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Development of Online Multi-Loop PID Controller in PLC For A Cascaded Level - Flow Process

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ABSTRACT

The cascaded control schemes are one of the complex multi-loop control systems preferred in process industries to have better control over the process variable. The PID controllers are the most preferred controller in industries even today for its effective control performance. The Programmable Logic Controller (PLC) is widely used in process industries for implementing many of the control schemes. The PLCs provide fast, reliable and easy implementation of control schemes in process industries. This paper aims at developing and implementing complex control scheme, cascade control with simple ladder logic program developed in a low-cost PLC rather than implementing with the built-in tools in relatively high cost Distributed Control Systems (DCS). The PID controllers are tuned for both the primary and secondary process, namely, level and flow. The multi-loop controller is developed with simple ladder logics in PLC. The PLC is interfaced with level-flow process and real-time results are obtained. The time-domain parameters of the process are obtained. Thus a complex control scheme is developed using ladder logic program in PLC and results are obtained for the level-flow process with a similar cascade controller developed using a digital PID. This control program can directly be implemented in process industries for online control of cascade systems with a low-cost PLC rather than adapting a high-cost DCS systems.

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INTRODUCTION

Industrial processes in real-application are non-linear in nature. Most of the industries are using conventional PID controllers to control the process due to its simplicity and easy implementation. It plays an important role in automation industries over five decades. PID controllers has several advantages over linear systems, but it is not effective to those systems which has large time delay, higher order systems, non-linear systems, etc,. Therefore modification have been made on controller tuningtechniques such as An online auto-tuning procedure for cascade process by Majhi[1999]. Parallel cascade controller to be used in chemical process industries to improve the dynamic performance of a control system is presented by Rao[2009]. Parallel cascade control strategies, to improve the dynamic performance of acontrol system, have been proposed earlier by Pathan[2012] mainly for control of stable processes. Nowadays, the advancement of technology in using digital processors with the implementation of soft computing techniques such as Genetic algorithm, Artificial Neural Networks for plant control, improves the process response with more accurate and robust control. Vineet and *et al*[2008] presented a work related to real time applications of cascade system entitled as Real-Time Performance Evaluation of a Fuzzy PI + Fuzzy PD Controller for Liquid-Level process.

From the literatures collected it is observed that only few researchers have made real-time implementation of neural network controller using digital processors. PLC is one of the micro-processor based systems or digital computer in today's industrial automation. Lakshmi Sangeetha and *et al* [2012] proposed a paper entitled as Experimental validation of PID based cascade control system through SCADA–PLC–OPC and internet architectures. The paper presents the experimental validation procedure of a simple cascade control system through number of architectures, such as SCADA, PLC, OPC and internet. The performance

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and effectiveness of individual architecture is evaluated on the basis of data rate, rise time, peak time and settling time.

In this paper design and real-time implementation of multi-loop online PID control program for cascaded level-flow process are carried out and performance measure is made. This cascaded digital PID controller is developed using ladder logic functions in the PLC. The control program is implemented in GE Fanuc Versamax PLC available in the Process Automation lab of our institution. This PLC supports arithmetic, logic and also floating-point operations. Hence the proposed control scheme is developed using simple ladder logic functions on a PLC which supports analog input and output module. The level-flow cascaded process trainer available in Process Automation lab is taken as the process to implement the control scheme.

Cascade Control System:

In a cascade control configuration there is one manipulated variable and more than one measurement. In this scheme there will be two controller's namely primary controller and secondary controller. The output of the primary controller is used to adjust the set point of a secondary controller, which in turn sends a signal to the final control element. The process output is feedback to the primary controller, and a signal from the intermediate stage of process is feedback to the secondary controller.

The process diagram setup for the level flow tank is shown in Figure.1. Two measurements are taken from the system and each used in its own control loop. The outer loop (primary controller) controller output is the set point of the inner loop (secondary controller). Thus, if the outer loop controlled variable changes, error signal that is input to the controller effects a change in set point of the inner loop. Even though the measured value of the inner loop has not changed, the inner loop experiences an error signal and thus new output by virtue of its set point change. Cascade control generally provides a better control of the outer loop variable when compared with a single variable system. The disturbances arising within the secondary loop are corrected by the secondary controller before they can affect the value of the primary controller output.

