AXIS IN VMC-400



6.2 INTERFACING DOCUMENTS:

6.2.1 INTRODUCTION:

Interconnecting the individual elements of both the machine and the CNC system using cables and connectors is called interfacing.

Extreme care should be taken during interfacing. Proper grounding in electrical installations is most essential. This reduces the effects of interference and guards against electronic shocks to personnel. It is also essential to properly protect the electronic equipment.

Cable wire of sufficiently large cross-sectional area must be used. Even though proper grounding reduces the effect of electrical interference signal cables require additional protection. This is generally attained by using shielded cables. All the cable shields must be grounded at control only, learning the other and free. Other noise reduction techniques include using suppression devices, proper cable separation, and ferrous metal wire ways etc. Electrical enclosures should be designed to provide proper ambient conditions for the controller. Power supply to the controller should match with the supplier's specifications.

6.2.2 SPINDLE MOTOR CONNECTIONS:

Spindle indication motor is connected to power terminals provided inside the panel. The earth point of the motor is to be connected to the earth provided on the inverter unit.

6.3 Inverter Drive:

This drive can be control the speed of normal motor to obtain the speed torque characteristics of a so motor. Speed of an induction motor can be controlled only by changing the frequency of the power fed into the motor or by changing the number of poles of the motor. Inverter converts the incoming 3-phase supply to a DC bus and then converts the DC bus to 3-phase output with frequency required to obtain commanded speed. Torque is maintained by the inverter at full load torque by maintaining the output voltage/frequency ratio as constant.

6.3.1 Drive Enable:

Enable signal to the drive is provided by shorting common (CM) and forward (FWD) terminals provided in the inverter unit. This shorting is done through NO contact of drive enable relay. Switching ON of this relay is controlled by PLC. Analog input to the drive is obtained through analog enable relay. When the emergency loop trips, this relay is switched off by the PLC, to isolate CNC input and short the analog input terminals.

6.3.2 Operation of Inverter Driven AC Spindle Drive:

When INVERTER drive is interfaced with CNC the desired spindle speed can be commanded directly through program. CNC stores the applicable spindle speed ranger in each gear setting M40 to M43. In part program used can command the required spindle speed by programming the gear range and the required spindle speed in that range. CNC will issue corresponding analog signal to the drive. IN CNC part program, M03 corresponds to spindle rotation in CW. Similarly M05 corresponds to spindle off. The M-codes can be read by the PLC using window markers 259, 260 and 261.

Spindle CW Operation:

When M03 is commanded PLC read the commanded and switches on spindle analog release relay and spindle enable relay if the following conditions are met.

- Chuck is clamped
- CNC is not in edit mode
- Proper gear is selected

CNC releases analog command corresponding to the spindle speed commanded. On receiving this signal drive will run the motor in required speed using closed loop control.

Spindle CCW Operation:

This operation is same as above except for the fact that M04 is commanded instead of M03 and spindle analog command is in negative direction.

Spindle off:

M-code M05 corresponds to spindle OFF operation. When M05 is commanded CNC reduces the analog command signal to zero. Motor speed reduces. On receiving 'Spindle encoder feedback zero' input from CNC through predefined address 518 PLC switches off spindle enable and analog command enable relay.

If instead of M05, emergency loop trips, then PLC switches off the analog enable relay thereby removing the spindle analog command and shorting the analog input to the drive. Spindle now brakes preventatively to halt. Feedback to PLC is obtained through 'Spindle encoder feedback zero' input from CNC through predefined address 518. DRIVE ENABLE relay is switched off by the PLC after motor stops to de-energize the drive.

Spindle Jog:

Spindle can be jogged only in manual mode as follows. Use spindle jog rotary switch on the operator plate to select the spindle jog direction. Actuate the SP JOG push button to jog the spindle in selected direction at the speed entered in SPINDLE JOG SPEED field in machine constant page of CNC.

Spindle Gear Selection:

When AC induction motor spindle is used, as the motor speed is fixed, different spindle speeds are obtainable only through gear shifting. In the PLC, whether M40-M43 command is read, a marker is set to indicate the CNC about the current gear setting. Then PLC waits for EAS.START input pulse from the operator to indicate that the manual gear change operation is complete. Till this confirmation is obtained. CNC waits at the current block. Note that this EXT.START is the push

button provided on operator panel. Do not operate the START key on the CNC keyboard to give gear change confirmation.

In case of automatic gear changing using hydraulic solenoids PLC shall switch on appropriate output to actuate the gear change solenoids and positive feedback is obtained to ensure correct gear change operation. In case of manual gear shifting system, PLC has no positive feedback except EXE.START confirmation by the operator. So, if the operator has changed the gear to a different range than the programmed range, spindle will run at different speed as per the ratio actually selected.

