PLC & HMI INTERFACING FOR AC SERVO DRIVE

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***Abstract*—**

Servo motors are used for motion controls in variety of electro-mechanical industries such as robotics, CNC manufacturing, aerospace technology etc. to maintain accuracy and precision. The control of servomotor in various modes like position, velocity and torque mode is achieved using servo drive. The position mode control is achieved through Programmable Logic Controller (PLC) ladder logic programming to oscillate the motor shaft forward/reverse direction for required speed and position. Position mode parameters are realized by configuring the application software (R-advanced Setup) for Sanmotion servo-drive. PLC ladder logic program developed is capable of reading serial encoder data in incremental mode by establishing RS485 communication with Sanmotion AC Servo drive. An attempt has been made to establish RS232 and Ethernet communication protocols to interface Redlion's Human Machine Interface (HMI) and Galil's DMC 21x3 (Digital Motion Controller) to monitor the servo motor parameters. The real time data related to DMC 21x3 controller and servomotor parameters are read/write with the help of HMI for supervisory monitoring of servo motor.

***Index Terms*— Galil's DMC Motion controller, HMI,** PLC, **Position Control,** Servo **Drive, Servo Motor.**

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Quick advancement in technology forces manufacturing tools to equip with more sensitive and faster actuating units such as servo motors and stepper motors. The use of PLCs in automation processes diminishes production cost and increases quality and reliability [1]. To obtain accurate industrial electric drive systems, it is necessary to use PLCs interfaced with power converters, personal computers and other electronic equipments for motion control of electric drives. Ladder logic programming is used to control induction motor through PLC [2]**.** The robustness of the PLC controller has been achieved by rotating the motor in both clockwise as well as counter-clockwise directions. Consequently, the PLC controller proves to be a simple tool for controlling robot by extremely simple algorithm. The dynamic model has been interfaced with a real-time industrial process control setup through a programmable logic controller (PLC) system. An integrated model is flexible and powerful for modern manufacturing applications [3].

The entire system along with servomotor and servo drive is called servo system because it responds faithfully or precisely to positioning commands [4]. It is a system that controls various mechanisms in compliance with the variation of position or target speed value i.e., designated value or command value.

By considering high precision positioning control and customized application product development for a servomotor drive automation leads to this present work carried out, which was intended to configure and develop an easy control strategy for servo motor positioning with the help of PLC, and simple monitoring of motion controllers available in automation industry.

I. INTRODUCTION

Automation of electric machines helps in precise control of industrial processes with higher productivity and product quality. The combinational use of both PLC and HMI systems helps in continuous monitoring, supervising and controlling process plants, has lead to new heights in the field of automation for ac machines and processes. For indirect control Panasonic FPX series PLC [9] is used. For direct control of servo motor, Sanmotion Servo drive [10] is used. Technical specifications of the PLC are given in Table 1. PLCs are important control units which provide adequate input output units for the controlling of hardware that are installed for industrial automation systems. They allow execution of a previously written program on demand and automatically

Ladder logic programming is performed to control the servo motor automation processes [8] using Pansonic FP Winpro 6.4 software. HMI screens are created using Crimsons 3.0 Software platform.

Catalog Number	FPXC30TD
Nominal Rated Voltage	24VDC
Input Voltage Range	16-point input of 24 V DC NPN or PNP configured
Output Voltage	0.5 A/5 to 24 V DC 14-point ,NPN type Transistor output

TABLE 1: PANASONIC FPX series PLC Specifications

II. SYSTEM OPERATION

Main control program is developed on PLC programming environment using FPWINPRO 6.4 (PANASONIC). In this control method application specific PLC ladder logic programs, are developed in software tool then complied and communicated to PLC hardware through RS232 serial communication (or even through Ethernet for high speed communication). This software integrates all the modules of PLC as well as the devices connected to its networking module. Block diagram of Experimental setup is shown in Fig 1.The following sections briefs about servo motor closed loop feedback technique and role of PLCs in servomotor automation.