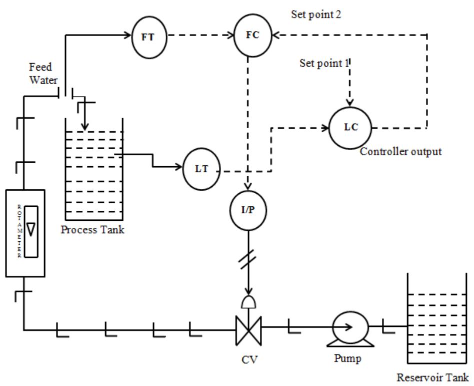

Fig. 1: Cascaded level flow process.

Here, the primary controller is a digital PID called Velocity form PID (VFPID). The digital PID is designed using GE FANU PLC in which the controller output is given as set point to the secondary controller. The secondary controller output is interfaced with the level flow process station. Both these controllers with the processes form the multi-loop cascade system.

While PLCs should be both powerful and reliable, some operations require the added features of flexibility and versatility for their controllers. GE Fanuc has developed the Versa Max PLC as part of an innovative control system that combines a powerful CPU with a broad selection of I/O modules, terminations, and power supplies. The GE Fanuc Versamax PLC available in the process automation lab of our institution is chosen for developing the digital PID controllers for both primary and secondary loop of the cascade control system as shown in figure.2. The GE Fanuc PLC has 16 digital inputs and 16 digital outputs and also 4 analog inputs and 4 analog outputs. Analog I/O supports both (0-10) VDC and (4-20)mA range. The IC200CPU001 is used as the processor for PLC module. Processor, inputs and outputs are powered by 24V DC power supply module. Programming is done in GE Fanuc using the Proficy machine edition software. The PID is programmed in personal computer (PC) and then downloaded to CPU of the PLC using RS 232 communication interface.

Design Of Cascade Control System:

(i). PID algorithm for cascade system:

Most process industries today use computers to carry out basic feedback control applications. Hence the formulae that are used to develop the control schemes and to calculate the controller output are in discrete form. Most of the computer based controllers use PID control algorithm. There are two forms of digital PID, namely, position form and velocity form. Position form of PID calculates the actual controller output. Equation (1) denotes the position form PID. The output expression of the PID is given by the equation (1),

$$u(t) = K_C\left(e(t) + K_I\int_0^t e(t)dt + K_D\frac{de(t)}{dt}\right) + m_r \quad (1)$$

where, u(t) is the controller output, m_r is the initial stem position of the control valve, K_c, the proportional gain, K_i, the integral gain, K_d, the derivative gain, e(t), error signal.

The Position form PID has an advantage of maintaining the final control element at its reference position. There are two main drawbacks associated with this position form. One, when switching from auto to manual mode it produces a sudden rise in output higher than the desired set point and the other is the integral windup when sudden change in set point is introduced in the system. The equation.2 represents the approximated discrete equivalent for the position form PID controller in continuous domain.

$$m(n) = K_C e(n) + K_C K_I T\sum_{n=0}^{k} e_n + K_C\frac{K_d}{T}(e_n - e_{n-1}) + m_r \quad (2)$$

In contrast to position form PID, velocity form calculates the change in controller output. The velocity form of PID can be derived by substituting n-1 for n sampling instant in equation (2) and it is given by,

$$m(n-1) = K_C e(n-1) + K_C K_I T\sum_{n-1=0}^{k} e_{n-1} + K_C\frac{K_d}{T}(e_{n-1} - e_{n-2}) + m_r \quad (3)$$

where T is the sampling time. The above expression gives the position of final control element before one sampling instant (n-1). Subtracting eqn. (2) and (3) gives the change in position of final control element and it is given by,

$$m(n) - m(n-1) = K_C\left(e(n) - e(n-1) + K_C K_I Te(n) + K_C\frac{K_d}{T}(e_n - 2e_{n-1} + e_{n-2})\right) \quad (4)$$

The above expression in (4) gives the output equation for the velocity form PID. It has the advantage that it inherently contains anti-reset windup as the summation of errors is not calculated explicitly.