6.4 HYDRAULIC CHUCK INTERFACE:

In HYDRAULIC chuck, the clamping and de-clamping jaw movement is obtained by operating a hydraulic cylinder controlled by two solenoids-one each for chuck opening and chuck closing. The hydraulic power pack is driven by a 3-phase induction motor.

Chuck operates in two modes CHUCK INTERNAL & CHUCK EXTERNAL. In internal operation, the clamping jaws move away from the job center when chuck clamp is commanded. This is used to hold jobs which are hollow. The jaws move towards the center when chuck de-clamp is commanded. When used in external clamp command will move the jaws towards the external modes of chuck operation is selected by a key switch-CHUCK INT./EXT.

Chuck Internal Operation:

Internal mode of operation is selected by selecting the CHUCK INT./EXT. key switch to INT position. This input has been wired to PLC selects proper direction of movement for the chucking jaws based on this input. External operation is selected when this input is LOW, internal chucking is selected in this input is HIGH.

Chuck CLAMP & DE-CLAMP command is given by two foot switches where are wired to PLC inputs. When chuck clamp foot switch is operated, PLC switches on the CHUCK OPEN relay which internal switches on the CHUCK OPEN solenoid.

When chuck de-clamp foot switch is operated, PLC switches on the CHUCK CLOSE relay which is turn switches on the CHUCK CLOSE solenoid. The jaws start

moving towards center. PLC is now waiting for the chuck de-clamp feedback. When chuck de-clamp pressure switch operates, PLC switches off the CHUCK CLOSE relay.

6.5 TAIL STOCK INTERFACE:

This is also called as QUILL interface. This is used to hold a between center job. Interface diagram shows interface details for the hydraulic quill.

Hydraulic Quill:

Hydraulic quill operates using a cylinder driven by two solenoids. The switching on of QUILL ON or QUILL OUT solenoid is controlled by tow relays. These relays are switched on by the QUILL IN/QUILL OUT S3 POSITION SPRING RETURN SELECTOR SWITCH. One end of these relays is connected to a PLC output. When the spindle operation is not active, these relays are enable by switching on the output by the PLC, when spindle is running, These relays are disabled by switching of the output, there by inhabiting the operation of QUILL when spindle is running.

When the selector switch is selected to QUILL OUT, sometimes a limit switch is used on the quill to limit the forward stoke. This limit switch is wired in series with the solenoid. If the limit switch is not used, put short link in place of the quill limit switch.

Quill Operation:

When QUILL IN position is selected and spindle is not operative, TAIL STOCK IN relay is switched on. This relay switches on the quill in solenoid. The solenoid is ON till the quill switch is ON. Switch returns to OFF position when not held in QUILL IN position.

6.6 CHIP CONVEYOR INTERFACE:

An Induction motor drives chip conveyor. The operation of this motor is controlled by a 3-position selector switch, which switches on a relay for CW and CCW direction. The NO contacts of this relay switch on the contractors, which control the direction of rotation of the motor.

Operation:

When the CHIP CONVEYOR CW/CCW selector switch is selected to CW direction, the motor runs in clockwise direction, driving the chip conveyor in forward direction. To stop the chip conveyor switch off the selector switch. When the CHIP CONVEYOR CW/CCW selector switch is selected to CCW direction, the motor runs in counter clockwise direction, driving the chip conveyor in reverse direction. To stop the chip conveyor switch off the selector switch.

6.7 TURRET INTERFACE:

Tool turrets are used for automatic tool changeover in CNC machines. These can be electro mechanically actuated or hydraulically operated. Interface diagram contains interface details for BTP turret. PLC ladder contains logic for the BTP turrets. The panel the turret to be chosen is indicated by a short link to PLC input for BTP turrets.

BTP Turret Interface:

BTP turret is a bi-directional 8-station tool turret. It consists of a 3-phase induction motor, which drives the tool disc in CW or CCW direction depending on the direction of rotation of the motor. Tool position feedback is obtained by a BCD encoder. Clamp signal is obtained by a proximity switch strobe signal and parity signals are obtained from the encoder. Turret also contains a thermal switch which operates when the turret motor overheats.

Turret Connection:

The turret motor 3-phase connection and turret thermal is connected to the junction box using TURRET POWER cable. Connection from the turret feedback signals to junction box is established using TURRET SIGNAL cable. Connection from junction box to panel is established by 37pin round shell connector and 1pin round shell connector cables running from junction box to panel.

Turret Operation:

When a tool is commanded is CNC M06 has to be commanded to indicate the CNC to automatically move the Turret to root changeover position. OLC reads the M06 command in marker 262 and switches on a timer. After the timer has counted, PLC checks for INPOSITION signal at address 512. This timer is required to confirm the PLC that tool changeover position starts indexing. PLC determines the direction of rotation of the turret depending on window markers 928 and 929 and switches on CW/CCW relay along with SSR (Solid State Relay). CNC monitors feedback from the turret and also strobe input to update window marker 904. PLC monitor the window marker 904 (Tool command = Tool feedback) to switch off turret motor after receiving clamp signal. The clamp signal received.