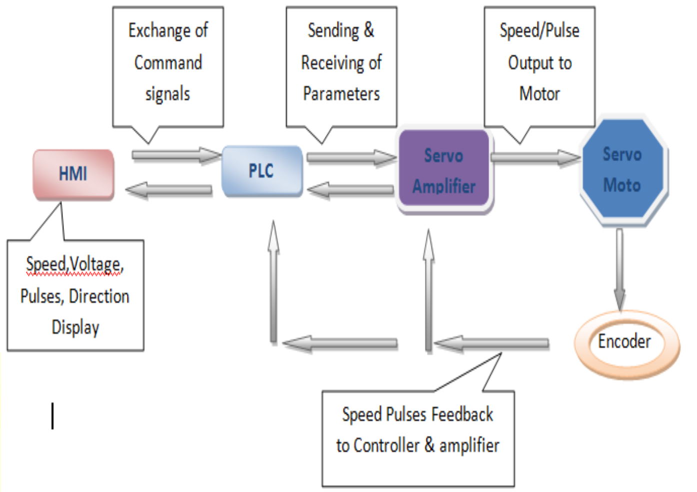

Fig 1: Block Diagram of Experimental setup

A. CLOSED LOOP FEEDBACK TECHNIQUE

Because of self adjusting nature, closed loop control systems are more complex in design. In servo closed loop systems, amplifiers (servo drive) can return data to the input stage, i.e the control element generally PLC or any microprocessor based speed controllers are used, those are capable of self adjustment based on the information received[5]. Servo positioning controls operate in a closed loop system, requiring feedback information in the form of speed or position. Normally Tachometer is used for speed feedback input to servo drive and Encoder is used for position feedback input to servo drive. The feedback signal provides information about actual speed of motor and the position of axis. This obtained feedback information is compared with desired velocity and position of the axis. If the servo drive or amplifier detects a difference between the obtained and desired values, it will correct its output until the error between the feedback data and the set point velocity and position is zero.

When servo drives are used for positioning control, the feedback resolution is the important issue. If an application uses a lead screw (a rotational to linear motion shaft) for axis movement and an encoder to provide a feedback signal to the servo drive. The user must know the lead screw pitch, the number of encoder pulses per revolution, and the multiplier value in the encoder section of the interface[6]. This servo amplifier allows user to select the multiplier, thus providing better feedback resolution without changing the encoder.

B. SERVOMOTOR AUTOMATION USING PLC

Programmable Logic Controller (PLC) is a programmable sequential device that controls machines and processes. The PLC processor sends all the direction and position information like acceleration, deceleration, final and initial speeds to the servo drive. It uses a programmable memory to store instructions and execute specific functions that include ON/OFF control, timing, counting, sequencing, arithmetic and data handling. The inputs are connected to the input module of the PLC and outputs are connected to the output module of PLC. In an automated system, a PLC controller is usually central part of a process control system. In this project, control and monitoring of servomotor parameters are carried out using PLC based controller. Based on the required application, the ladder logic program is developed and exported to PLC hardware. Once the program is compiled when PLC is in RUN mode, the system works on user defined instruction.

$$\text{Target Speed} = \frac{\text{Input Pulse @ controller}}{\text{Encoder Pulse @ Drive}} \times 60 = \text{Required speed in RPM}$$

$$\text{Target Value/Distance} = \frac{\text{Input Pulse @ controller}}{\text{Encoder Pulse @ Drive}} = \text{No. of revolutions}$$

For example by considering the feedback pulses counts from the servo drive, target speed and position is calculated by using above equations and set in PLC ladder logic program for the required application. PLCs can be easily interfaced with field devices and supports almost all types of communication systems in present day control industry.

PLC based systems are cost effective, less downtime, minimum manual labor intensive, can be networked together, enables real-time monitoring, troubleshooting and adjustments to set points. Present day PLCs are extensively used for controlling, manufacturing and treatment processes.