Algorithm:

1) The Process Variable, (PV, level) is acquired from the analog input channel.
2) The Controller Output is read from the analog output channel at every sampling instant.
3) The result of step 2 is moved to another location to represent m(n-1).
4) The present error, e(n) = Set point – PV is calculated for each sampling time.
5) The result of step 4 is moved to two locations to represent e(n-1) and e(n-2).
6) The steps 1 through 5 are repeated for each sampling time.
7) The VFPID controller O/P is generated by substituting all the parameters in the controller expression.
identified.

(ii). PLC for level-flow cascade process:

The cascade system is formed by interfacing level and flow process with the PLC. The primary and secondary controllers are developed using PLC ladder programming. The control program output is interfaced with the process station. The figure.2 shows the multi-loop cascade control loop using PLC.

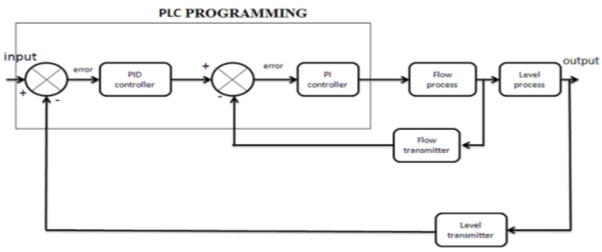

Fig. 2: Level flow cascade process control with PLC.

Cascade control generally provides a better control of the outer loop variable when compared with a single variable system. The disturbances arising within the secondary loop are corrected by the secondary controller before they can affect the value of the primary controller output. The flow chart for level flow cascade system is shown below in figure.3

Online Multi-Loop Cascade Control Using Plc:

The level-flow cascade system with Digital PID in primary loop is designed and implemented using GE Fanuc PLC. The primary input which is the level and secondary input which is the flow is taken from the process station and it is given to the analog input channels 1 and 2 of the analog input/output module. The connection diagram is shown in Figure.4. The analog input which reaches the analog input module will be a current input which ranges between 4–20mA. This analog signal is converted to digital form while giving as input to the PLC. The digital values that are accepted by the PLC will be displayed as real values that range between -32767 to +32767. Correspondingly, the output from the PLC which is in the real form will be converted to the analog values which varies between 4-20mA. The output from the analog output module is interfaced to the process station again to complete the cascade system. The results obtained and the performance measures of the proposed cascade scheme are also discussed. Digital PID controller described in the previous section is implemented in real time in cascade control configurations for controlling the liquid level in the overhead tank with the help of GE Fanuc PLC.

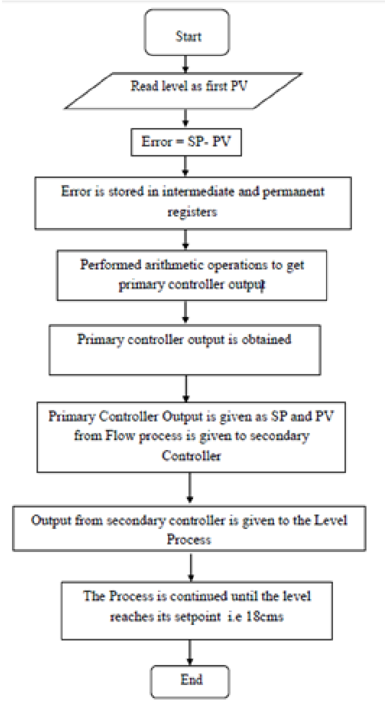

Fig. 3: Flow chart of cascade control scheme in PLC.

