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PLC Based Contactor Test Bench

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Abstract
The purpose of the project is to carry out different test to check electromechanical contactor's parameters using Programmable Logic Controller. Contactor is a device which is used in many industrial as well as commercial applications. So it is necessary to check whether all parameters of contactor are within specified range. This test bench is a modular design which tests a contactor for its parameters (continuity, pick-up time & drop-off time). It tests the product automatically & displays result as either PASS or FAIL. Test bench gets advantage of using PLC. We can change the program as per the requirement without changing the hardware configuration in case of change in product parameter values, etc. Introduction of such a test bench eliminates human errors as well as increases productivity or rate of testing contactors because of high speed benefits of automation tools used in test bench. It takes very less time to carry out testing automatically. Further due to benefits of automation data recording facilities can be also provided with test bench so that it will be easy to check for rejected product faults.

Keywords: PLC, automation, control, process, switch and sensor.

1. INTRODUCTION

1.1 Need of test bench

Automatic contactor test bench is developed to test MNX 9 contactor parameters automatically using PLC as controller. It eliminates human errors in testing process. The productivity or rate of testing contactor is also increased because of test bench. It takes very less time to carry out testing automatically than required for manual testing of contactor.

1.2 Unit Operation for test bench

Following tests are carried out on this test bench:

1. Flashing test:

   This test is carried out at 100% of rated voltage and rated frequency for definite number of cycles. This test is basically done to ensure continuity between main and auxiliary contacts and also for proper functioning of the contactor. Any part wrongly inserted or component missing during final assembly and any such errors is elevated during flashing test.

2. Pick-up time:

   This test ensures that the contactor pick-up time is appropriate and which is within the standard specified range.

3. Drop-off time:

   This test ensures that the contactor drop-off time is appropriate and which is within the standard specified range.

1.3 General description of test bench:

The MNX contactor test bench is a automatic system designed to perform various test of MNX contactor.
It consists of:

- 1 fixture for testing 1 product at a time.

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- Fixture supporting assembly with terminal connectors
- Programmable Logic Controller
- Control Panel as Man Machine Interface

Fixture is to support product during test. It holds product in it and avoid excessive movement of product during test.
Supporting assembly has legs welded to fixture base which supports fixture and it also has terminal connectors fixed below fixture base. These connectors connect fixture IO's and control panel IO's to PLC.
PLC is the brain of test bench. It has the program that executes all test of the contactor and gives results as per standards.
The control panel and its control buttons enables use of the various operating modes and gives information of the product result.

1.4 MNX 9 Contactor

MNX Series of contactors are Power contactors. These contactors are used in actual circuit of the power consuming device and have higher current ratings up to 650A. in most of the power contactors there is inbuilt auxiliary contacts which can be conventionally used for control circuit.

MNX Contactor Features:

- Ratings: 9A to 650A
- Available in six frame sizes
- Easy inspection and replacement of coils and contacts
- Alpha-numeric terminal markings
- Front ON/OFF indication
- Aesthetic appearance
- CE marked and CSI approved
- Conforms to IEC60947-4-1, BSEN 60947-4-1, IS 13947-4-1
- Entire range UL listed
- Operating band from 62% to 120% up to 32 A

Special features of 9A- 40A Contactors

- Snap fit construction
- Finger proof terminals
- Common coil for entire range

Accessories available

- Add-on auxiliary contact block
- Surge suppressor
- Mechanical interlock kit

2. HARDWARE DESIGN AND IMPLEMENTATION

2.1 Mechanical Hardware

This section deals with the designing of the contactor fixture and whole testing assembly, drawing, materials used, etc.
The fixture is divided into two sub sections:

2.1.1 Clamping device

The product is clamped in the fixture. This ensures no miss alignment of product during test. The fixture is designed such that bottom part of contactor gets fitted into bottom part of fixture with clearance of 1 mm.

Material used- Derline, Nylon.

2.1.2 Testing assembly

a) Connecting pins: Required voltage is applied to the coil through the pins and various testing is done. Continuity is checked by pins touching on the contacts. These pins are attached to movable plate which moves when pneumatic cylinder is extended.

Material used- Brass

b) Plates: Total 3 plates are used out of which 2 are fixed and 1 is movable. Fixed plate supports the movable plate and also guides the pins to move into contactor contacts accurately. Movable plates have pins connected to PLC via plug and which get connected to contacts of the product during testing. When cylinder gets retracted movable plates

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disconnects pins from contacts of product. Springs are used for proper contacts between pins and contactor.

