ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Volume 5, Special Issue 1, March 2016

National Conference on Recent Trends in Electronics and Instrumentation Engineering (NCRTE 2K16)

1st & 2nd March 2016

Organized by

Department of Electronics &Instrumentation Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India

Evaluation of Series and Parallel Cascade Using Optimal Controller

Thirumarimurugan.M[1], Mahalakshmi.D[2], Sivakumar.V.M[3], Dinesh Kumar.V[4]

Department of Chemical Engineering, Coimbatore Institute of Technology, Coimbatore, Tamil Nadu, India

Department of Electronics and Instrumentation Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India

ABSTRACT:A cascade control strategy can be used to enhance the performance of a control system particularly in the presence of disturbances. In industries, majority of the cascade systems are of parallel type i.e., both the manipulated variable and the disturbance affect the primary output and the secondary output through the parallel actions. In this paper, comparison is made between parallel cascade system and the series type for the application of distillation column by using PI controller. Simulation results for both parallel and series type is obtained and the result is compared using peak overshoot, settling time and steady state error by using MATLAB code.

KEYWORDS: Cascade systems; load disturbance; Parallel cascade control; PI Control; Distillation column.

I.INTRODUCTION

In process industries, cascade control is extensively used to reduce the different effects of possible disturbances and to maintain the dynamic performance of the closed-loop system. Cascade control was introduced many years ago by Franks and Worley. The standard feedback control loop sometimes does not provide performance good enough for processes with long time delays and strong disturbances. Cascade control loops can be used and are a common feature in the control industries for the control of temperature, flow and pressure loops. In series cascade control, are the manipulated variable and the disturbance affect the primary output through the intermediate (secondary) output? In case of parallel cascade systems, the manipulated and disturbance variables simultaneously affect primary and secondary outputs. Parallel cascade control was first considered by Luyben.

The cascade control structure is made of two loops: primary (outer) loop and secondary (inner) loop. In parallel cascade control, the secondary loop dynamics should be much earlier than the primary loop because the disturbances entering into the secondary loop should be discarded immediately so that it reduces the steady state error in the primary loop. The typical example of a parallel cascade control system is the overhead composition control of a distillation column cascaded onto the control of a tray temperature]. The reflux flow rate (manipulated variable) and the feed flow or composition (disturbance, d) have aneffect on both the purity of the overhead product (primary output, y_1) and the tray temperature (secondary output, y_2). The control purpose is to maintain the overhead composition at the set point.

The output form of the composition controller resets the variable setpoint for the temperature controller. By controlling the temperature in the cascade manner, the variation in the feed control can be compensated sooner than it disturbs the product composition. If a long delay exists in the primary loop, the cascade control may not give satisfactory closed loop responses to set point changes. To overcome this problem, many researchers use a dead time compensator scheme in the primary loop of the series cascade control system .This paper shows how effective the parallel cascade control structure achieves the steady state response with the minimum overshoot in comparison with series cascade control structure.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Volume 5, Special Issue 1, March 2016

National Conference on Recent Trends in Electronics and Instrumentation Engineering (NCRTE 2K16)

1st & 2nd March 2016

Organized by

Department of Electronics &Instrumentation Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India

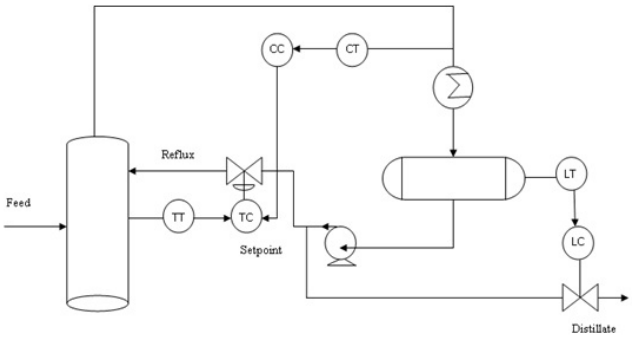

Figure 1. An overhead composition control in the distillation column

II.METHODOLOGY

In this paper, the comparison between series and parallel cascade control is done with the help of PI controller. Generally PI controller offers the minimum overshoot and the settling time and also there is no steady state error because of the absence of derivative effect. Therefore PI controller has more advantages in the terms of error with that of the PID controller. More often in many industries, where the steady state error is the major criteria, PI controller is used which improves the steady state accuracy by decreasing the steady state error.