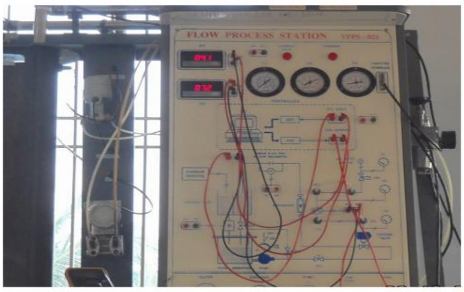

Fig. 4: Front panel of Level flow process station.

Time-domain Specifications:

For controlling level in the overhead tank of the process control unit the main performance evaluation criteria was taken as peak of overshoot. This is because in the level control system sufficient care should be taken to avoid overflow of liquid from the tank. If the overshoot is huge the tank might overflow. The next priority in the time domain criteria is given to the settling time. The initial settings can be changed by adjusting the partially open valve. These settings may act as disturbance if changed during the transient state of the process and will affect the steady-state. The settings are kept same for the whole experiment for carrying out the performance comparison.

Results:

The response of conventional cascade control program and the proposed cascade control using PLC program are compared and the results are presented. Figure.5 shows the real time response from Conventional PID controller. With the same settings as used in conventional controller, the response for online multi-loop cascade controller using PLC is obtained. The set point is maintained at 18cm in the level-flow process.

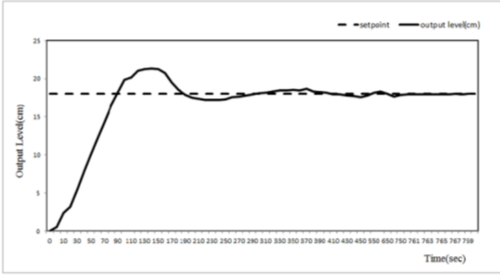

Fig. 5: Response of conventional cascade controller.

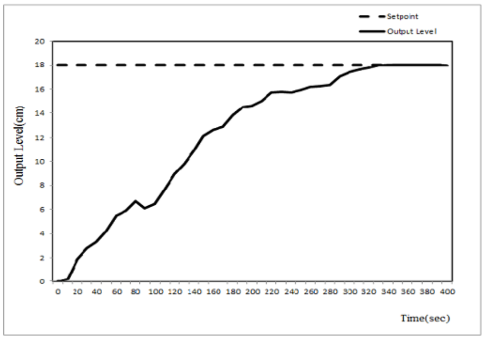

Fig. 6: Response of cascade control system using PLC.

Discussion:

The tuning parameters for this controller are calculated using the Cohen-cohn tuning method. The tuned controller gain values are:
Primary loop (conventional PID controller)
$K_p = 4$, $K_i = 0.008$ $K_d = 0.2$
Secondary loop (conventional PI controller)
$K_p = 1.5$, $k_i = 0.01$

The response in Fig. 5 indicates that the rise time is quick with the conventional controller. However a phenomenal overshoot of 18.3 % is observed from the response. The settling time from the response is 760 seconds, which is more than 10 minutes. But in the response of cascade control developed using PLC for the same process, there is no occurrence of peak overshoot. It is also observed that the settling time is much faster, which is less than 5 minutes.

Table 1: Performance comparison of proposed and normal cascade system.

Type of Cascade system	Rise Time (sec)	Peak value (%)	Overshoot (%)	Settling Time (sec)
Cascade system using GE Fanuc PLC	330	0	0	340
Conventional Cascade System	100	30.42	18.3	763

In Table.1, the results of the conventional cascade controller is compared with the multi-loop cascade controller developed using GE Fanuc PLC. It is observed that the cascade system interfaced with GE Fanuc PLC stands out in performance according to our chosen criteria, for the set point of about 18 cm.