If the tool commanded is not a valid tool CNC displays the message NO SUCH TOOL. If tool commanded is the tool already exiting on turret PLC displays a message TOOL CALLED IN POSITION.

Power On Turret Clamp:

On reset of the machine if the turret is not in clamped condition. PLC execute a routine called POWER ON TURRET CLAMP to clamp the turret to next immediate tool before any further operation can be done. If turret to next immediate tool before any further operation can be done. If turret cannot be clamped within one second after machine reset, machine trips with INDEX FAIL. A marker is set in the PLC to indicate power on turret clamp condition, which is active till the next power off of the machine.

CHAPTER 7

AC SERVO DRIVES

7.1 Construction of the Three Phase Servo Drive System

The AC servo drive system consists of the supply module and the servo drive units. The supply module is capable of supplying several servo drive units of different power rating. The programming module matches the servo drive units precisely to the particular drive application. It provides easy servicing. For special applications the capacity of the servo drive system can be further increased by adding additional bleeder additional capacitance i.e., by add-on-modules.

The three phase, 440V, AC supply from the incoming power feed through autotransformer (DTS) shown in the figure (b) is converted to a DC supply of two wires. This is given to the servo drive module. Which is inverted to three phase AC supply of desired values which is needed to the feed motor?

The signal processing unit provides several voltages like $\pm 5V$ DC, $\pm 15V$ DC, $\pm 24V$ DC to the required units. Controller enable. Speed set point is the input devices of PLC and Ready for operation and drive torque are the output devices of PLC.

Thus a drive system consists of a common power supply unit supplying to one or more AC servo amplifiers, which control the respective motors. The power supply contains an uncontrollable rectifier, filter capacitor, bleeder circuit and auxiliary/protection circuits. Insulated Gate Bipolar Transistor (IGBT) operates at a high Pulse with Modulation frequency is used in the servo amplifier unit. The control circuit obtains rotor position and velocity information from the rotor position encoder and brushless tacho generator. Based on these signals and the velocity reference signal the control circuit controls the three phase current.

7.2 Principle of Operation

The supply module generates the intermediate DC voltage from the input AC voltage. The servo drive module develops in this three-phase system with amplitude. Frequency and phase relationship control. This is applied to the AC servomotor in accordance with the actual rotor position and the desired speed.

The relationship between the regulated three phase system and regulated operating conditions of the servomotor is established in accordance with the following criteria.

7.2.1 Torque

Together with the field of the rotor, which is excited by a permanent magnet, the current amplitude of the three phase system in the stator of the servomotor determines the torque produced. This current amplitude originates from the control derivation of the speed regulator.

7.2.2 Speed

The frequency of the three-phase system determines the speed of the servomotor. Conditional upon the required synchronism between the position of the rotor magnetic field and the position of the stator current, the rotor position and the rotor frequency are derived from the signals of the rotor position transmitter BLC signals.

7.3 Control Circuit for Signal Processing

It consists of servo motor and servo drive module. The stator of the motor is connected in delta, where the supply is given. Rotor shaft is connected to rotor position detector and brushless tacho. Speed regulator compares set point and actual value of speed.

The output of brushless tacho is the actual speed in terms of voltage. The speed regulator gives the error in speed, which will be in the form of current. It generates the current set point, which is fed to current direction controller through a limiter circuit. Depending upon the rotor position, the current direction for the three-phase stator winding is controlled. The resulting current flow in the stator controls the magnetic flux in the rotor. Torque is directly proportional to the stator current of the motor. Motor current is controlled by current regulator. This is linked to current direction controller to regulate the current in the three-phase stator winding. The output signal of the regulator is given to PWM circuit and amplified by a driver stage. These amplified signals are given to power transistor circuits and controls the three-phase system.

DIGITAL AC DRIVES

7.4 Introduction

Two significant developments that have transformed the entire drive technology into new era are

Development of Power Transistors / GTOs.

Use of Microprocessors in Control Systems.

Use of power transistors of GTOs is rating dependent transistors upto about 300Kw and GTOs for larger rating, even up to MW range. However, microprocessor based control is more universal irrespective of rating of the device.

7.5 Construction of AC Drives System

The scope of standard converter is shown in figure. Power transistors permit high switching frequencies, high efficiency & optimum operating characteristics. Converter provides the motor with a variable voltage three-phase ac system. This is achieved in two steps using line side converter and load side inverter. The line side converter rectifies the line voltage in the DC link is smoothened by capacitors. The inverter section on motor side generates three-phase variable frequency variable voltage system from dc voltage.