Material used- MS, Derline

Fig1.Design of testing assembly

Height of the movable plate is 5 mm less than that of fixed plate to have proper sliding of plate.

2.2 Electrical Hardware**:**

This section deals with the electrical components, their connections, wiring, etc.

2.2.1 Components

a) Push Button: The push button is used to start the test. This is mounted on Panel and wires are connected to its NO contact through terminal connectors according to the wiring diagram.

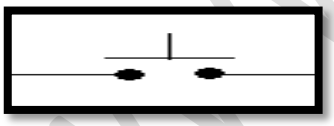

Fig2. Symbol of Push Button

Specifications of push button

Switch Type	Momentary- Round Head
Permissible Temperature for Soldering	270^{o} C for 5 sec. max.
Terminal Style	Solder-Ttype
Product Weight	4.7 gm
Mounting	Panel, Screw-Type
Mechanical Life	50,000 Cycles
Materials- Terminals	Copper, Silver Plated
Contact Arrangements	DPDT, push button switch
Contact and Voltage Ratings	3 A, 250 V AC
Electrical Life	10,000 Cycles

b) Emergency stop push button: The rocker switch is used as an emergency stop device is a manual control device. It is the method of initiating the emergency stop function. The actuator of an emergency stop device is the component that is actuated by a person.

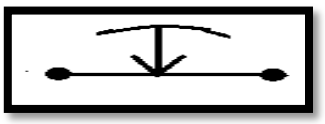

Fig3.Symbol of emergency switch Specifications of emergency switch

Mechanical Life	300,000 operations
Operating Force	0.8 kg
Mounting Adapter Plastic Button	Fixed to the mounting surface using incorporated screws (Tmax = 0.6 Nm)
Environmental Rating	IP65; NEMA 4, 13
Operating Temperature	-25^{o} to $+60^{o}$ C (-13^{o} to

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	+140° F)
Mechanical Life	1,000,000
Connection	(1 or 2) 12AWG ($2.5mm^2$) maximum wire size

c) Pilot Indicator: The main function of pilot light is to signalize when an event occurs or to indicate a state. The source of light is LED. It gives optimum perception due to the ideal colour rendering. Besides, it is reliable and cost saving due to its long lifetime.

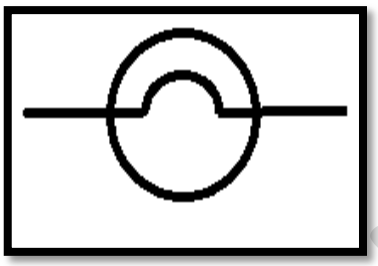

Fig4. Symbol of Pilot Indicator

Specification of Pilot Indicator

Rating	24V DC, 2Wmax.
Terminal Capacity	Screw Connection
Rated Insulation Resistance	500M ohm at 1000V DC
Current Consumption (maximum)	15mA for DC circuit
Viewing Angle°	More than 100
Corrosion Protection	All metallic parts are electroplated for corrosion protection
Contact Material	Phosphor bronze for LED, PCB contact brass (tin plated)
Temperature Range	-25° to +70°C (-13° to +158°F)
Degree of Protection	IP65

d) Limit Switch: A switch that limits the activation of an electrical circuit is a limit switch. Switches can control the flow of electrical current by opening and closing. When a circuit is closed, it allows electrical current to flow to the device that is powered. When open, the electrical flow stops. A Mechanical limit switch is a mechanical device which can be used to determine the physical position of equipment. The limit switch gives ON/OFF output that corresponds to object position.

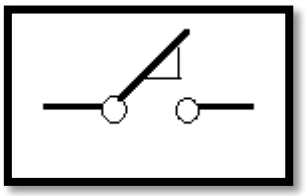

Fig5. Symbol of Limit Switch

Specification of Limit switch

AC Ratings	0.1A to 3A, 125V AC
Electrical life	100,000 cycles per min.
Operating Temperature	0°C to +55°C
Pre Travel	<0.5mm
Over Travel	0.2mm min.
Movement Differential	<0.2mm

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Nominal Input Voltage	24V DC
Typical input Voltage	18 mA
Typical Response Time	8 mS
Typical Release Time	10 mS
LED Indication	Yes
Contact Configuration	DPDT
Maximum Switching Voltage	250V AC/DC
Minimum Switching Voltage	5 V
Continuous Current	6 A
Maximum Inrush Current	8 A
Minimum Switching Current	10 mA
Contact Gap	<3mm
Operating Position	5.5+ 0.3mm

e) Relay: A relay is similar to a switch; it is either open or closed. When the switch is open no current passes through the relay, the circuit is open, and the load that is connected to the relay receives no power. When a relay is closed, the circuit is completed and current passes through the relay and delivers power to the load.To open and close a reelay an electromagnet is used. When the coil controlling the electromagnet is given a voltage, the electromagnet causes the contacts in the relay to connect and transfer current through the relay. Here relay is DPDT relay, which is used to energize contactor coil frequently via 24V DC control signal.