Conclusion:

As a result, the performance of cascade controller developed using multi-loop PID in PLC has better results than the conventional cascade controller using digital PID with respect to the time-domain specifications. The proposed structure gives significant improvement in the closed-loop performances with less number of controllers when compared with some recently reported methods. Thus the functional capability of PLC is utilized efficiently by developing ladder logic program for a complex cascade control scheme. The program developed in GE Fanuc PLC can be directly implemented in any low-cost PLCs with analog input and output module. The cost of implementing the same cascade control scheme in advanced PLCs or DCS will be extremely high. Thus a cost-effective PLC program for multi-loop cascaded level-flow process is developed and experimental results are reported. This control program shall be recommended for implementing online in any PLC system with analog input and output module in industrial process applications.

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REFERENCES

Alfaro, V.M., R. Vilanova and O. Arrieta, 2009. ‘Robust tuning of 2- DoF PI/PID based cascade control systems’ Journal of Process Control, 19: 1658–70.

Rao Seshagiri.A., 2009. “Enhancing the performance of parallel cascade control using Smith predictor”, ISA Transactions, 48(2): 220-227.

Arrieta, O., R. Vilanova and P. Balaguer, 2008. ‘Procedure for Cascade Control Systems Design’, International Journal of Computers, Communications &Control, 3: 235-48.

Bhattacharyya, S., H. Chapellat and L. Keel, 1995. ‘Robust Control the Parametric Approach’ Englewood Cliffs, NJ, USA Prentice Hall.

Barmish, B.R., 1989. ‘A generalization of kharitonov’s four Polynomial concept for Robust Stability Problems with Linearly Dependent Coefficient Perturbations’, IEEE Transactions on Automatic Control, 34: 157-65.

Carvajal, J., G. Chen and H. Ogmen, 2000. ‘Fuzzy PID Controller Design, Analysis, Performance evaluation, and stability analysis’ Information Sciences, 123: 249-270.

Franks, R.G. and C.W. Worley, 1956. ‘Quantitative Analysis of Cascade Control’, industrial and engineering chemistry, 48(6): 1074–9.

Hen, G., 1996. ‘Conventional and Fuzzy PID Controllers an Overview’, International Journal of Intelligent and Control Systems, pp: 235-246.

Huang, H.P., I.L. Chien and Y.C. Lee, 1998. ‘Simple Method for Tuning Cascade Control Systems’, Chemical Engineering Communications, 165: 89-121.

Kaya, I. and D.P. Atherton, 2008. ‘Use of Smith predictor in the outer loop for Cascaded Control of Unstable and Integrating Processes’ Industrial and Engineering Chemistry Research, 47: 1981-7.

Kaya, I., N. Tan and D. Atherton, 2007 ‘Improved Cascade Control Structure for Enhanced Performance’ Journal of Process Control, 17: 3–16.49.

Lee, Y.H., S.W. Park and M.Y. Lee, 1998. ‘PID Controller Tuning to Obtain Desired Closed Loop Responses for Cascade Control Systems’,Industrial and Engineering Chemistry Research, 37(5): 1859-65.

Majhi, S. and D.P. Atherton, 1999. ‘Auto tuning and Controller Design for Processes with Small Time Delays’ IEEE Proceedings Control Theory and Applications, 146(5): 415–25.

Padhan, D.G. and S. Majhi, 2012. ‘Modified Smith Predictor Based Cascade Control of Unstable Time Delay Processes’ ISATransactions, 51: 95-104.

Stephanopoulos, G., 1984. ‘An Introduction to Theory and Practice’, Chemical Process Control, Prentice-Hall of India, New Delhi.

Visioli, A. and A. Piazzi, 2006. ‘An automatic tuning method for cascade control systems’ In: Proceedings of the IEEE international conference on control applications, Munich, Germany, 4–6 October.

Lakshmi Sangeetha, A., B. Naveen kumar, A. Balaji Ganesh and N. Bharathi, 2012. Experimental validation of PID based cascade control system through SCADA–PLC–OPC and internet architectures, Measurement journal, Elsevier publication, 45(4): 643–649.

Vineet kumar, K.P.S. Rana and Vandna gupta, 2008. Real-Time Performance Evaluation of a Fuzzy PI + Fuzzy PID Controller for Liquid-Level Process, International Journal of Intelligent Control and Systems, 13(2): 89-96.