C.OVERVIEW OF AC SERVO DRIVE

Figure 2 shows a AC servomotor drive (Servo amplifier). The rectifier circuit converts 1 ph or 3 ph AC voltage source into DC voltage which is then fed to three-phase inverter through a DC link capacitor (smoothening circuit. The DC link capacitor removes ripples in the converted voltage and regenerative resistor is meant for dissipation of regenerative energy produced during braking. Table 2 lists the specifications of AC Servo drive.

Part No.	RS2A03A0AL0W00
Power Rating (KW)	1.5
Phase / Voltage	Three Phase 200-230VAC.5.8A
Voltage Range	Three Phase:100-220VAC
Frequency Range	50/60 Hz ± 5%
Encoder Resolution	2000 ppr Encoder(10000 counts/rev)

Output Rating	3 phase ,0-326V ,5.2A
Tuning modes	Auto/Manual
Communication Interface	RS-232/RS-422/RS-485/Ethercat

Table 2: Technical specifications of AC Servo drive

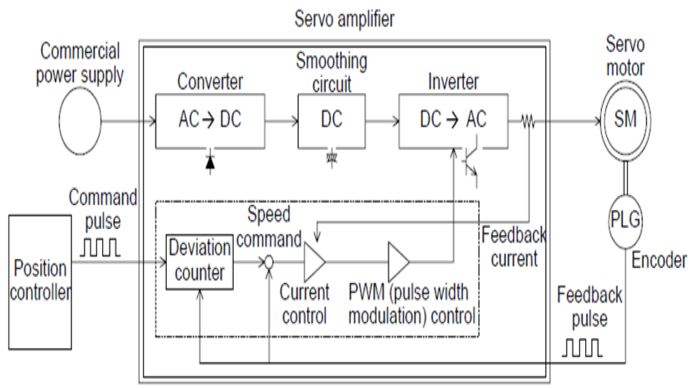

Fig 2: Typical Servo motor drive

The drive has a protection circuit which protects motor against undue overloading, faults, etc. The closed loop control circuits for control of position, speed and current (torque) are also present within the drive. Suitable pulses (position mode), a suitable current (torque mode) or an adjustable voltage (speed mode) as required for controlling motor operation is provided by PWM control. The pulses to the gate circuitry of IGBTs are controlled by gating circuits and in turn AC servomotor operation is controlled. The drive has a display screen to view and change various parameters as and when required.

III. SOFTWARE REQUIREMENT FOR CONTROL AND MONTIORING FOR AC SERVO DRIVE

A PLC and HMI based monitoring and control systems for AC Servo motor have been successfully implemented and tested for application development. The drive system provides precise position and speed control and also enables an online monitoring of drive speed, position, error, Kp, Ki ,Kd, position deviation etc. through HMI system. The following softwares are used for control and monitoring of AC Servo drive.

FP WINPRO 6.4

This is software specially meant for Panasonic PLC simulating environment. The ladder logic programs are developed according to the user defined control logic and the same is compiled and made run in PLC hardware, The software interface provides an option of compiling the program in offline mode where the status of inputs and outputs are monitored and controlled according to user requirement.

R Advanced Setup

This software interface enables the user to directly control the Servomotor through the Sanmotion's Servo drive settings and monitor the Servomotor parameters. The Servo drive settings can be changed directly through the software installed on the PC or through a digital keypad provided on the drive itself.

Galil Tools

This software interface is used to configure Galil's DMC 2143 motion controller and parameter monitoring with external device[11]. Galil's DMC2143 controller is programmed for precision motion control applications to observe, monitor and control the process parameters efficiently.

Crimson 3.0

HMI screens are created and developed in Crimson 3.0 software interface. Developed HMI screens provides user interface between operator and machine[12]. Reading and writing of controller parameters is made possible from and to the HMI.

