Automation of Shell and Tube Heat Exchanger using PLC

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Abstract— Heat exchanger is a unit operation used in many industrial processes for transfer of thermal energy. The main purpose of HE is to maintain specific temperature conditions, which is achieved by controlling the exit temperature of the process fluid in response to the variations of operating conditions. In this paper PLC control schemes to maintain exit temperature of process fluid is discussed. Here process fluid (i.e. cold fluid) temperature is maintained using hot fluid. Simple feedback temperature control loop can be implemented to regulate controlled variable i.e. outlet temperature of cold fluid with manipulation of hot fluid flow. Experimental results for more optimum control using cascade loop with temperature controller (primary feedback controller) combined with disturbance function cold fluid inlet flow controller are used to regulate the temperature of outlet fluid of shell and tube HE system to overcome due to deviations in the input fluid flow.[4].

Keywords: PLC control, Heat Exchanger, RTD

I. Introduction

Heat exchanger is a device that is used to transfer thermal energy between two or more fluids. There are different types of heat exchangers used in industries, Shell and Tube heat exchangers are having special importance in boilers, oil coolers, condensers, pre-heaters. Shell and Tube heat exchanger is one such heat exchanger, provides more area for heat transfer between two fluids in comparison with other type of heat exchanger. This operation is often performed in heat exchangers where the hot or cold fluid flows inside and outside the tubes. Shell and tube heat exchangers are most widely used in practical applications. In this paper we have presented automation system comprising temperature sensors, PLC (AB micrologix 830) as controller and pneumatic valves as final control elements. The designed controller (PLC) regulates the shell outlet temperature of the fluid to a desired set point in the shortest possible time. SCADA system is used to give a virtual display of the proposed process. [4] The end system is a fully automated for the transfer of energy in industrial applications. PLC is a digital electronic device which uses a programmable memory to store instructions and data and implement specific function such as timing, counting, logics etc. To configure the devices with the PLC we have used CC Workbench (Connected Components Workbench) software. Connected Components Workbench design and configuration software offers many advantages over controller programming, device configuration, and integration with HMI editor. This software is developed based on proven Rockwell Automation and Microsoft Visual technology and is

Easy to configure: this single software package reduces initial cost and machine development time.

Easy to program: it simplifies programming process with sample code and user defined function blocks.

II. Reviews of literature

A. Heat Exchanger

A heat exchanger is a device used to transfer heat between two or more fluids.

Heat naturally flows from higher temperature to lower temperature, on this principle heat exchanger works. Therefore if separation of a hot fluid and a cold fluid is done by a heat conducting surface heat will transfer from the hot fluid to the cold fluid. There are parallel flow, cross flow and counter flow arrangement to obtain better efficiency. This paper deals with counter flow arrangement as shown in Fig 1, as maximum heat transfer between two fluids can be achieved using this kind of arrangement. Countercurrent flow and long passage lengths enable close temperature approaches and precise temperature control.