7.5.1 Mode of Operation

The inverter consists of three phased, each of the phased is made up of two series connected power transistor and diodes in an anti parallel connection. The inverter phases represent electronic switches so that output terminals of the converters are alternately connected to the positive and negative potential of the dc link voltage. There are eight different combinations of switching states, whose effect on motor is described by voltage phasors. The motor terminal voltage in the first compination defines a voltage in R Phase. The length of the voltage phasor is determined by the magnitude of the dc link voltage. When switching from first combination to the second one, the voltage phasor advances by 60 degree. The length of the voltage phasor remains unchanged.

7.5.2 Variable Voltage Generation in a PWM Inverter

Variable output voltage is obtained by varying the gain of the inverter which is accomplished by pulse width modulation control within the inverter. Inverter gain is the ratio of ac output voltage to the dc input voltage. By varying the inverter gain, we can get variable ac voltage. PWM inverters can be designed using IGBTs or GTOs.

The advantages of using power transistors are,

High Efficiency

Low Noise

Small Space Requirements

It can be easily turned off

Converter can be over loaded by 50% of rated power for 60 seconds

The carrier and reference waves are mixed in a comparator. When sinusoidal reference wave has magnitude higher than the triangular carrier wave, the comparator output is high. The comparator output is processed in a trigger pulse generator in such a manner that the output voltage wave on the inverter has a pulse width in agreement with the comparator output pulse width.

The pulse patterns for controlling the inverter are generated by the microprocessor in gating module. The pulse patterns are selected which ensure optimum operation with almost sinusoidal motor current and minimal losses over the complete converter control range. Varying the ratio of ON times of adjacent voltage phasors controls the phase angle of the voltage. The amplitude of voltage is obtained by varying width of zero voltage intervals. Therefore, the signals controlling the inverter phases allow the voltage as well as frequency to be continually adjusted from zero to rated or maximum values.

7.5.3 Microprocessor Control

Microprocessor technology provides the advantage of increased accuracy, precise adjustability and reproducibility of set points and control parameters. Control variables are no longer adjusted using potentiometers but are adjusted using parameters.

The open and closed loop control includes among other things.

Four selectable data sets of characteristics with adjustable set points, ramp-up and ramp-down times, torque limiting, voltage / frequency characteristics etc.

Self-optimization of the drive closed loop control. i.e. automotive and error free adjustment of all closed loop control parameters using an automatically executed measuring and test program. This significantly simplifies the start up procedure.

Possibility of masking out a specific speed range to prevent mechanical drive resonances.

The serial interface option permits the interfacing an automation system. The converters can be integrated into automation systems using serial communication interfaces. All converters function such as set point inputs, operation and monitoring can be activated and documented through this serial interface.

The standard operator panel is essentially used for local converter control. However, it can also be incorporated in a control room as remote operator panel unit (option). The maximum permissible distance in this case is 50m. Internal inputs can be provided and drive parameters set via the operator panel. Set points and parameters can be selected and set using the decimal keypad directly or the raise / lower keys.

The display on the operator panel provides detailed information. All operational values such as voltage, current, power parameters, etc can be read. Alarms as well as upto 16 diagnostic and fault message can be called up together with elapsed time from the diagnostic memory. External converter control is possible via the control terminal strip. This includes,

Analog inputs of set points for speed, torque limiting, etc.

Analog outputs for actual values selectable through parameter setting.

10 binary inputs for control commands.

10 binary outputs for control commands.

This ensures a comprehensive and flexible external converters control. In addition, as adoption, the converter can be controlled via serial interface. All set points and actual values, Operating values, control commands and diagnostic information can be transmitted via this interface as for the operator panel with the additional capability if comprehensive logging. The serial interface is especially recommended for sectional drives where the individual drives are involved in one process.

CHAPTER 8

CONCLUSION

Automation and mass productions are associated with advancement technology. Machining has always been and even today one of the high cost component of the manufacturing process. The manufacturing engineer's aim is to affix the ideal combinations of production techniques in preparation handling and cutting operations, so as to yield minimum cost and minimum production role. The CNC system has complete machining operation which requires a variety of tools. So there arises a need for automatic controlling of various tools. The CNC machines work is based on theory of closed loop control system. The PLC is inbuilt in CNC and it will control the system. The hardware installation consists of wiring the PLC to all switches and sensors of the system and to such output devices as relay coils, indicator lamps, and motors. The control program is usually developed on the PC, using software provided by the PLC manufacturer. This software allows the user to develop the control program in the form of STL on the monitor screen. Once the program is complete, it is automatically converted into instructions for the PLC processor. The completed program is then downloaded into the PLC. Once the program is in the PLC memory, the programming terminal can be disconnected and PLC will continue to function on its own.

