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Modelling, Controlling and Monitoring of Heat Exchanger using Cascade Controller

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Abstract—In every power plant, the heat exchanger system is one of the most important part and has its own significance in their function. The shell and tube heat exchanger is the most commonly used type of heat exchanger. Since the performance characteristics of shell and tube heat exchanger is non-linear, time varying and time lag. The mathematical model for the function of each element of control loop has been developed and the temperature control system of shell and tube heat exchanger by conventional PID controller and cascade controller has been designed. The simulation of the conventional PID controller and cascade controller was done using MATLAB. The set point tracking and load disturbance rejection features of the controllers are analyzed using different transient criteria and error parameters. The simulation results shows that the performance of cascade controller outperforms the conventional PID controller.

Keywords:-Shell and Tube Heat Exchanger ; Conventional PID Controller; Cascade Controller; MATLAB

I. INTRODUCTION

Heat exchanger system has a wide range of application which includes power generation,oil and gas industry, chemical processing. The heat exchanger system takes a heated or cooled source from one resource and use is to cool or heat a source in another process. This transfer of heat occurs without the two products coming into physical contact with each other.

There are various types of heat exchanger systems. The most typically used are shell and tube heat exchanger and plate heat exchanger system.To maintain specific temperature condition of any process is done by heat exchanger which can be achieved by controlling the output temperature of one of the medium in response to operating condition.

The objective of developing a control model for controlling a systems using a control action without delay or overshoot and ensuring its control stability. Doing this type of a controller with requisite corrective behavior is needed. Generally the controller monitors controlled process variable (pv), and then compares it with the reference or set point (sp). The difference between actual value of process variable and desired value of the process variable, is called error signal, and it is applied as feedback to the system for generate a control action to get the controlled process variable to the same value as the set point given.

Tuning of PID controller is mostly a wide area with many tuning rules, where the main objective of tuning a PID is to formulate such a tuning rules which can be characterized from mathematical model of the system. Generally PID controller has a three parameters which are mostly tuned by using empirical tuning rules like ziegler-nichols but this tuning method is not always suitable for all kind of process dynamics. The process also have its own dynamics such as long dead time, oscillatory behavior and unstable. There are different set of conditions and their different set of tuning rules available for each and every process dynamics.

The performance of control techniques of conventional PID controller and cascade controller are analyzed in this paper for controlling a regulatory control process.

II. LITERATURE SURVEY

This chapter deals with the literature survey of Modeling, control and monitoring of heat exchanger systems. Various details and information are collected from these sources.

***[1]SubhransuPadhee (2014*)** had analyzed the performance of different controllers such as feedback, feedback plus feed-forward and internal model controller to regulate the temperature of outlet fluid of a shell and tube heat exchanger to a certain reference value. The transient performance and the error criteria of the controllers are analyzed and from the simulation results, it was found out that the internal model control outperforms feedback PID and feedback plus feed-forward controller.

[2] AbdulrahmanA.A.Emhemed, Rosbi Bin mamat and DirmanHanafi (2012) had developed a heat exchanger mathematical model in this case is constructed using dynamic modelling based on real parameters of the heat exchanger. The simulation result shows almost similar trend of responses with the experiment result, it means they are can used as a model of the heat exchanger.

[3]Mr .P. Sivakumar, Dr. D. Prabhakaran and Dr. T. Kannadasan (2012) had implemented the temperature

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control system of the shell and tube heat exchanger by combining fuzzy and PID control methods. The simulation and experiments are carried out, making a comparison with conventional PID control showing that fuzzy PID strategy can efficiently improve the performance of the shell and tube heat exchanger.

[4] Salam K.Al-Dawery, Ayham M. Alrahawi and Khalid M. Al-Zobai (2012) had developed dynamic modeling and control of heat exchanger. The mathematical model developed for the plate heat exchanger shows a considerable level of non-linearity. Based on the result obtained from their developed model they concluded that their model can used as a tool to enhance the operation of the plate heat exchange. 22

[5] Chhaya Sharma, Sanjeev Gupta and Vipin Kumar (2011) had developed the model equations for closed loop temperature control of heat exchanger used in soda recovery Sectionof Star Paper Mills Ltd., Saharanpur (U.P) and the performance analysis of module is examined with PID controller by varying the controller parameters and set-points.