IV. OBJECTIVE FULFILLMENT

Following section deals with the scope of the present work. The control schemes developed are able to control and monitoring of servo motor used for application specific requirement.

A.Development of PLC ladder logic program to run AC Servomotor

The experimental setup in fig 3 consists of a 400W, AC servomotor, with a built in encoder, Sanmotion AC servo drive and Panasonic PLC. The servomotor is fed through a PWM based Sanmotion servo drive, which provides high frequency controlled voltage to stator windings of motor. A 2000 ppr (10,000 Quadrature counts/ revolution) built in position encoder is used for speed and position feedback in terms of number of pulses. Initially ladder logic programming is performed according to the customised logic using FP WinPro 6.4 software platform on a PC, then it is made online by running the developed program in PLC hardware. Overall the system is setup and implemented for tuning and selection of servo parameters in position mode control of servo system for different process applications.

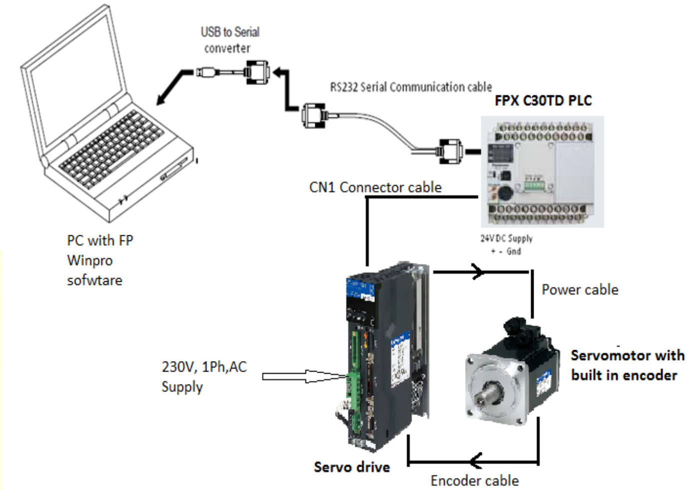

Fig 3: Experimental setup to run servomotor motor using PLC

In this method, direct control of servo drive through PLC has been implemented. The developed ladder logic is transferred into PLC processor and control of motor is achieved by activating the particular logical input involved, which ultimately results in instigation of ladder logic program developed. The experimental work involves parameter grouping for position mode run of the servo motor and configuring these grouped parameters in R advanced software tool, exporting them into the servo drive, development of ladder programs for the control of Servomotor.

In order to provide convenient position control using servo drive, the position control mode parameters are listed, configured and set using Servo amplifier configuration R Advanced setup software. Thus each parameter is set according to the requirement and transferred to the drive by serial communication (RS232) cable provided from PC to Servo Drive unit. The ladder logic program is developed in the PLC to satisfy the application requirement. The unique feature of this program is that the target speed, target position, initial speed, final speed, acceleration time, deceleration time, control code for forward & reverse direction are completely user defined, and all the above are considered as input variables to run the motor in required speed and position.

B. *To read serial encoder data in PLC by serial communication*

Absolute encoders provide position data without referencing to a mechanical home. For every position a unique binary word is generated. In single turn absolute encoders, words are repeated for every revolution of the encoder's shaft. In multi turn absolute encoders, words are unique for every position, through multiple rotations of the shaft. For both single and multi turn encoders the resolution of a single turn and number of turns are programmable. The total number of bits is limited to 32, which means each word varies with the interval of 1F in Hexa-decimal equivalent.

The Sanmotion servo drive is able to read absolute positions from compatible absolute encoders. This information can be relayed or displayed in the monitor window of R advanced setup software. CN2 Encoder communication cable is connected from motor encoder to servo drive unit

The value displayed in the serial encoder PS data monitor should be transferred to PLC program by means of Serial communication, to perform this operation there is need of communication module for the PLC connected by CN1 connector of servo drive, after establishing the RS485 communication, the ladder logic servo pulse conversion block is created to read this serial encoder data in decimal equivalent format .The encoder serial data will be in unreadable hexadecimal format. The serial data will be in structure of frames of 11 bit data length consisting of start bit, stop bit, parity bit of each 1 bit respectively, 3 bits of address bits, 5 bits of data bits, Structure of each frame is shown in fig 4.