APPENDIX-I

INPUT DESCRIPTION

INPUT ADDRESS	PIN NUMBER	INPUT ELEMENT	DESCRIPTION
00	30	RSS	INDUCTION MOTOR
01	32	RSS	SPINDLE JOG AXIS SELECT
02	37	RSS	
03	35	RSS	SPINDLE SPEED OVER RIDE
04	29	RSS	
05	27	RSS	
06	25	RSS	
07	23	RSS	JOG/FEED OVER RIDE
08	18	RSS	
09	16	RSS	
10	14	RSS	
11	12	PB	X JOG PB
12	10	PB	X JOG PB
13	8	PB	OPTIONAL BLOCK STOP
14	6	PB	OPTIONAL BLOCK SKIP
15	4	KEY SWITCH	EDIT LOCK ON
16	31	SPRING	COOLANT ON
17	33	RETURN SWITCH	COOLANT OFF
18	35	KEY SW	DRY RUN
19	34	KEY SW	CHUCK INT/EXT
20	28	SELECTOR	QUILL IN

21	26	SWITCH	QUILL OUT
22	24	SELECTOR	CHIP CONV. FWD (NOT USED)
23	22	SWITCH	CHIP CONV. REV (NOT USED)
24	17	NO CONTACT	RESET RELAY FEEDBACK
25	15	FOOT SW1	CHUCK CLAMP
26	11	FOOT SW2	CHUCK UNCLAMP
27	13	PS	CHUCK CLAMP
28	09	PS	CHUCK UNCLAMP
29	07	PB	Z<JOG INPUT
30	03	PB	Z>JOG INPUT
31	05	PB	SPINDLE
32	30	LIMIT SW1	X+ VECTOR LIMIT SWITCH
33	32	LIMIT SW2	X- VECTOR LIMIT SWITCH
34	37	LIMIT SW3	Z+ VECTOR LIMIT SWITCH
35	35	LIMIT SW4	Z- VECTOR LIMIT SWITCH
36	29	FLOAT SW	LUB FLOAT SWITCH
37	27	TURRET TB	TURRET CLAMP PROXIMITY
39	23	TURRET TB	TURRET PARITY
40	18	TURRET TB	TURRET TOOL POSITION
41	16	TURRET TB	TURRET TOOL POSITION BIT2
42	14	TURRET TB	TURRET TOOL POSITION BIT4
43	12	TURRET TB	TURRET TOOL POSITION BIT8
44	10	RSS	MANUAL PULSE GENERATOR
45	08	RSS	
46	06	RSS	MANUAL PULSE GEN. AXIS ELECT

47	04		NOT USED
48	31	PB	EXT START
49	33	PLC O/P	CLEAR FOLLOW UP ERROR
50	36	DRIVE	DRIVE ENABLE
51	34		NOT USED
52	28	KEY SW	ROM ENABLE
53	26	LIMIT SW	X END LIROMMREACHED
54	24		NOT USED
55	22	TB	PERDEFINED
56	17	LIMIT SW	X END LIMIT REACHED
57	15	TURRET	TURRET MOTOR THERMAL
58	11	X MOTOR	X MOTOR THERMAL
59	16	Z MOTOR	Z MOTOR THERMAL
60	09	SP MOTOR	SPINDLE MOTOR THERMAL
61	07	IRLE	INDEX FAIL RELAY
62	03	PB	EMERGENCY STOP PUSH BUTTON
63	05	PB	EXTERNAL HOLD

APPENDIX-II

OUTPUT DESCRIPTION

OUTPUT ADDRESS	PIN NUMBER	OUTPUT ELEMENT	DESCRIPTION
512	20	LED	IN POSITION
513	21	LED	SPINDLE CW
514	22	LED	OPTIONAL STOP
515	23	LED	TURRET CLAMP
516	27	--	NOT USED
517	26	LED	OPTIONAL SKIP
518	25	--	NOT USED
519	24	LED	PROGRAM ACTIVE
520	28	LED	SPINDLE CCW
521	29	LED	INDEX FAIL

522	30	LED	DRY RUN
523	35	SSR	SOLID STATE RELAY
524	34	IRLA	TURRER CW
525	33	IRLB	TURRET CCW
526	32	IRLC	H/S LUB
527		IRLD	COOLENT ON

APPENDIX-III

LIST OF OPERANDS AND SYMBOLS

OPERAND	SYMBOLS
I 0.0	MODE: A
I 0.1	MODE: B
I 0.2	MODE: C
I 0.3	MODE: D
I 0.4	SP OVRDE: A
I 0.5	SP OVRDE: B
I 0.6	SP OVRDE: C
I 0.7	SP OVRDE: D
I 1.0	AXIS SEL: A
I 1.1	AXIS SEL: B
I 1.2	AXIS SEL: C
I 1.3	AXIS SEL: D
I 1.4	AXIS SEL: D
I 1.5	RAPID
I 1.6	DIR + PB
I 1.7	DIR - PB
I 2.0	NC STOP PB
I 2.1	NC START PB
I 2.2	FEED OFF PB
I 2.3	FEED ON PB
I 2.4	SP OFF PB
I 2.5	SP ON PB
I 2.6	I 2.6
I 2.7	I 2.7
I 3.0	FEED OVERDE: A
I 3.1	FEED OVERDE: B
I 3.2	FEED OVERDE: C
I 3.3	FEED OVERDE: D
I 3.4	FEED OVERDE: D