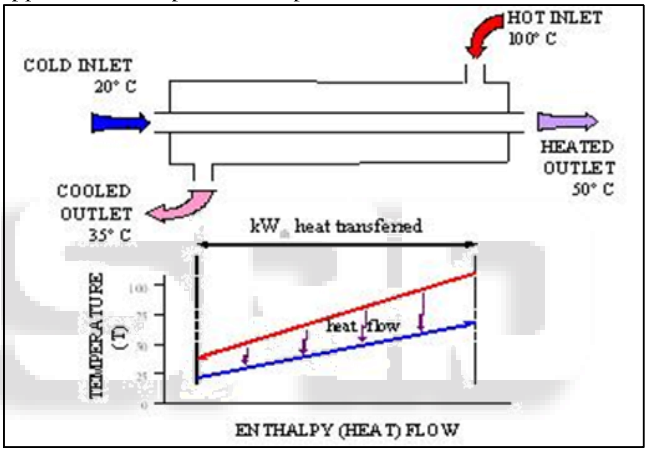

Fig. 1: Counter flow Heat exchanger

1) Shell and Tube Type Heat Exchanger

The shell and tube heat exchanger consists of a shell, usually a circular cylinder, with a large number of tubes, attached to an end plate and arranged in a fashion where two fluids can exchange heat without the fluids, coming in contact with one another. The most common types of heat exchangers configurations is illustrated in Fig: 2. Shell and tube heat exchangers have multiple tubes through which liquid flows. The tubes contains process fluid (cold fluid) and the other fluid used as utility is hot fluid which flows through shell side passes. Baffles are utilized to direct the fluid through the tube bundle and are designed and strategically placed to optimize heat transfer A measure of the complexity of predicting shell side heat transfer can be obtained by considering the path of shell side fluid flow. The flow is partially perpendicular and partially paralleled to the tubes. It reverses direction as it travels around the baffle tips and the flow regime is governed by tube spacing, baffle spacing and leakage flow paths. Throughout the fluid path, there are a number of obstacles and configurations, which cause high localized velocities and minimize pressure drop.

B. Shell

- Heat exchanger is placed on the stand for support and convenience.
- Shell is made up of mild steel with the length of 956mm and diameter 100mm.
- Total opening – 4

2 for water inlet
2 for water outlet

C. Tubes

- It consists of 7 copper tubes internally placed in the shell.
- For better turbulence of water, 2 baffles are placed internally at equal distance.

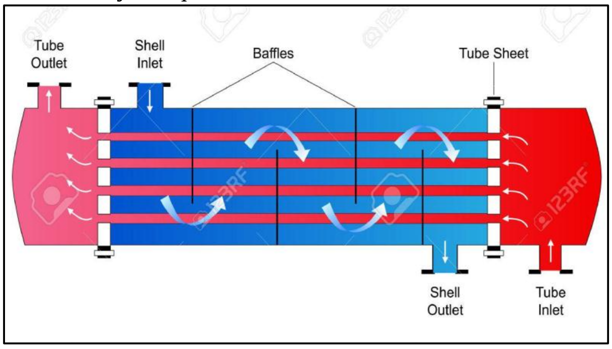

Fig. 2: Shell and Tube Heat Exchanger (Counter flow arrangement)

D. PLC (Programmable Logic Controller)

Fig. 3: Micro830® Programmable Logic Controller

The Micro830® controller allows easy incorporation of as many as five plug-in modules. The plug-in modules enable machine builders to personalize the controllers to increase functionality without expanding the product footprint. The new controller family also offers removable terminal blocks (most models) and communication via serial port. Transistor Output models have been enhanced with embedded motion capabilities with up to 3 axes of motion, allowing these controllers to support a wider range of applications. Connected Components Workbench software is used among the entire Micro800 family of controllers, as well as other component products, such as PanelView Component HMIs and PowerFlex drives. Based on proven Rockwell Automation and Microsoft Visual Studio technology, the new software provides controller programming, device configuration and data sharing with the HMI editor for PanelView Component operator products. In addition, the software supports three standard IEC programming languages: ladder diagram, function block diagram and structured text. [1]

Micrologix 830 (Allen Bradley)

Power supply	Base unit has 24v DC
Base digital I/O	16 10 inputs/6 outputs
Base analog I/O channel	4 2 input/2 output
Base programming PORT	Embedded USB (2.0) (Non isolated)

Table 1: PLC specifications.

E. Resistance Temperature Detector (RTD)

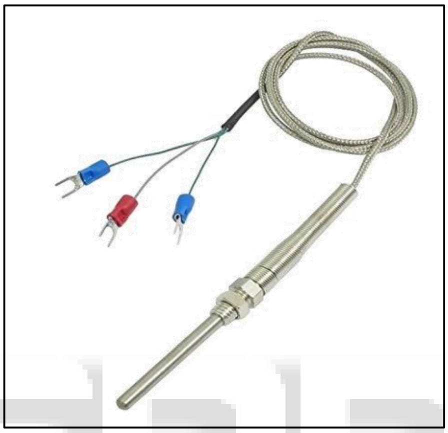

Fig. 4: RTD Pt 100

The resistance of highly conducting materials increases with increase in temperature. Here we are using RTD Pt-100 is more linear than Ni and Cu. With the operating range of -200 to 500 °C.

