Operational Logic Development and Deployment for Factory Automation Using PLC

Vanditha G[1], Dr. Hemalatha. J. N.[2], Ragavendiran. L[3]

[1]Vanditha G, Student, Mtech-Power Electronics, RVCE, Karnataka, India
[2]Dr. Hemalatha. J. N., Assistant Professor, Department of EEE, RVCE, Karnataka, India
[3]Ragavendiran. L., Operations Manager, Closoft Technologies Private Ltd, Karnataka, India

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Abstract - *Testing the overall functionality of the product during the manufacturing process is an important task to detect all the potential faults of a product. The process cycle time is more and accuracy of test results are less due to manual method of product validation. This work is focused on the real time implementation of End of Line (EOL) testing machine automation in the factory-manufacturing unit to conduct ohmic and surge test on the solenoid bobbin to validate the functional unit. The Programmable Logic Controller (PLC) used is Siemens S7-300 Controller. Automation of EOL machine is implied using PLC and Human machine interference (HMI) programming in Relay Ladder Logic (RLL) using Totally integrated automation (TIA) portal. The main basis of the system is PLC program, drives the robotic arm to conduct the tests and reject the non-functional component. The switchgear components for Electrical Panel design is selected based on Input/output Points. The hardware implementation is designed using sensors, relays, MCBs, and terminal blocks and RLL is embedded in PLC using HMI.*

Key Words: PLC, HMI, Relay Ladder Logic (RLL), End of Line (EOL)

1. INTRODUCTION

Industrial automation is the operation of the system through the intelligence of PLC programming. The tasks once performed by humans are intervened by PLC through automation of the entire system. Automation is employed mainly in manufacturing, storage and baggage handling, Food processing, pharmaceutical industries. The Factory automation results in increased accuracy of the entire system with increased production efficiency, ensuring the best in quality [1].

In manufacturing industries, the functional test (FCT) is performed at the end of production line. This is commonly referred to as a final quality control test, and it is performed to ensure the FCTs meet the specification. The FCT process entails the emulation or simulation of the environment, a product is expected to operate. This is done to check for and correct any functional issues [2]. In this process, cycle time is more and accuracy of test results are less due to manual method of product validation.

A critical step in the manufacturing process is testing a manufactured unit at the end of the assembly line. Defective products, as well as those that do not closely match specification limits, must be separated from functional units. EOL testing evaluates not only the product's quality, but also the stability and yield of the manufacturing process. The primary goal of the test is to reliably detect non-functional units [3]-[5].

In the proposed work traditional method to validate the component by EOL testing is automated by applying PLC Relay Ladder Logic program to S7-300 Controller. The system is made intelligent enough to sense the presence of Bobbin and conduct the test accordingly. The graphical interface screens are developed to control the operation and to get the count of components tested. If there is no component present sensor detects it and automatically the system will be turned off [6]-[7].

2. OVERALL BLOCK DIAGRAM

Figure 1 shows the Block diagram of EOL testing station with S7- 315 PN DP Controller and IO modules. In traditional EOL testing machine automation is introduced by using PLC and HMI. Functioning of EOL Machine is when the bobbin is placed in anyone of the fixture out of eight stations the servo movement causes the movement of robotic arm down and gripper closes to hold the component in place. Ethernet module plugs directly onto remote control and switching. It is immediately detected on the network and each of the I/O points is monitored and switched from any point on the network.
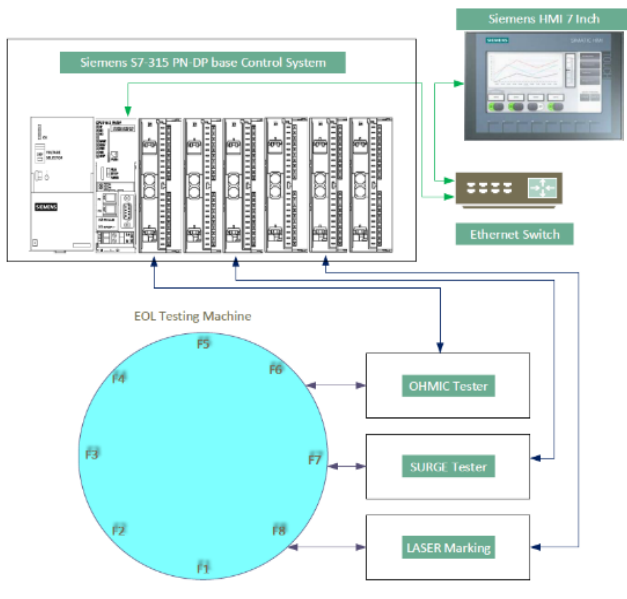
Fig -1: Block Diagram