I 3.5	SINGLE BLOCK FB
I 3.6	KEY SWT
I 3.7	RESET PB
I 4.0	X + LIMIT LS
I 4.1	X - LIMIT LS
I 4.2	Y + LIMIT LS
I 4.3	Y - LIMIT LS
I 4.4	Z + LIMIT LS
I 4.5	Z - LIMIT LS
I 4.6	* X DEC LS
I 4.7	* Y DEC LS
I 5.0	* Z DEC LS
I 5.1	# * 4 DEC LS
I 5.2	4 AXIS ENABLE SS
I 5.3	COLLET OPEN/CLOSE
I 5.4	LUB ON PB
I 5.5	LAMP TEST PB
I 5.6	COOLENT ON/OFF SS
I 5.7	OTOR KS
I 6.0	*EM OFF CONTACT
I 6.1	*M/C PM CONTACT
I 6.2	*MCB CONTACT
I 6.3	AXIS OVER TEMP
I 6.4	LUB PS
I 6.5	RUB PS
I 6.6	COLLECT POEN PXS
I 6.7	COLLECT CLOSE PXS
I 7.6	HYD CLOSURE PRESSURE
I 7.7	COLLECT CLOSE/OPEN SS
I 8.0	MAG REF PB
I 8.1	MAG CW PXS
I 8.2	MAG CCW PXS
I 8.3	MAG PKT POSN.PKS
I 8.4	MAG REF PXS

I 8.5	MAG PARK POSN PXS
I 8.6	MAG IN T/C POSN PXS
I 8.7	SP ORIENT POSEN PXS
I 9.0	Z TOOL CHANGE POSN LS
I 9.1	Z TOOL CHANGE ZONE LS
I 9.2	Z MAG INDEX POSN LS
I 9.3	ROT TABLE CLAMB PXS
I 9.4	ROT TABLE DE-CLAMB
I 9.5	# TABLE CLAMB PXS
I 9.6	# TABLE DE-CLAMB PXS
I 9.7	AIR PRESSURE PS
I 10.0	COOLANT LOW PS
I 10.1	I 10.1
I 10.2	COOLANT HP PM
I 10.3	TABLE CLAMP PS
I 10.4	PIN UP PS
I 10.5	# MAG +
I 10.6	# MAG -
I 10.7	# TABLE ENABLE
I 27.7	RESET (IMCP)
I 32.1	NC READY 2
I 32.3	NC READY 1
I 33.0	PROG. RUNNING CH1
I 33.4	GOO: CH1
I 33.6	M02/M30:CH1
I 33.7	M00/M01: CH1
I 35.4	X REFERENCED
I 36.4	Y REFERENCED
I 37.1	4 IN POSN. CORSE
I 37.4	4 IN POSN FINE
I 38.0	4 - DIRM CMD
I 38.2	4 + DIRM CMD
I 38.3	SP STOP
I 39.4	SP POSN.REACHED

Q 0.0	E-STOP FROM PC
Q 0.1	LUB ON
Q 0.2	COOLANT ON
Q 0.3	TOOL CLAMP
Q 0.4	TOOL DE-CLAMP
Q 0.5	AIR FLOW IN SPINDLE
Q 0.6	HYD OIL PR LOW
Q 0.7	Q 0.7
Q 1.0	TURRET MOTOR CW
Q 1.1	TURRET MOTOR CCW
Q 1.2	HYD PP ON
Q 1.3	PALLET UNCLAMP
Q 1.4	MAG AWAY FROM SPINDLE
Q 1.5	MAG TOWARDS SPINDLE
Q 1.6	COMP CLAMP
Q 1.7	COMP DE-CLAMP
Q 2.0	MACHINE ON
Q 2.1	MOVEMENT OFF
Q.2.2	CYCLE ON
Q 2.3	SP ORIENTED
Q 2.4	MAG REFERENCED
Q 2.5	COOLANT HP MOTOR ON
Q 2.6	COOLANT THRO NOZZLE
Q 2.7	Q 2.7
Q 3.0	COOLANT THRO TOOL
Q 3.1	COOLANT DUMB HP
Q 3.2	ROTARY TBL CLAMPED
Q 3.3	#NC ROTARY TBL UNCLAMBED
Q 3.4	PIN UP
Q 3.5	PIN DOWN
Q 3.6	#NC TABLE CLAMBED
Q 3.7	Q 3.7
Q 10.5	Q 10.5
Q 12.0	Q 12.0