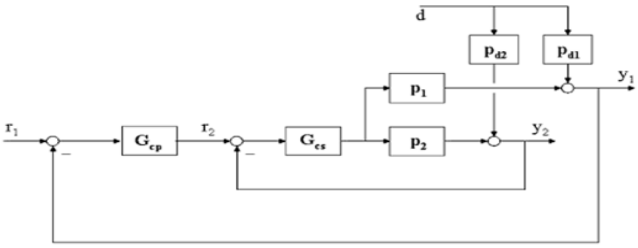

Figure 2. Parallel cascade control

Fig. 2 shows the parallel cascade control structure in which G_{cp} and G_{cs} are the primary and the secondary controller. Here P_1 and P_2 are the process transfer function of outer and the inner loop. First, the secondary controller is tuned based on the dynamic form of the secondary process with the primary controller in manual mode. It is tuned using the dynamic model obtained with the secondary loop in automatic mode. In this paper, both the outer loop (G_{cp}) and the inner loop (G_{cs}) use the PI controller.

III. SERIES CASCADE CONTROL

In series cascade control systems, (as shown in Fig. 3) the manipulated variable r_2 affects directly one intermediate variable (y_2) and this in-turn affects the primary controlled variable (y_1). The primary loop controls the controlled variable y_1 by manipulating the set point of the secondary controller G_{c2}. Thus we have the same controlled variable and set pointas like a single feedback loop but the control valve has been augmented by an inner control loop. The disturbance P_{d2} is rejected by the secondary loop before they affect the full process, and thus response is quicker and the impact on y_1 is less. The primary loop is necessary to handle the other disturbances, such as P_{d1} that always exist.
The process transfer function for the outer and the inner loop which is given by [3],

$$P_1 = P_{d1} = \frac{e^{-4s}}{(20s+1)}$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Volume 5, Special Issue 1, March 2016

National Conference on Recent Trends in Electronics and Instrumentation Engineering (NCRTE 2K16)

1st & 2nd March 2016

Organized by

Department of Electronics &Instrumentation Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India

$$P_2 = P_{d2} = \frac{1}{(10s + 1)}$$

P_1 and P_2 are outer loop and inner loop process transfer function whereas P_{d1} and P_{d2} are outer loop and inner loop disturbance transfer function. By using MATLab, the series cascade control structure is designed as shown in Fig. 3 and the simulation results are found.

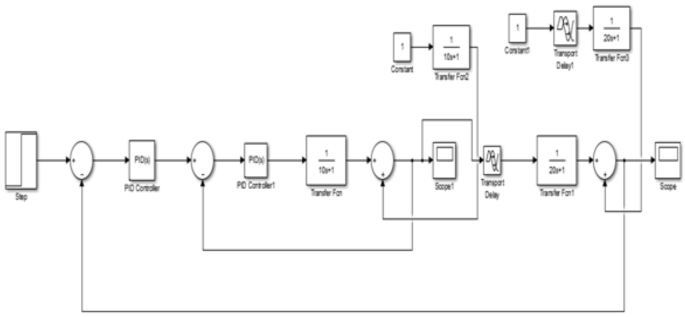

Figure 3. Simulink model of series cascade control

IV.PARALLEL CASCADE CONTROL

A parallel cascade system is one in which both the manipulated variable and the disturbances affect the both primary and secondary outputs method through parallel action. Disturbance rejection is the major concern in the design of variable process control systems. In this method the absence of disturbances, a process will remain at the steady state, and the control is not necessity. Many control algorithms were proposed to improve disturbance-rejection capability. Two controllers can be designed separately for servo purposes and disturbance rejection. This type of approach increases the complexity of control system design be designing two controllers for a single pair of input and output. Using the combination of primary and secondary measurements, a simpler approach can be taken to overcome the load disturbance problems. For this purpose parallel cascade control structure is used, in which the primary controller is designed for the servo purpose and the secondary controller is designed for the disturbance-rejection purpose. The general block diagram of a parallel cascade control structure has been shown in fig (2).
The process transfer function for the outer and the inner loop which is given by

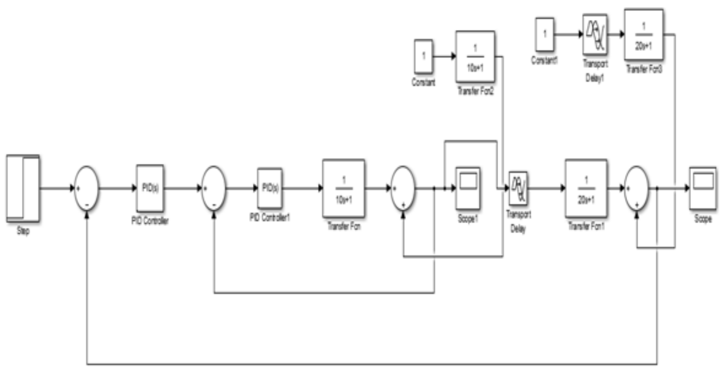

Figure 4. Simulink model of parallel cascade control

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization *Volume 5, Special Issue 1, March 2016*

National Conference on Recent Trends in Electronics and Instrumentation Engineering (NCRTE 2K16)

1st & 2nd March 2016

Organized by

Department of Electronics &Instrumentation Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India

$$P_1 = P_{d1} = \frac{e^{-4s}}{(20s + 1)}$$

$$P_2 = P_{d2} = \frac{1}{(10s + 1)}$$

P_1 and P_2 are outer loop and inner loop process transfer function whereas P_{d1} and P_{d2} are outer loop and inner loop disturbance transfer function. By using MATLab, the parallel cascade control structure is designed as shown in Fig. 4 and the simulation results are found.