2.1 Specification of Controller

Controller is selected as per below specifications:

MPI Protocol	Yes
Load memory, integrated	4MB
Processing time for bit operation	0.085µs/operation
Hardware configuration	3 communication modules, 1 signal board, 8 signal modules
DI, DO, AI, AO	14,10,2,2
Encoder	2 wire sensor
Interface type	PROFINET
Physics	Ethernet, 2port switch, 2RJ45

3. RELAY LADDER LOGIC

The Relay Ladder Logic is designed to achieve the desired action to conduct ohmic and surge test on the Bobbins placed in the fixture. The proximity sensor senses the part placed in fixture and cycle starts, resistance cylinder forward command will be ON, that makes the cylinder to move forward and inserts the testing part to bobbin to conduct ohmic test. If the

part is functional or non-functional either of the resistance test OK, NOT OK, dummy feedback, is turned on that gives the command to cylinder to move in reverse direction (ref Fig 2).
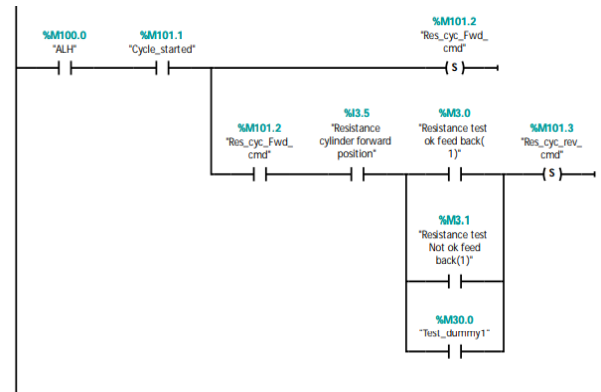

Fig - 2: RLL for Resistance Test Cylinder Movement

Inputs and Outputs (6 inputs and 2 outputs):

I0.0	ALH
I0.1	Cycle start status
I2.0	Resistance Cylinder Forward position
I2.1	Resistance test OK feedback
I2.2	Resistance test NOT OK feedback
I2.3	Dummy Part status
O1.2	Resistance cylinder forward command
O1.3	Resistance cylinder reverse command

Once the ohmic test is conducted functional and nonfunctional parts has to be separated the RLL is designed as shown in figure 3.
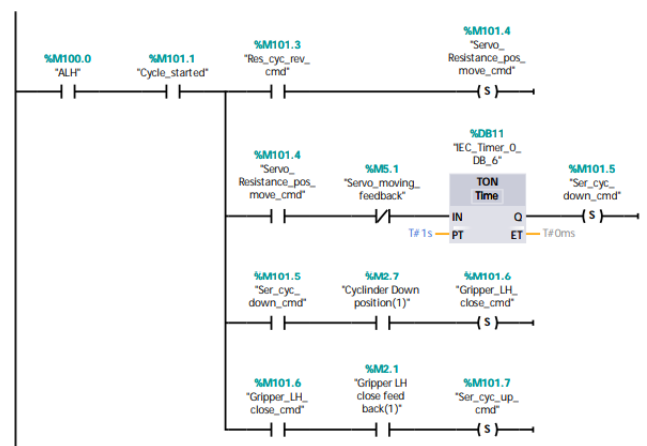

Fig -3: RLL for Resistance Test OK and NOT OK Part Separation

After the Resistance cylinder reverse command, Servo resistance position move command is initiated. The servo

cylinder down command is turned ON, Gripper holds the part and turns ON the status command, servo cylinder up command is turned ON.

Inputs and Outputs (5 inputs and 5 outputs)

I0.0	ALH
I0.1	Cycle start status
O1.3	Resistance cylinder reverse command
O1.4	Servo resistance position move command
I5.1	Servo moving feedback
O1.5	Servo cylinder down command
I2.4	Cylinder down position
I2.5	Gripper close feedback
O1.6	Gripper close command
O1.7	Servo Cylinder up command