Q 12.1	* EM OFF
Q 12.7	RESET
Q 13.7	DRF ACTIVE
Q 14.5	READ IN ENABLE: CH1
Q 18.7	TOTAL FEED ENABLE
Q 20.2	X SERVO ENABLES
Q 20.4	X DECELERATION
Q 20.5	X FEED ENABLES
Q 20.7	X MIRROR
Q 21.6	X JOG -
Q 21.7	X JOG +
Q 22.2	Y SERVO ENABLES
Q 22.4	Y DECELERATION
Q 22.5	Y FEED ENABLE
Q 22.7	Y MIRROR
Q 23.6	Y JOG -
Q 23.7	Y JOG +
Q 24.2	Z SERVO ENABLES
Q 24.4	Z DECELERATION
Q 24.5	Z FEED ENABLES
Q 24.7	Z MIRROR
Q 25.6	Z JOG -
Q 25.7	Z JOG +
Q 26.2	4 CONTROL ENABLE
Q 26.4	4 DECELERATION
Q 27.5	4 FEED ENABLE
Q 27.6	4 JOG -
Q 27.7	4 JOG +
Q 28.6	SP SERVO ENABLES
Q 28.7	SP SPINDLE
Q 30.2	SP ACL 1: M19
F 0.1	ONE
F 0.7	ZERO
F 10.1	END LIMITS OK

F10.2	M/C ON CONDN.1
F 10.3	M/C ON CONDN.2
F 10.4	F 10.4
F 10.5	FOR FEED RELEASE
F 10.6	REPS MODE
F 10.7	F 10.7
F 11.0	MDA MODES
F 11.1	JOG MODE
F 11.2	AUTO MODES
F 11.3	REF MODES
F 11.4	INC MODES
F 11.5	MANUAL MODE SELECTED
F 11.6	AUTO MODE SELECTED
F 11.7	F 11.7
F 12.0	FOR LUB, PR NOT OK
F 12.1	SP SPEED REACHED
F 12.2	SN. SPINDLE ORIENTED
F 12.3	SP RUNNING CW
F 12.4	SP RUNNING CCW
F 12.5	SP OFF THRO M05
F 12.6	M19 COMMANDED & ON
F 12.7	MANG IN PARKPOSN
F13.0	F 13.0
F 13.1	SP NOT RUNNING
F 13.2	FOR COOLANT OFF
F 13.3	F 13.3
F 13.4	SENSING M08
F 13.5	SENSING SP ON
F 13.6	FOR TOOL DE-CLAMP
F 13.7	FOR TOOL CLAMP
F 14.0	F 14.0
F 14.1	F 14.1
F 14.2	SN M06 COMMANDED
F 14.3	MANUAL/ AUTO MODE PULSEF

F 14.4	F14.4
F 14.5	Z IN MAG INDEX POSN
F 14.6	F 14.6
F 14.7	F 14.7
F 15.0	F 15.0
F 15.1	SN T>20
F 15.2	SN T CALL = MAG T POSN
F 15.3	F 15.3
F 15.4	FOR MAG REFERENCING
F 15.5	F 15.5
F 15.6	F 15.6
F 15.7	F 15.7
F 16.0	FOR MAG AWAY FROM SP
F 16.1	FOR MAG TOWARDS SP
F 16.2	F 16.2
F 16.3	F 16.3
F 16.4	F 16.4
F 16.5	F 16.5
F 16.6	F 16.6
F 16.7	F 16.7
F 17.0	F 17.0
F 17.1	F 17.1
F 17.2	F 17.2
F 17.3	F 17.3
F 17.4	F 17.4
F 17.5	F 17.5
F 17.6	F 17.6
F 17.7	F 17.7
F 18.0	FOR READ IN DISABLE
F 18.1	F 18.1
F 18.2	F 18.2
F 18.3	F 18.3
F 18.4	F 18.4
F 18.5	F 18.5

F 18.6	F 18.6
F 18.7	F 18.7
F 19.0	F 19.0
F 19.1	F 19.1
F 19.2	F 19.2
F 19.3	F 19.3
F 19.4	F 19.4
F 19.5	F 19.5
F 19.6	F 19.6
F 19.7	F 19.7
F 20.0	F 20.0
F 25.0	F 25.0
F 25.1	F 25.1
F 36.0	4 AXIS COMMANDED
F 36.1	4 INC POSN DWELL FLAG
F 37.5	5 AXIS SELECTED
F 37.6	F + JOG
F 37.7	F - JOG
F 64.3	T - MOD: CH1
F 73.0	M??? (PLC MD: 020)
F 85.0	M03 (PLC MD: 120)
F 85.1	M04 (PLC MD: 121)
F 85.2	M05 (PLC MD: 122)
F 85.3	M06 (PLC MD: 123)
F 85.4	F 85.4
F 85.5	M08 (PLC MD: 125)
F 85.6	M09 (PLC MD: 126)
F 85.7	F 85.7
F 87.0	M19 (PLC MD: 136)
F 87.1	F 87.1
F 87.2	M21 (PLC MD: 138)
F 87.3	M26 (PLC MD: 139)
F 87.4	F 87.4
F 87.5	M25 (PLC MD: 141)

