Abstract: PLC and ladder logic are the workhorses of factory automation. Earlier automated systems used hundreds or thousands of electromechanical relays; which used to consume lot of time in wiring. A single PLC can be programmed as an efficient replacement. This paper speaks of programming the PLC and designing HMI screens used in the design & development of an induction hardening machine. Induction hardening is a form of heat treatment in which a metal part is heated by induction heating and then quenched. PLC is a digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions for implementing specific functions, such as logic, sequencing, timing, counting and arithmetic, to control various types of machines or process through digital or analog input/output. HMI is the part of the machine that handles the Human-machine interaction. This helps in communicating with the machine. HMI screen is also referred as the operator interface terminal, it allows to: view faults, operate machine and control manual functions.

Keywords: PLC, Ladder logic, Simatic Manager, Induction hardening, Quenching, Quenchant, WinCC Flexible Advance and HMI.

I. INTRODUCTION TO PLC
Programmable Logic Controller (PLC) is a specialized industrial computers used for controlling and operating the manufacturing process and machinery. It uses a programmable memory to store instructions and execute functions including on/off control, timing, counting, sequencing, arithmetic, and data handling. The PLC accepts inputs from switches and sensors, evaluates them based on a program (logic), and changes the state of outputs to control a machine or process. Programmable Logic Controllers (PLC’s) are used in every aspect of industry to expand and enhance production. Where older automated systems would use hundreds or thousands of electromechanical relays, a single PLC can be programmed as an efficient replacement. Programming is carried out using “LADDER LOGIC”.

II. INDUCTION HARDENING
Heat treatment is usually carried out to provide metal with desirable properties. Induction hardening is a thermal hardening process in which the material is austenitized through inductive heating followed by quenching, which causes the austenitized volume to transform to martensite. It is an energy effective method; only the volume to be hardened is heated. This method provides the desired hardness profile at a reasonable cost. Hardening is carried out to improve the final properties of the metal such as, tensile strength, fatigue strength, elasticity and wear resistance.

Quenching is the rapid cooling of a work piece to obtain certain material properties. It must be rapid enough to transform austenite to matensite. Commonly used water based polymer quenchants are: Polyalkylene Glycols (PAG) and acrylates (PA).

III. DESCRIPTION OF CPU “315-2 PN/DP”

Fig. 1. PG to PLC interface
1. Status and Error display:
   It is used to display internal CPU fault or fault in module.

2. Bay for Simatic Micro card:
   It is the slot provided for a memory card. Programs are saved in memory card.

3. Mode selector:
   It allows us to select the mode of PLC; Run mode or Stop mode.

4. Industrial Ethernet twisted pair cable for connecting to additional PROFINET devices:
   It is used to interface PLC and Human Machine Interface.

5. Industrial Ethernet twisted pair cable for interconnecting PN interface X2:
   It is used to interface PLC and computer/PG.

6. Programming device (PG) with STEP 7 software:
   It is referred to the computer/laptop in which the software is installed. Step 7 or Simatic Manager is the software used for programming.

7. Mounting rail:
   It is used to mount the CPU/PLC.

8. Power supply ON/OFF:
   It is used to indicate the supply given to the PLC.

IV. HARDENING MACHINE OPERATION

Below figure 2 represents the block diagram of hardening machine. It consists of Chiller unit 1 and 2, Control panel, Air blower, Quench water, Quench tank, Power source, Loading conveyor, Unloading conveyor and heating station.

A. Heating station
   Component/Parts are heated at the heating station. In this station metal is heated to hardening temperature (austenitizing).

B. Cooling station or Quench water
   Component/Parts are cooled using continuously showering quench water. It is carried out to transform austenite to martensite.

   Hardening is followed by quenching in a suitable quenchant.

   Quenching should be fast enough, but not so fast that it causes problems such as cracking or unnecessary distortion.

   The most used quenchant is a polymer solution in water and the next most used is pure water.

   The heating zone can be quenched in different ways, but the spray quenching method is the most common.

C. Chiller unit
   It is used to remove heat from liquid via a vapor-compression or absorption refrigeration cycle. This liquid can then be circulated through a heat exchanger to cool air or equipment as required.

D. Source
   Power source used is CAMI 100kw, with low frequency.

E. Control unit
   CPU, S7 315-2 PN/DP is present on the control unit. Programs are downloaded onto the CPU, S7 315-2 PN/DP using MPI.