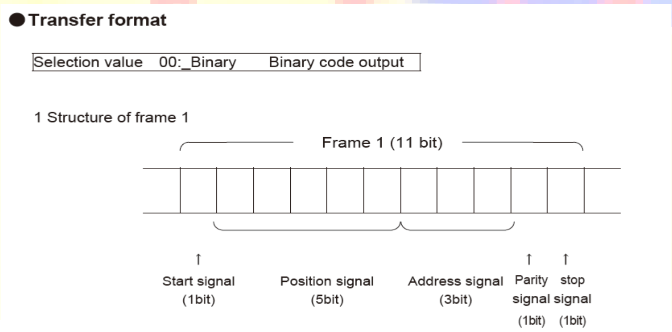

Fig 4: Structure of Serial data frame

In Serial Transmission, each position bit is transmitted over a separate data line, and all bits are read simultaneously into the control. Serial transmission is generally used for shorter cable runs, or when real-time transmission of all data bits is required. For the PLC to communicate with the Sanmotion Servo drive, additional AFPX COM 3 card should be installed and configured with CN1 Connector cable.

C. Interfacing Redlion's HMI & Galil's DMC 21x3 motion controller

The DMC-21x3 motion controllers are available with a variety of plug-in multi-axis amplifier boards that are designed to eliminate the wiring and any connectivity issues between the controller and drives. The interfacing is made possible by RS232 communication protocol. User can create screens according to process control application requirement and transferred to HMI, Ethernet communication protocol is established to Read & Write the parameters between the HMI & the Galil Motion controller. Fig.5 represents hardware requirement and devices used for interfacing Galil's DMC 21x3 motion controller and Redlion HMI.

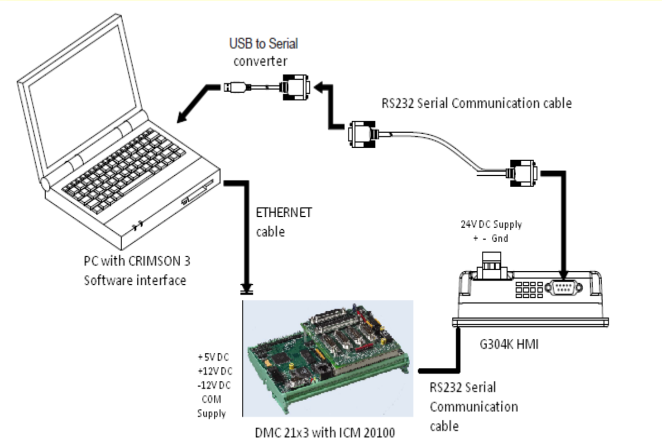

Fig 5: Experimental setup for interfacing HMI & Galil's DMC2143 motion controller

V. Results & discussions

The following section describes about the results obtained and verified by fulfillment of objectives in the present work carried out.

A. Position mode parameter grouping and PLC ladder logic program development to run servomotor.

After setting and selecting the appropriate configuration of position mode parameters in R advanced setup software, the parameters are exported to the Sanmotion servo drive by using RS232 serial interfacing cable, provided the servo drive is online. Ladder logic program is developed to run the motor as forward run and reverse run with user specified dwell time (wait time to change the direction of rotation). It is observed that shaft is rotating according to user specified requirement.

B. Reading of Serial encoder data in incremental mode

The decimal converted value is shown in fig 6. In the developed PLC ladder logic program, the servo pulse conversion blocks produces the output equivalent to decimal value scaled from 0 to 131072 by converting each bit divisions into binary value as shown in fig 6.