F 87.6	M26 (PLC MD: 142)
F 87.7	F 87.7
F 89.0	F 89.0
F 89.1	M65 (PLC MD: 153)
F 89.2	M66 (PLC MD: 154)
F 89.3	M67 (PLC MD: 155)
F 89.4	M68 (PLC MD: 156)
F 89.5	M?? (PLC MD: 157)
F 101.1	F 101.1
F 109.1	PRG> T 20
F 111.4	R PAR: CH1
F 200.0	AL: 6000
F 200.1	AL: 6001
F 200.2	AL: 6002
F 200.3	AL: 6003
F 200.4	AL: 6004
F 200.5	AL: 6005
F 200.6	AL: 6006
F 200.7	F 200.7
F 201.0	AL: 6008
F 201.1	F 201.1
F 208.0	MS: 7000
F 208.1	MS: 7001
F 208.2	MS: 7002
F 208.3	MS: 7003
F 208.4	MS: 7004
F 208.5	MS: 7005
F 208.6	MS: 7006
F 208.7	MS: 7007
F 209.0	MS: 7008
F 209.1	F 209.1
F 209.2	MS: 7010
F 209.3	MS: 7011
F 209.4	MS: 7012

F 209.5	MS: 7013
F 209.6	F 209.6
F 209.7	MS: 7015
F 210.0	MS: 7016
F 210.1	MS: 7017
F 210.2	MS: 7018
F 210.3	MS: 7019
F 210.4	MS: 7020
F 210.5	MS: 7021
F 210.6	MS: 7022
F 210.7	MS: 7023
F 211.3	MSG: 7027
F 211.4	MSG: 7028
F 211.5	MSG: 7029
F 211.6	MSG: 7030
F 224.0	PLC MD: 3000
FY 21	PROGRAMMERD T WORD
FY 30	MAG PKT NO
FW 20	PROGRAMMED T WORD
FW 69	T WORD: CH1
T 0	FOR SP ORIFNTATION
T 1	FOR LUB ON 15 SEC
T 2	FOR LUB INT 30 MTS
T 3	FOR LUB PRESENCE
T 4	T 4
T 5	T 5
T 6	TIMER FOR TOOL CLAMP
T 7	FOR TURRET CW 2 SEC
T 8	4 IN POSN DWELL
C 0	PRESENT T NO
C 1	FOR TURRET COUNTING CW
C 2	FOR TURRET COUNTING CCW
C 3	C 3
C 4	C 4

APPENDIX-IV

ADDITIONAL AXIS OF VMC

Operation	Operand	Comments
:A	Q 2.0	Hold Signal
:=	Q 1.2	Rotary Table Power Pack On
:A	F 38.0	New
:O	F 38.1	New
:=	F 36.0	New
:A	F 38.2	New
:O	F 38.3	New
:L	KT 002.2	
:SD	T 8	20 Seconds
:A	T 8	20 Seconds
:=	F 36.1	New
:A	Q2.0	Hold Signal
:A	I 7.5	New
:A	F 36.0	New
:AN	F 36.1	New
:=	Q 26.2	TB of X, Y, Z, B
:A	I 5.1	10-S 92 For Rotary Table
:=	Q 26.5	New
:A	I 5.2	Rotary Table Enable Select Switch
:A	F 0.7	New
:=	F 211.6	Fourth Axis Enabled Message [BLINK]
:A	I 9.3	Rotary Table Clamp Pro Switch
:AN	F 0.7	

:=	F 211.5	Rotary Table Clamped Message [BLINK]
:A	I 9.4	Rotary Table Declamped Pro SW
:AN	F 0.7	
:=	F 211.4	Rotary Table Declamped Message [BLINK]
:A	I 9.3	Rotary Table Clamp PSW
:A	I 9.4	Rotary Table Declamped PSW
:O		
:AN	I 9.3	Rotary Table Clam PSW
:AN	I 9.4	Rotary Table Declamp PSW
:=	F 211.3	Rotary Table Clamp/declamp Switch Fault
:A	I 9.3	Rotary Table Clamp PSW
:=	Q 3.2	Rotary Table Clamped Indication
:AN	I 5.2	Rotary Table Enabled Select Switch
:R	F 211.6	Fourth Axis Enabled Message
:R	F 211.5	Rotary Table Clamped Message
:R	F 211.4	Rotary Table Declamped Message

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