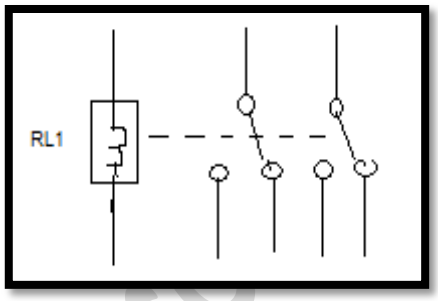

Fig6. Symbol of Relay

Specification of Relay

1.2.2 Wiring Diagram:

Wiring diagram for the project as per component terminals is as follows; it includes connections to fixture as well as to the control panel.

The wires are tagged according to component connections to PLC. Table below describes tag of each component on panel as well as fixture.

2.3 Control Panel

A control panel is a flat, often vertical, area where control or monitoring instruments are displayed.They are found in factories to monitor and control machines or production lines and in places such as nuclear power plants, ships, mainframe computers and air craft. Older control panels are most often equipped with push buttons and analog instruments whereas today in many cases touch screens are used for monitoring and control purposes.

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Fig7. Figure of control panel

The control panel for this test bench has indication for all test as well as inputs that the user has to give to PLC for starting operation of the test bench.

2.4 Pneumatic Section

This section deals with the pneumatic components, specifications, connection diagrams and accessories used.

2.4.1 Components:

Cylinder: Pneumatic cylinder (sometimes known as air cylinder) is mechanical device which produce force, often in combination with movement and are powered by compreesed gas (typically air).

Types of pneumatic cylinder:

1) Single acting cylinder
2) Double acting cylinder
3) Double rod end cylinder
4) Tandem cylinder
5) Telescopic cylinder

Single acting cylinder:

Solenoid valve: A solenoid valve is an electromechanical valve for use with liquid or gas. The valve is controlled by an electric current through a solenoid; in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports.

Types of solenoid valve:

1) 2 way solenoid valve
2) 3 way solenoid valve
3) 4 way solenoid valve

Compressor: The air compressor is the source of compressed air that a pneumatic tool is powered by. The hosing is run from the air compressor to the equipment carrying the compressed air. The tool manipulates the work piece.

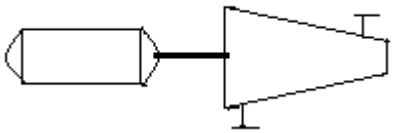

Fig8. Symbol of compressor

Air Filter Regulator (AFR): It removes solids and liquid contaminants to prolong service life of actuators, solenoid valves, positioners, I/P pressure transducers and other pneumatic controls. The use of clean, dry plant air reduces the costly repairs associated with water and particulate contaminants present in supply air. The filter regulator combines the functions of a filter and pressure regulator into one compact, rugged design

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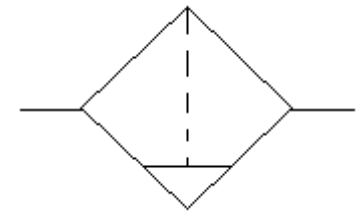

Fig9. Symbol of AFR

2.4.2 Drawing

Pneumatic Drawing

Above figure shows pneumatic connections for test bench. Compressed air is taken from compressor and is given to DCV via AFR.

DCV is solenoid operated 3/2 valve which drives single acting cylinder. When solenoid is energized SAC will extend and will retract when solenoid is de-energized.

Pneumatic tubing and connectors are used to connect components to each other.

2.5Algorithm

In this three test are carried which are flashing test, pick-up time & drop-off time as follows:

- Flashing test:

1) Whether the contactor is placed in the fixture is detected using a limit switch & its presence or absence in indicated using indicator.
2) If the object is present then the process is started.
3) The pneumatic cylinders are extended to its full stroke length so that pins get connected to contactor contacts.
4) When limit switch 2 sense the position of cylinder the contactor is energized through a relay & de-energized with a proper delay.
5) Continuity of R,Y,B contacts is checked using counter function which should exceeds lower limit of counts desired.
6) If limit is exceeded then product is PASS& go for next test.
7) If limit is not exceeded then product is FAIL is indicated.