III. DISTURBANCES IN HEAT EXCHANGER

The disturbances are also called as the load variables. These variables represent the input variables that cause the controlled variables to deviate from their respective set points. The various disturbances of heat exchangers are surrounding ambient temperature changes, change in flow rate of the flowing fluid. The effect of disturbances are on measurable intermediate or secondary process output which directly affects the primary process output that we wish to control the gain of the secondary process including the actuator is non-linear. The cascade control system can limit the effect of disturbances entering the secondary variable on the primary output and the control system parameters. The gain variations usually arise from changes in operating point due to set point changes or sustained disturbances.

IV. PROPOSED SYSTEM

The schematic diagram of temperature control of the heat exchanger is shown. The shell side of the heat exchanger is fed with input cold water and the tube side is supplied with steam. The output temperature of the heat exchanger is measured by using a 2-wire RTD which is connected to the transmitter.Theoutput produced by the transmitter is standard 4-20mA which is proportional to the temperature.The output from the transmitter is given to the PC device which is connected via DAQ card.The PC output is current signal which is connected to the current to pressure converter.This converter produces pressure output based upon the appropriate current signal produced by the control action of the PC which is used to actuate the steam valve in proper manner.Generally there are two objectives of cascade controller,the effect of disturbance on the primary process output is suppressed by the action of secondary process and the other objective is that the sensitivity of primary process variable is reduced in order to gain variations in the inner control loop.