A three-wire configuration can be used, in order to minimize the effects of the lead resistances. The two leads to the sensor are located on adjoining arms. To cancel out the resistance there is a lead resistance in each arm of the bridge, so that the two lead resistances are accurately the same.

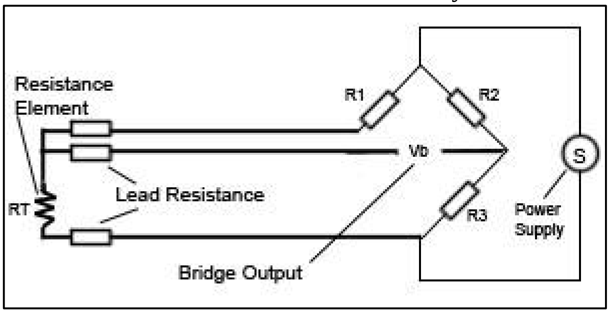

Fig. 5: Three wire configuration

1) Advantages of RTD

1) Stable for long periods of time
2) Ease of recalibration
3) Accurate reading over relatively narrow temperature spans.

2) Disadvantages of RTD

1) Smaller overall temperature range
2) Higher Initial cost
3) Less rugged in high vibration environments
4) They requirement more complex measurement circuit

5) Self-Heating when high accuracy is needed.

F. Temperature Transmitter (FR- block)

Temperature transmitter is an electrical instrument that interfaces a temperature sensor (e.g. thermocouple, RTD) to a measurement of control devices like PLC, DCS, loop controller etc.

This is a head mounted temperature transmitter connected to any standard Pt-100 resistance sensor which converts the linear temperature to 4-20 mA signal.

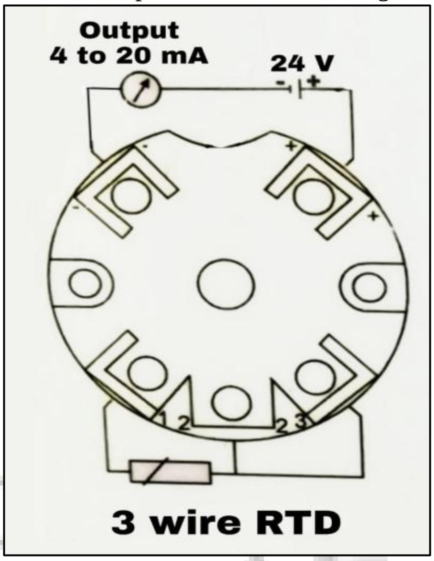

Fig. 6: Temperature Transmitter

G. I to P Converter

The I/P (i.e. current to pressure) converter uses an electromagnetic force balance principle to change electric signal into pneumatic signal. The input current flows in the coil and produces a force between the coil and the flapper valve as shown in the fig: 7, which controls the servo pressure and the output pressure. A current to pressure converter converts an analog signal to a pneumatic output, the pneumatic output generated is proportional and linear to the input current. I/P converter coverts 4-20 mA to 3-15 psig.