The RLL is designed as shown in figure 4 to place the nonfunctional part in the rejection bin.
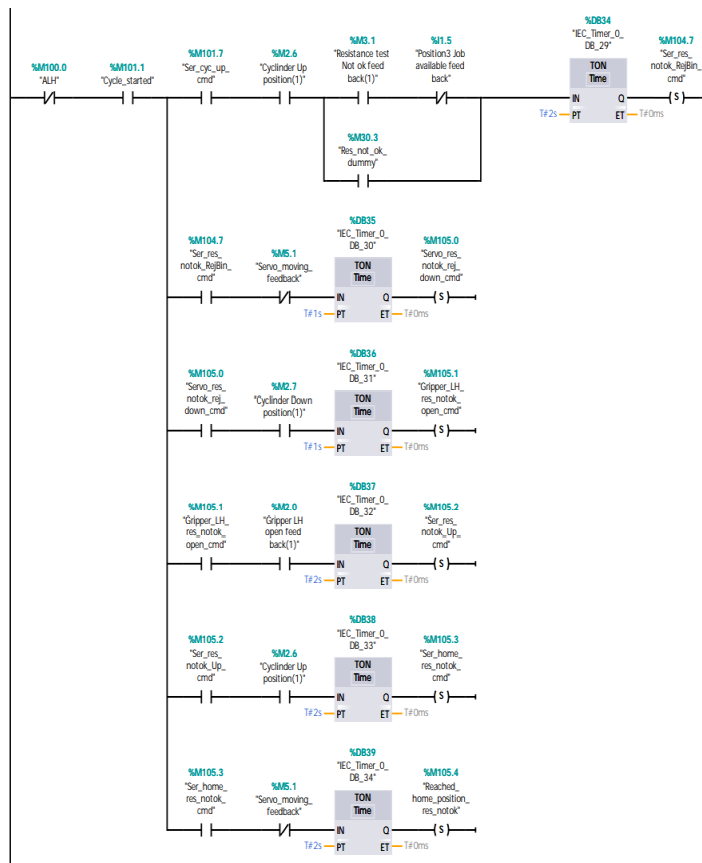
Fig -4: RLL to Place the Part in Rejection Bin

Inputs and outputs (9 inputs and 8 outputs)

I0.0	ALH
I0.1	Cycle start status
I2.5	Gripper close feedback
O1.6	Gripper close command
O1.7	Servo Cylinder up command
I2.6	Cylinder Up position
I2.2	Resistance test NOT OK feedback
I2.3	Dummy Part status
O4.1	Servo resistance not ok rejection bin command
I5.1	Servo moving feedback
O5.0	Servo resistance not ok rejection down
I2.4	Cylinder down position
O5.1	Gripper not ok open command
I2.6	Gripper open feedback
O5.2	Servo resistance not ok rejection UP command
O5.3	Servo home Not OK command
O5.4	Reached home position resistance Not ok

The Relay ladder logic program to perform surge test is as shown in figure 5 below, here ALH feedback initiates the surge test and servo movement command is passed, feedback of part tested is OK, or NOT OK command is taken.
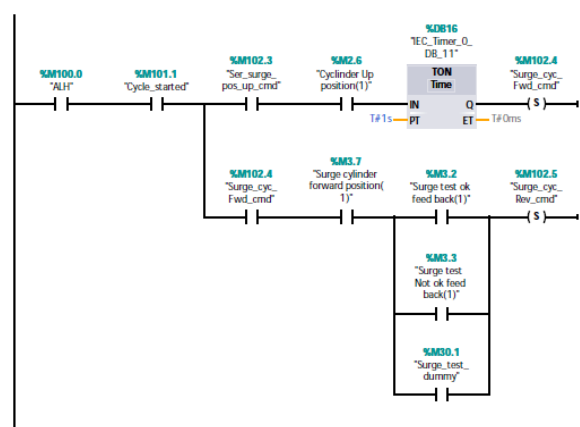

Fig -5: Surge Test Logic

After the Surge test, the part that obeys the given specification is moved to next station 3 and rejected part is moved to rejection bin. The ladder logic developed to move the bobbin to rejection bin is as shown in figure 6 below, if

the resistance NOT OK feedback is on the cylinder up position feedback is given and part placed in not ok bin is activated.
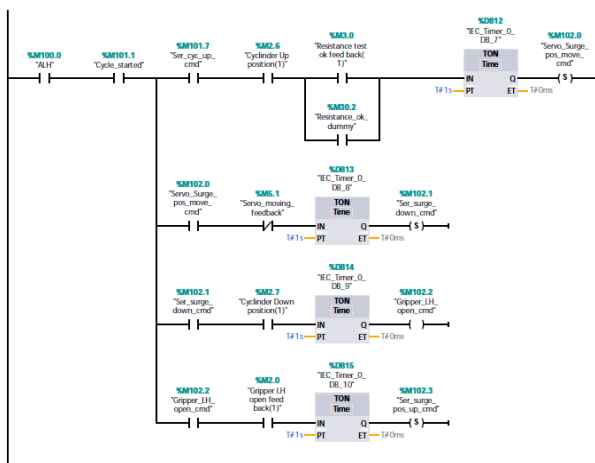