- Pick-up time:

1) Apply voltage to contactor coil through relay.
2) Record the time between energizing the coil and contacts are closed.
3) Check that this time is within specified limit.
4) If it is within limit then indicate that product is PASS.
5) If it is not within limit then indicate that product is FAIL.

- Drop-off time:

1) Apply voltage to contactor coil through relay.
2) De-energized the coil after some time and record the time between de-energizing the coil and contacts are open.
3) Check that this time is within specified limit.
4) If it is within limit then indicate that product is PASS.
5) If it is not within limit then indicate that product is FAIL.

2.5 Operation

Steps to perform test;

1. Switch on mains and other power supplies including pneumatic supply.
2. Insert the product into the fixture.
3. Ensure that it is aligned perfectly (check that CONTACTOR NOT FOUND indicator is OFF)

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4. Ensure compressor pressure has reached minimum limit.
5. Press START button on panel.
6. Wait for indication of PASS or FAIL on panel.
7. Note for which test product is failed and take appropriate action in case of failure.

3. Software Details

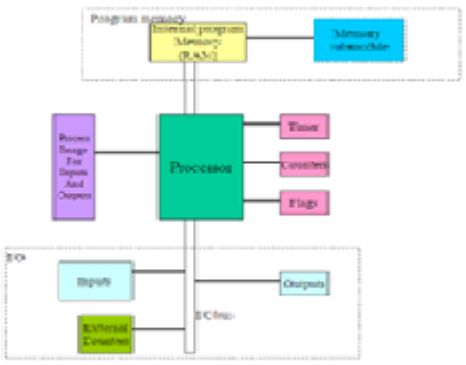

Fig10. PLC Architecture

3.1. Introduction

APLC, is a small computer with a built-in operating system (OS). This OS is highly specialized to handle incoming events in real time, i.e. at the time of their occurrence.The PLC has input lines where sensors are connected to notify upon events (e.g. temperature above/below a certain level, liquid level reached, etc.), and output lines to signal any reaction to the incoming events (e.g. start an engine, open/close a valve, etc.).The system is user programmable. The PLC is primarily used to control machinery. A program is written for the PLC which turns on and off outputs based on input conditions and the internal program. It is designed to be programmed once, and run repeatedly as needed. It can run an automatic machine for years with little human intervention. They are designed to withstand most harsh environments.

3.2Basic Elements of PLC

PLC mainly consists of a CPU, memory areas and appropriate circuits to receive input/output data. We actually consider the PLC to be a box full hundreds and thousands of relays, counters, timers and data storage locations. They don't physically exist but rather they are simulated and can be considered as software counters, timers, etc. Each components of PLC has specific function.

3.2.1. Languages in PLC

1. Ladder Diagram
2. Functional Block Diagram
3. Structural text
4. Instruction List
5. Sequential functional chart

From the above mentioned languages ladder diagram is explained as follows:

3.2.2. Ladder Diagram

The ladder diagramhas the traditional way of representing electrical sequences of operations. These diagrams represent the interconnection of field devices in such a way that the activation or turning ON, of one device will turn ON another device according to a predetermined sequence of events. Ladder logic uses graphic symbols similar to relay schematic circuitdiagrams.
Ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines between these two verticals.

1. Ladder diagram features-
   1. Power flows from left to right.
   2. Output on right side can not be connected directly with left side.
   3. Contact can not be placed on the right of output.
   4. Each rung contains one output at least.
   5. Each output can be used only once in theprogram.
   6. A particular input a/o output can appear in more than one rung of a ladder.7.The inputs a/o outputs are all identified by theiraddresses, the notation used depending on the PLC manufacturer.

4. Conclusion / Future Scope:

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The MNX9 contactor is tested for its parameters with the help of PLC. It is easy to test the product automatically rather than testing it manually. Time required to test the product is also decreased with the benefits of automation tools. Indication of pass/fail helps to sort product accordingly.

Thus with proper interfacing of software with hardware can improve this test bench to test many products at a time. Further HMI can be provided with interfacing PLC to PC and using SCADA or Visual Basic. Visual Basic will also provide facility of data recording if bar coding is provided with the product.

In future pick and place assembly can be added to this test bench to take product into fixture automatically and take out product after test is over.

So we conclude that contactor testing can be automated with proper PLC and HMI , making use of PLC can make testing more advanced.

5. Manufacturers

These are generally incorporated in industries where contactors are manufactured also where there is constant use of this device. Some of the industries are:

1) L & T., Mumbai
2) Siemens Ltd., Mumbai
3) English Electric. Pondicherry.
4) L-Con Components, Chandigarh.
5) ABB., Bangalore.

6. Reference

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