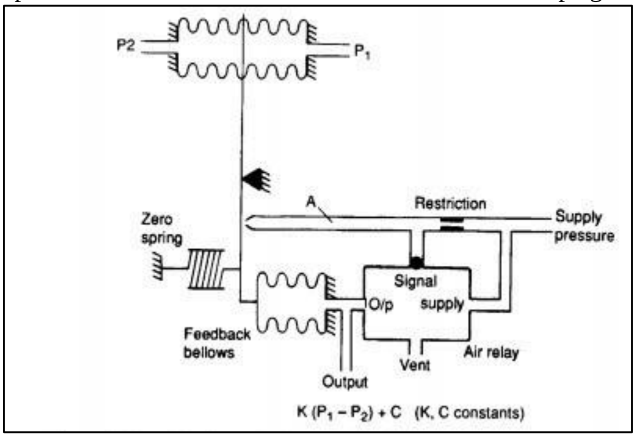

Fig. 7: Force balance principle for I/P converter

H. Air to Close Control Valve:

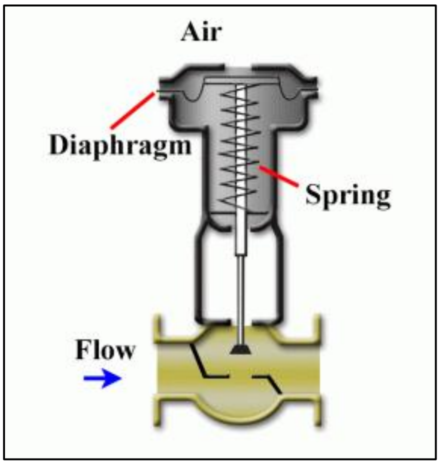

Fig. 8: Pneumatic control valve.

A control valve is a valve used to control fluid flow by varying the size of the flow passage as directed by a signal from a controller. This enables the direct control of flow rate and the consequential control of process quantities such as pressure, temperature and liquid level.

III. PANEL DESIGNING

Design for Control Panels Considerations

A. Enclosures:

Panel Dimensions – 75cm x 45cm
Material - MS plate
Type - vertical stand panel

B. Wire Sizing and Component Types:

We have considered the wire size based on the load current i.e. the protection of the circuit is based on the wire size. By selecting the proper wire size, it reduces the risk of fire by preventing wires from overheating

C. Control Components and Circuits:

There are variety of components like 4-channel relay, Switch Mode Power Supply (SMPS), Junction box, Mini circuit breaker (MCB) switch, terminals, Switches and PLC.

D. Labeling:

Labeling of all wires, terminals and other components has been done by using ferules. By labeling, the error of margin reduces while routine testing, maintenance and repair.

E. Front Panels and Faceplates:

We have taken care that the Mini Circuit Breaker (MCB) is isolated from all the components, while considering the safety. [5]

1) *PLC trainer kit designing on AutoCAD*

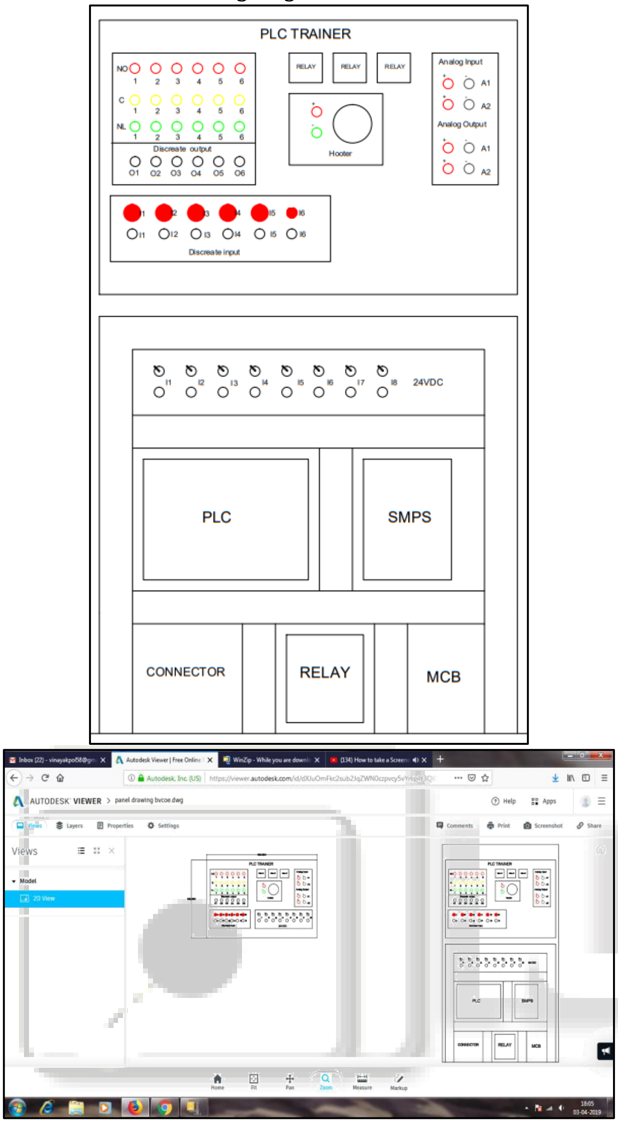

Fig. 9: PLC trainer kit

IV. CONTROL SCHEMES

The HE works on the principle of transfer of thermal energy between tow fluids without mixing them. Controlling the temperature of process fluid at specific and stable set point is challenging, however these challenges can be overcome by understanding different control schemes.