Fig -6: Not OK Part Moved to Rejection Bin Logic After Surge Test

3.1. DESIGN OF SWITCH GEAR COMPONENTS

Rating of MCB is 2 times the rating of module to be protected i.e.,

For 16 Digital inputs module with 0.5A rating,

$I = 0.5*2*3 = 3A$

Terminal Block =

Total IO points $* 2 = 72*2 = 144$

Relays = Total no of digital outputs = 26

4. RESULTS AND DISCUSSIONS

Proposed system is implemented using the programmable logic controller and results are discussed as per the input output port switching in HMI screens developed. Figure 7 shows the electrical panel with PLC implemented for control with relay, MCB and terminal blocks.
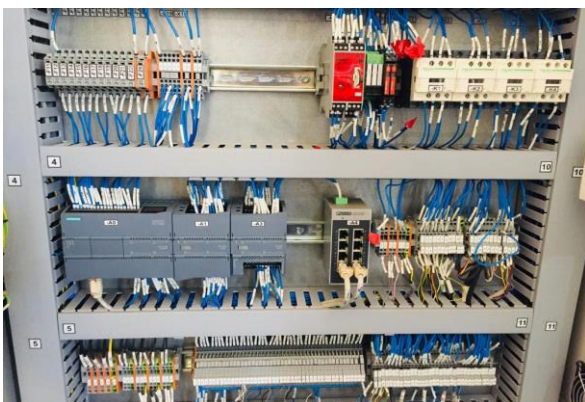

Fig -7: PLC Control Panel

The ladder logic implemented to programmable logic controller is analysed by the status of input and output command executed through the graphical interface screens developed to monitor the operation of EOL testing.

Figure 8 below shows the input status of the automated machine from the input address X0.0 to X0.7 and X1.1 to X1.5.
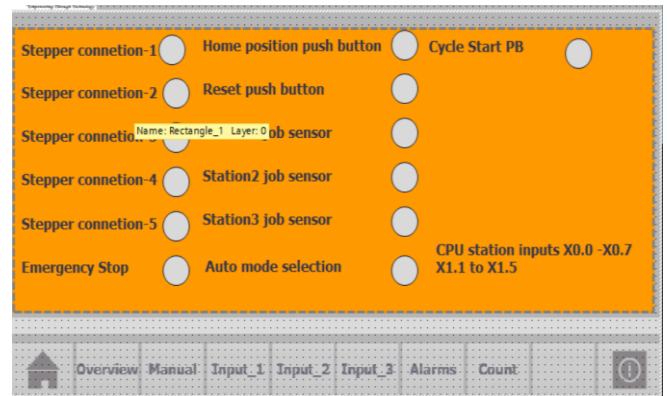

Fig -8: HMI Screen Monitoring for X0 & X1 Inputs

The input status for the Cylinder movement monitor, Gripper position, Conveyor movement, surge test and ohmic test feedback is obtained from input address X2.0 TO X2.7 AND X3.0 TO X3.7 as shown in figure 9 below.
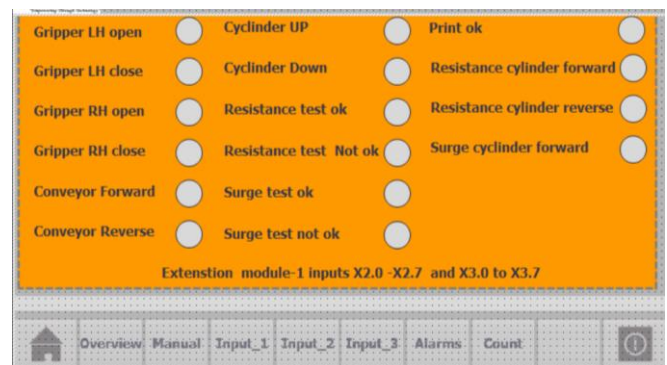