Three modes of operation are: Manual mode, Semi Auto mode and Auto mode.
a) Manual mode: Entire machine operations (from loading the component till unloading) are controlled manually.

b) Semi Auto mode: Loading and unloading the component is done manually, remaining operation is carried out automatically.

c) Auto mode: Entire machine operation is carried out automatically. Components are loaded with the help of lifter unit and singling unit. Lifter unit is used to lift the work piece, whereas singling unit is used to select single component from group of components.

V. ALGORITHM

Step 1: Cycle start

Step 2: Turn on the pumps.

Step 3: Check for Pre-condition. If the condition doesn’t satisfy, then go to Step 2.

Step 4: Press cycle start button.

Step 5: Check for Alarms. If there are any active alarms, then go to Step 20.

Step 6: Start loading and unloading conveyor motor.

Step 7: Check whether the work piece/part is present at loading side.

Step 8: Check whether the work piece is present at heating point.

Step 9: Switch ON the heat.

Step 10: Check whether PS2 and PS 3 is low.

Step 11: Switch OFF the heat.

Step 12: Wait till PS 3 becomes high.

Step 13: Switch ON the Air blower.

Step 14: Wait till PS 4 becomes low.

Step 15: Switch OFF the Air blower.

Step 16: Part/ work piece is cooled at Quench station.

Step 17: Wait till PS 5 becomes high.

Step 18: Unload the part/work piece.

Step 19: Check if Emergency/Cycle stop/Reset button is pressed. If yes, then go to Step 20.

If no, then repeat the steps from Step 7.

Step 20: Stop.

VI. FLOW CHART

Figure 3 shows the flow chart of machine operation.

VII. SIMATIC MANAGER

Figure 4 represents the elements present on the “Simatic Manager” window. Simatic Manager is the tool used to carry out PLC programming.

Programmable Logic Controller (PLC) is a specialized industrial computer used for controlling and operating the manufacturing process and machinery.

It uses a programmable memory to store instructions and execute functions including turning ON/OFF the control, timing, counting, sequencing, arithmetic, and data handling. The PLC accepts inputs from switches and sensors, evaluates them based on a program (logic), and changes the state of outputs to control a machine or process.

Programmable Logic Controllers (PLC’s) are used in every aspect of industry to expand and enhance production.
Fig. 4. PLC editor Window

Programs are written on the editor window. On completing the programming part, the programs are compiled, and then the programs are downloaded to the PLC. To download the program, click on the download button. And then the program can be put to run mode.

VIII. WINCC FLEXIBLE ADVANCE

Figure 5 represents the elements present on the “WinCC Flexible Advance” window. WinCC Flexible Advance is the tool used to carry out HMI screens designing.

HMI is the part of the machine that handles the Human-machine interaction. This helps us to communicate with the machine. Using HMI, we can perform necessary operations like controlling and monitoring the machine operations.

HMI screen is also referred as the operator interface terminal, it allows to: view faults, operate machine and control manual functions.

In some machines, the viewing screen is touching sensitive. On other machines, a separate keyboard and mouse is used to select and input the data.

IX. COMMUNICATION BETWEEN HARDWARE AND SOFTWARE (PLC AND PC/PG):

Using the STEP 7 software, S7 program can be created within a project. The S7 programmable controller consists of a power supply unit, a CPU, and input and output modules (I/O modules).

MPI is used to communicate between PC and PLC. Through this, the Ladder logic or the programs from PC/PG is downloaded to PLC.

Fig. 6. Communication between PC and PLC

X. COMMUNICATION BETWEEN PLC AND HMI:

MPI network is used to communicate between the Programmable Logic Controller (PLC) and the Human Machine Interface (HMI)

Fig. 7. Communication between PLC and HMI

XI. CONCLUSION

PLC is very versatile and effective tool in industrial automation. It cuts the production costs and increases the quality. Load to load time taken is 90 seconds. Troubleshooting is easy in PLC. Wiring is complicated when electromechanical relays are used, where as wiring
is easy when PLC’s are used. Hence it is reliable to operate/ control a machine using PLC.

REFERENCES


[6] Saracin, C.G.; Saracin, M.; Zdrentu, D. "Experimental study platform of the automatic transfer switch used to power supplies back-up", Advanced Topics in Electrical Engineering (ATEE), 2013 8th International Symposium on, On page(s): 1 – 6