A. Feedback control scheme

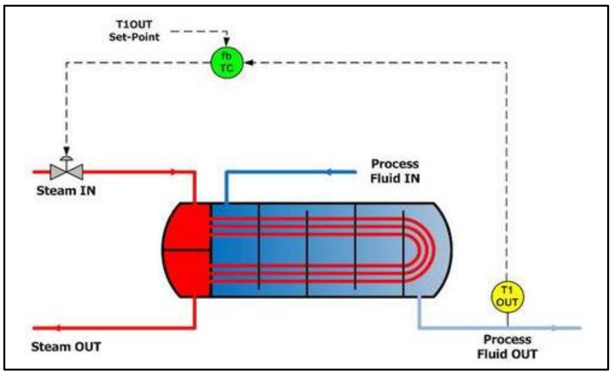

Fig. 10: Feedback control

In the feedback control scheme, temperature of the process fluid out (T1 out) is measured and applied to the feedback temperature controller (fb TC) which compares the process variable to the set point and accordingly generates the control action i.e. open or closes the steam valve.

Regardless of the disturbance sources, the controller will take corrective action- this is the most important advantage of feedback control scheme. [3]

B. Cascade Control Scheme

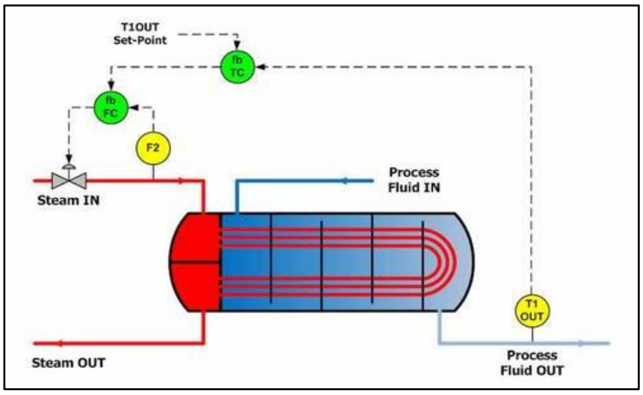

Fig. 11: Cascade control

In the cascade control scheme, the temperature of the outlet fluid is given to the temperature controller but the output of the temperature controller is not directly given to the control valve, it is instead fed as the set point to the steam flow controller (fbFC)s show in the fig: 11 Here temperature loop is the primary loop and steam flow control loop is the secondary loop.

By implementing the cascade strategy, the feedback flow control loop fbFC will adjust the valve position immediately when the steam flow rate has changed to bring the flow back to the value of the previous steady-state condition (because the flow setpoint given by the temperature controller didn't change as the outlet temperature did not yet change), preventing a change in the outlet temperature before it happens. [3]

V. PROGRAM ALGORITHM

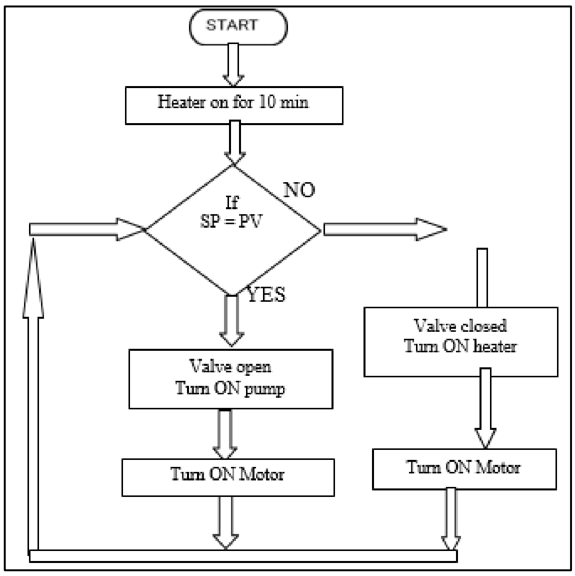

Fig. 12: Program Algorithm.