Fig -9: HMI Screen Monitoring for X2 & X3 Inputs

Figure 10 below shows the output for input extension module 1 from X4.0 to X4.7 and X5.0 to X5.7 for the stepper motor position and additional spares considered for future requirement in case of added field devices.
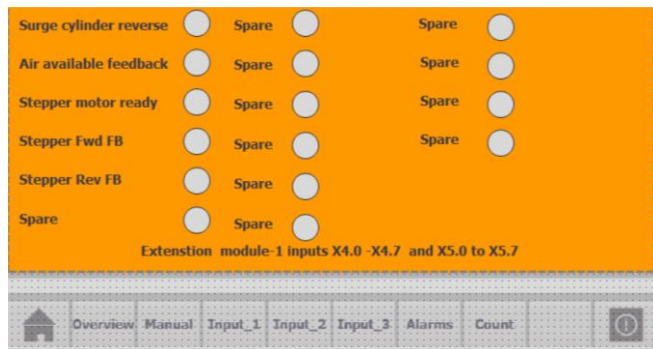
Fig -10: HMI Screen Monitoring for X4 & X5 Inputs

The output command monitoring is done through the below HMI screen as shown in figure 11 to give manual and automatic command for stepper motor, Gripper position, Cylinder movement, Conveyor movement, and Ohmic test Command.
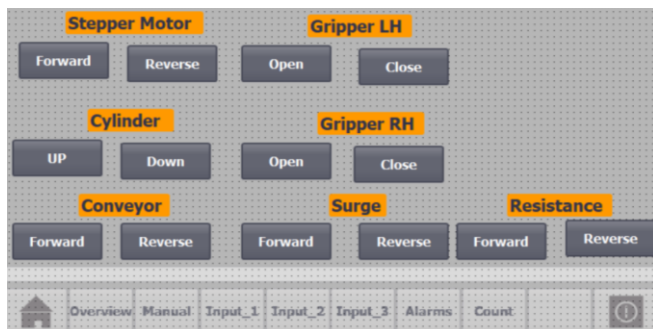

Fig -11: HMI Output Screen for Outputs

Ohmic test result is obtained by real time implementation of PLC program and establishing communication between the Agilent meter and PLC. Figure 12 below shows the meter reading after ohmic test. Table 1 represents the meter reading
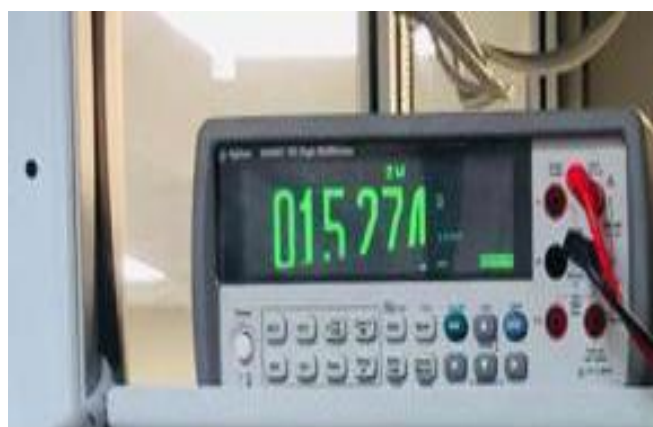

Fig -12: Ohmic Test Meter Reading

Table -1: Resistance readings

Sample 1	1.5274
Sample 2	1.5273
Sample 3	1.5281
Sample 4	1.5199
Sample 5	1.5273

Surge test result is obtained by real time implementation of PLC program and establishing communication between the Insulation testing meter and PLC. Figure 13 below shows the interpreted graph test result.
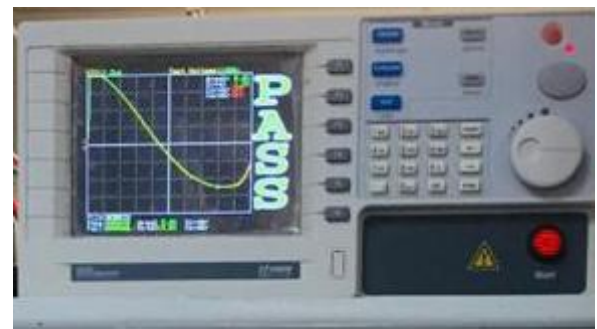

Fig -13: Surge Test Output

5. CONCLUSION

The proposed EOL testing machine was automated completely, it could sense the presence of the bobbin placed in each station and conduct ohmic test and surge test. The Relay Ladder Logic was designed and implemented in EOL machine using TIA portal and it was communicated to HMI using Ethernet switch. The proximity sensor senses the part placed in fixture and each cycle starts. The resistance values obtained in the range of 1.5 to 1.8 ohm were validated.

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