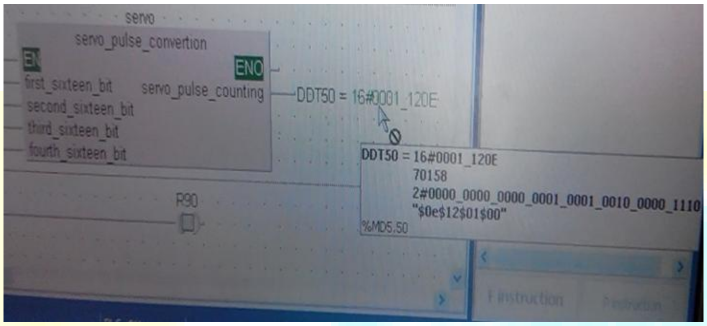

Fig 6: Screen capture for serial encoder data read in PLC ladder logic program

The decimal equivalent serial encoder data is read in the DDT50 double data type register as shown in fig 6. After running the servo pulse conversion block in the ladder logic programming, the status of the DDT50 register in hexa decimal value is 16#0001_120E

The equivalent binary data is displayed as

2#0000_0000_0000_0001_0001_0010_0000_1110

The decimal value scaled between 0 to 131072 pulses is displayed as 70158 in incremental mode. The number of pulses displayed in decimal value in incremental mode refers to the encoder shaft is rotating for one single rotation, the home position or zero position is scaled to 0^{th} pulse or starting pulse. when the shaft is about to rotate, the final pulse number in decimal value after rotating one single rotation can be scaled as 131072^{nd} pulse.

Again for the next rotation the home position will get the decimal value of 0 no. of pulses and at the end of 2^{nd} rotation the decimal value will be 131072 only, this is the special observation made while reading serial encoder value in incremental mode.

C. Servo Parameters Monitoring in HMI Display Screen

After the establishment of communication protocols between HMI and Galil,s DMC 2143 controller, the values entered in the terminal window of Galil tools is same as the displayed values in Parameter display screen. Similarly we can able to modify or manipulate these values in HMI screen by typing in the keypad displayed in the HMI , and observed that the terminal window of

Galil tools window is updated in particular page where parameter read / write screen is displayed. Data tags are assigned to each and every particular parameter able to read/write. This verifies and justifies the establishment of RS232 and Ethernet protocols successfully.

VI. CONCLUSION

The present work is emphasized to develop an online scheme to monitor and control of AC Servo drive using PLC and HMI. A detailed study of the Permanent Magnet Synchronous Motor Servo Motor used in this set-up is done including its construction, working, control strategies adopted and specific features. A 400W , 3000rpm, Permanent Magnet Servomotor was fully automated using Panasonic FPX series PLC and Sanmotion AC Servo Drive by configuration of position mode parameters with the help of software systems. Various operation configurations like remote start and stop operations, to oscillate the motor shaft for required speed and position are achieved by developing ladder logic programming were demonstrated successfully An effort is made to read Serial encoder data in incremental mode in PLC by creating special servo pulse conversion block by developing ladder logic program

Redlion HMI and Galil's Digital Motion Controller is communicated by establishing RS232 and Ethernet communication protocols to read and write servo parameters like acceleration, deceleration, Kp Ki, Kd, error, position values for achieving efficient monitoring of servomotor. The control system designed is based on the most advanced HMI technology which gives high amount of flexibility and efficiency.

VII. SCOPE FOR FUTURE WORK

Following aspects can be explored as an extension to this work. Firstly, backup battery can be externally connected for absolute encoder fitted in the system and implement the present control scheme thus reading the serial encoder data even after interrupted power failure or mechanical disturbances by using developed ladder logic program. Position dominant process control applications involving absolute encoder system can be replaced with developed ladder logic for reading serial encoder data by continuous testing and implementation for on floor practical applications. Secondly various modes of control can be done without controller by means of commanding directly from software called EtherCAT.

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