V.RESULTS AND DISCUSSION

In this paper, specification parameters using series and parallel cascade control strategies have been exhaustively explored. The performance indices obtained are quite straight forward and simple. The results of the output response to a step response in a cascade loop using a described Simulink models for series and parallel cascade control are presented in Fig. 5. Both the series and the parallel cascade controller is tuned using the Cohen-Coon (open loop) method. The tuned values for both series and parallel cascade are in Table 1.
The tuned values for K_p and K_I are used to simulate the response of both series and parallel cascade. The results of the output response for a step input using the described simulink models for a series and parallel cascade by conventional PI controller is presented in Fig.5. It is observed from the result that the designed parallel cascade controller possesses better tracking capability and less overshoot. The results are further compared quantitatively in Table 2. Table 2 lists the control parameters for both the cascade controller (series and parallel).

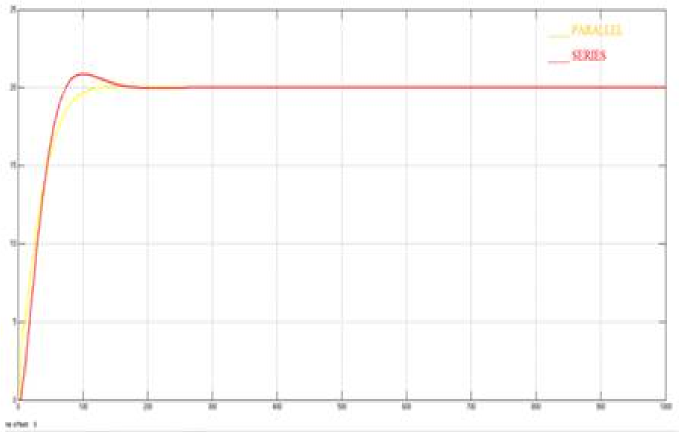

Figure 5. Simulation results of series and parallel cascade controller

VI.CONCLUSION

Parallel cascade controller, provides the good tracking capability with very minimum overshoot (5%) and rise time (40 sec). with regards to overshoot, parallel cascade shows the least value (5%) and hence the best behaviour is provided.

Table 1. Open loop PI tuning values for both series and parallel cascade controller

Series Cascade Controller		
Controller	**K_p**	**K_I**
Primary loop	0.257	0.023
Secondary loop	64.48	97.72
Parallel Cascade Controller		
Primary loop	0.257	0.023
Secondary loop	65.48	98.72

Table 2. Control parameters obtained from the obtained response

Cascade Controller Parameters				
	Rise time (t_r) in sec	**Settling time(t_s) in sec**	**Overshoot (M_p) in %**	**Tracking capability**
Parallel	42	235	6	Good
Series	57	269	88	Better

REFERENCES

[1]. R.G. Franks, and C.W. Worley, "Quantitative analysis of cascade control", Ind. Eng. Chem., vol. 48(6), pp. 1074-1079, 1956.
[2]. W. Luyben, "Parallel cascade control", Ind. Eng. Chem. Fundamentals., vol. 12, pp. 463-467, 1973.
[3]. Y. Lee, M. Skliar, and M. Lee, "Analytical method of PID controller design for parallel cascade control", Journal of Process Control, vol. 16, pp. 809-818, March 2006.
[4]. P. Dola Gobinda, and M. Somanath, "An improved parallel cascade control structure for processes with time delay", Journal of Process Control, vol. 22, pp. 884-898, April 2012.
[5]. M. Bharathi, and C. Selvakumar, "Comparison of cascade and parallel cascade control", Int. J. Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 1, November 2012.
[6]. P. Dola Gobinda, and M. Somanath, "Synthesis of PID tuning for a new parallel cascade control structure", IFAC Conference on Advances in PID Control, March 2012.
[7]. B. Deepak Nagrath, V. Prasad, and W. Bequette, "A Model predictive formulation for control of open-loop unstable cascade systems", Chem. Eng. Science, vol. 57, pp. 365-378, 2002.
[8]. I. Kaya, "Improving performance using cascade control and a smith predictor", ISA Transactions, vol. 40, pp. 223-234, 2001.
[9]. I. Kaya, and D.P. Atherton, "Use of smith predictor in the outer loop for cascaded control of unstable and integrating process", Ind. Eng. Chem. Res., vol. 47, pp. 1981-1987, 2008.
[10]. Y.H. Lee, S. Oh, and S. Park, "Enhanced control with a general cascade control structure", Ind. Eng. Chem. Res., vol. 41(11), pp. 2679-2688, 2002.