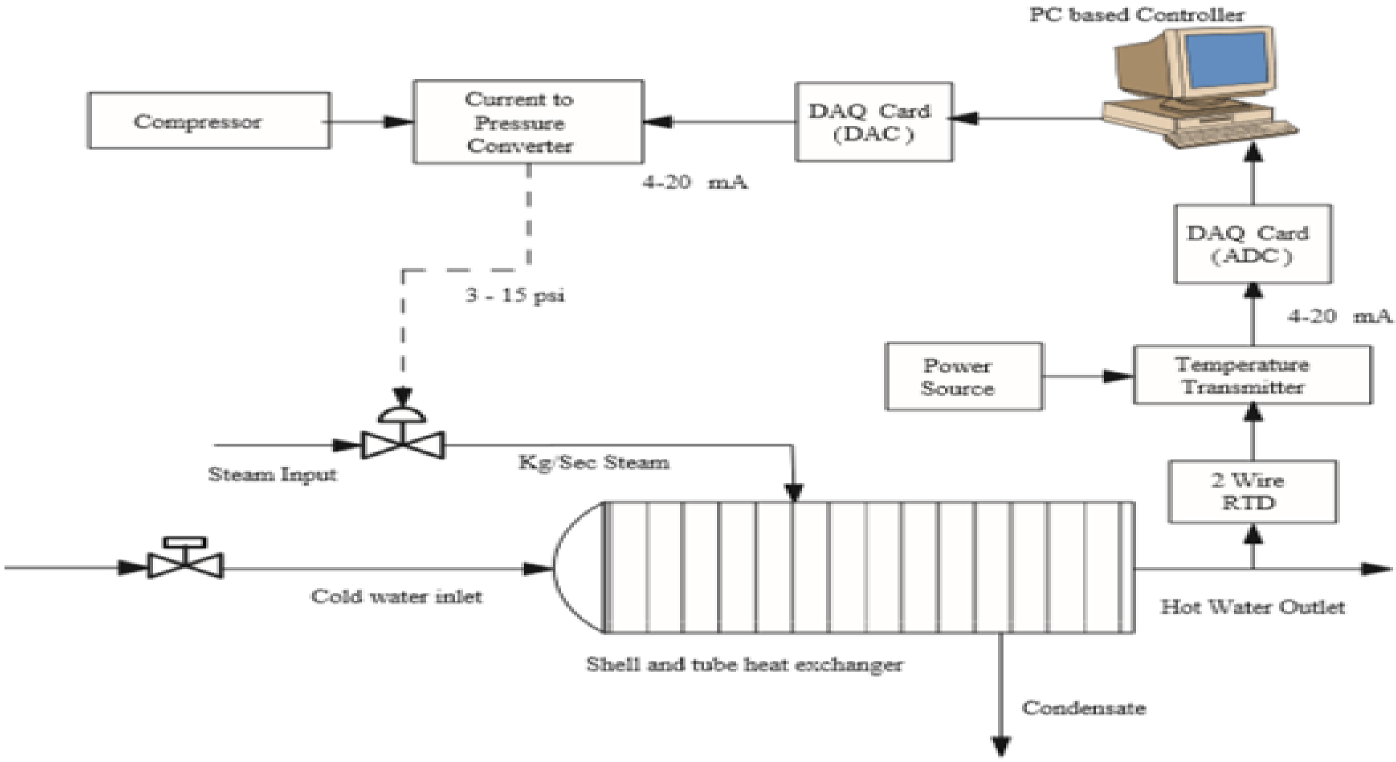

Figure 1. Systematic Diagram of Temperature Control in Shell and Tube Heat Exchanger

V. MATHEMATICAL MODEL

The proper mathematical model of the system has to be determined in order to design a controller. Most of the industrial system are non-linear in nature and can be approximated as first order plus time delay (FOPTD) or second order plus time delay (SOPTD) models. The open loop response data or the frequency response data are used to obtain the parameters of the first order plus time delay and second order plus time delay system. The general form of FOPTD model can be expressed as

$$G(s)=kp\ e^{-\tau Ds}/(\tau s+1) \qquad (1)$$

The general form of SOPTD model can be expressed as

$$G(s)=kp\ e^{-\tau Ds}/(\tau 1s+1)(\tau 2s+1) \qquad (2)$$

K_p - process gain
τ_D - time delay
τ - time constant of FOPTD system
$\tau 1$ and $\tau 2$ - time constant of SOPTD system
Transfer function model of heat exchanger system is

$$Gp(s)=50/(30s+1) \qquad (3)$$

Transfer function model of valve is

$$Gv(s)=0.13/(3s+1) \qquad (4)$$

Transfer function model of sensors

$$H(s)=0.16/(10s+1) \qquad (5)$$

Transfer function model of disturbance is

$$Gd(s)=1/(10s+1) \qquad (6)$$

The process transfer function is represented as

$$G(s)=5/(90s^2+33s+1) \qquad (7)$$

which is in the form of SOPTD represented in Eq. 2

VI. SIMULATION AND RESULTS

To control and maintain the temperature of a shell and tube heat exchanger system with different controllers are analysed and the simulated studies of these controller performance is discussed here. Performance of these controller is the widely researched area which determines the performance of the controller by various methods. Oscillations occurs in these process control loop are determined by using different parameters which is used to evaluate the performance of control loops are

$$IAE=\int_0^\infty |e(t)|dt=\int_0^\infty r(t)-y(t)|dt \qquad (13)$$

$$ISE=\int_0^\infty e^2(t)dt \qquad (14)$$

$$ITAE=\int_0^\infty t|e(t)|dt \qquad (15)$$

$$ITSE=\int_0^\infty t^2\ |e(t)|dt \qquad (16)$$

By using Ziegler-Nichols tuning method, conventional PID controller tuned which is used to control the output temperature of heat exchanger. Therefore, due to the high overshoot of conventional PID controller, cascade controller is added.