A. Ladder Logic

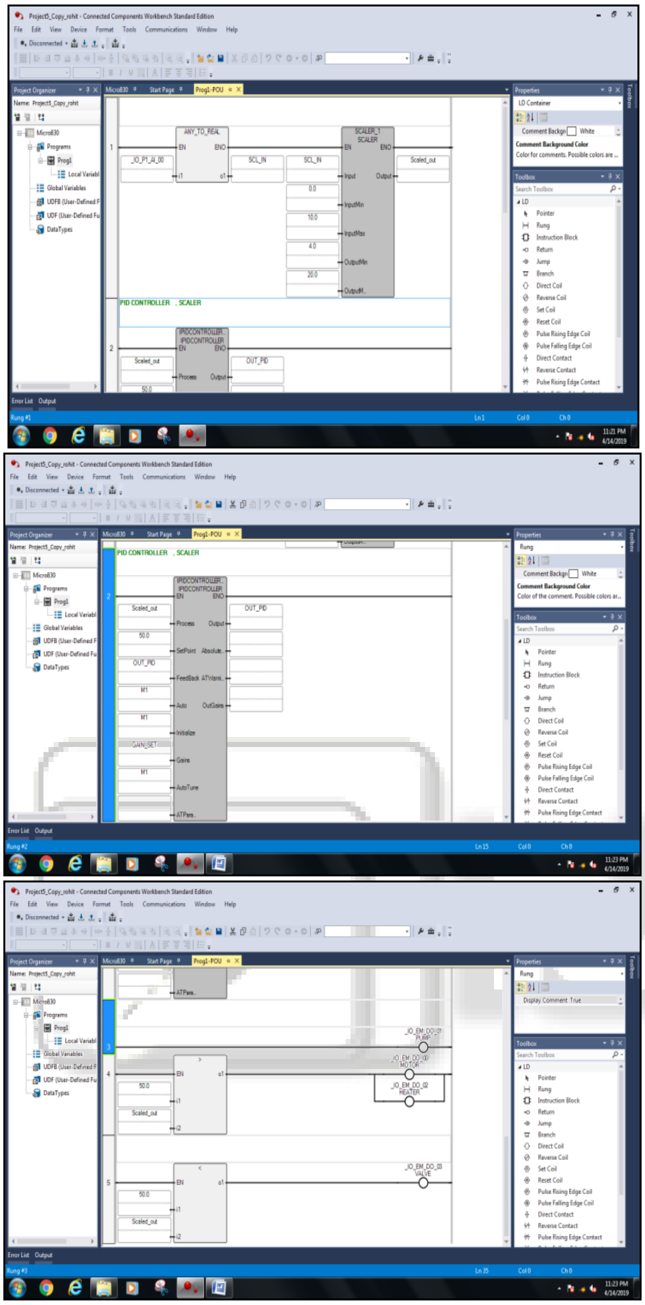

Fig. 13: ladder logic program

1) Once start switch is ON, turn the heater ON for 10 minutes.
2) After 10 minutes as the heater gets OFF, check the set point and the process variable (outlet temperature)
3) If the process variable is below set point, then turn the heater and the motor ON.
4) If the process variable is above the set point, then turn the pump ON.

VI. CONCLUSION

One of the first and simplest advantages of PLC is reliability and thus controlling a temperature control loop using PLC is become easier. The internal relay system of PLC is solid state, which means that the relay function is not mechanical like conventional relay systems and PID block.

In PLC system, a good technician can read through the programming and usually figure out what is and isn't working. In a relay system, their will be several more wires plus the relay and possibly other components that aren't needed in the PLC. It becomes easy to troubleshoot the PLC system with multiple output versus the relay system with four times the numbers of wires.

Most of the physical relay, timers, counters and controllers from a realy logic system are all contained in the PLC itself.

One of the best features that the PLC system has over a traditional relay system is versatility with the programming and easy expandability.

Scaling feature in PLC ladder diagram makes operator to obtain real time temperature values. We learned that how Overall combination of software & hardware makes the system more easy and convenient.

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