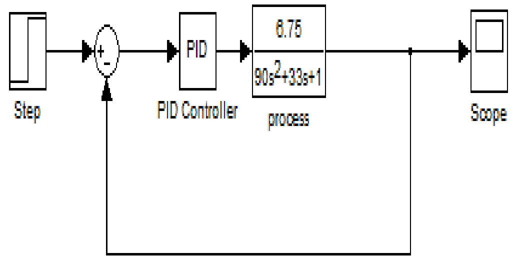

Figure 2. System Model of PID Controller

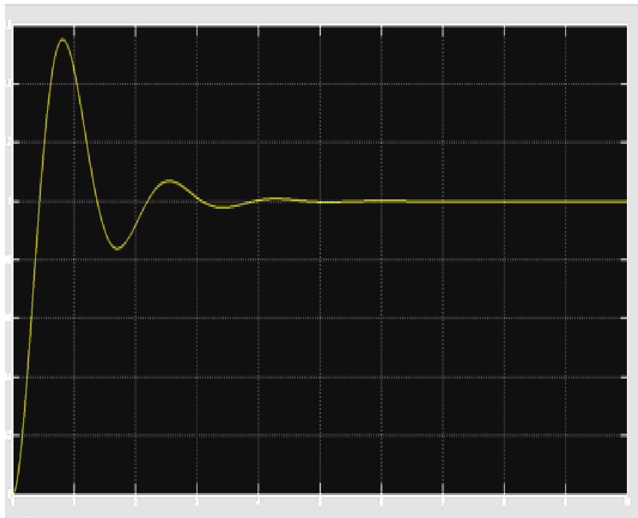

Figure 3. Response of PID Controller

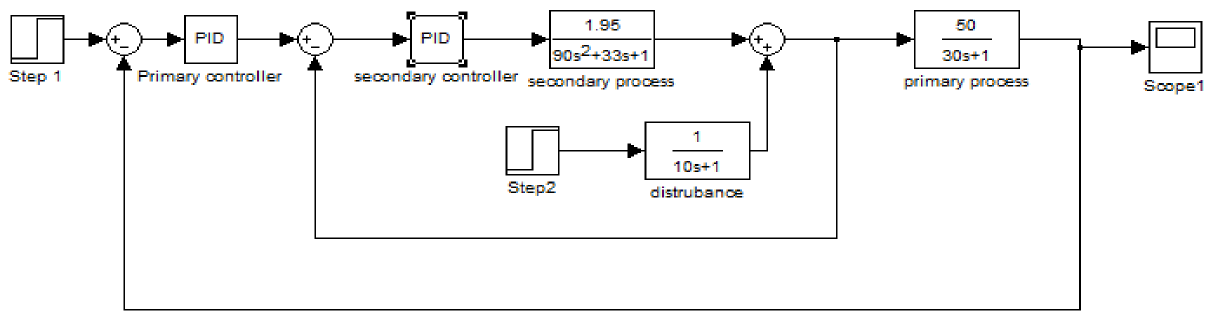

Figure 4. System Model of Cascade Controller

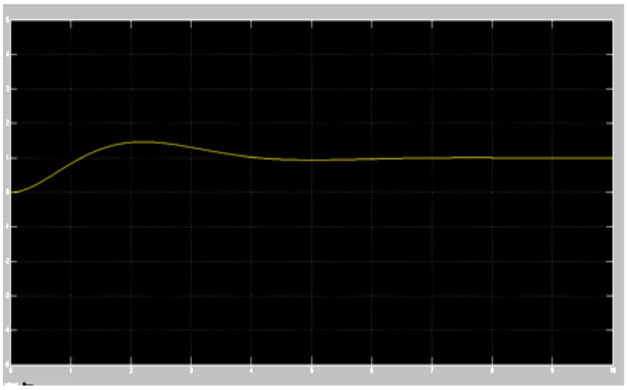

Figure 5. Response of Cascade Controller

VII. CONCLUSION

The design of a temperature control of a shell and tube heat exchanger based on cascade controller is done and the response is compared with the conventional PID controller. The analysis of the controller is designed in MATLAB and the tuning of the PID control system is done by SIMULINK. The result shows that the response of cascade controller has a smaller system overshoot ,faster response and less steady state error thereby making it better than conventional PID controller. Therefore the cascade controller has better dynamic response and steady state error characteristics. The system obtained can satisfy the requirements of temperature control system of the shell and tube heat exchanger.

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