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Response Time Behavior Trends of Proptional, Propotional Integral and Proportional Integral Derivative Mode on Lab Scale

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***Abstract*—**The industrial automation is dependent upon pneumatic control systems. The industrial units are now controlled with digital control systems to tackle the process variables like Temperature, Pressure, Flow rates and Composition.

This research work produces an evaluation of the response time fluctuations for proportional mode, proportional integral and proportional integral derivative modes of automated chemical process control. The controller output is measured for different values of gain with respect to time in three modes (P, PI and PID). In case of P-mode for different values of gain the controller output has negligible change. When the controller output of PI-mode is checked for constant gain, it can be seen that by decreasing the integral time the controller output has showed more fluctuations. The PID mode results have found to be more interesting in a way that when rate minute has changed, the controller output has also showed fluctuations with respect to time. The controller output for integral mode and derivative mode are observed with lesser steady state error, minimum offset and larger response time to control the process variable. The tuning parameters in case of P-mode are only steady state gain with greater errors with respect to controller output. The integral mode showed controller outputs with intermediate responses during integral gain (ki). By increasing the rate minute the derivative gain (kd) also increased which showed the controlled oscillations in case of PID mode and lesser overshoot.

***Keywords*—**Controller Output, P, PI &PID modes, Steady state gain.

I. Introduction

INDUSTRIAL automation and digital control technology is being adopted by the Engineers and Designers to control the chemical process industries. The practical demonstration of it can be seen in the digital control rooms of fertilizer plants and refinery. Digital control technology use pneumatic system for controlling the instruments and process.

There are three modes of controllers which are extensively used in industrial world. These are Proportional-mode, Proportional Integral-mode, and Proportional Integral derivative-modes. The closed loop responses of three modes directly affect the overshoot, steady state gain, Integral time and rate minute. For Proportional-mode overshoot is more and stability is lower. For Proportional Integral-mode again overshoot is higher with more oscillations due to which stability is again lowered. Now for Proportional Integral derivative-mode, the derivative mode can control the overshoot and system show improved stability [1].

A large number of process and instrumentation Engineers know the importance of controllers. There are many methods still known to install, tune and use control loops for industrial chemical process control. The PID controllers are robust and there tuning is found to be more complicated as compared to other controllers. However, worthwhile improvements can be done through proper understanding of process as well as knowledge and the function of controllers [2].

The purpose of a controller is to adjust the process variable until a set point is achieved. So in case of Proportional mode a controller output is changed which is directly related to the error value of the controller. This mode is also called “Gain”. If the gain is very much greater, the output of the controller may become inconsistent. However, if the value of the gain is lower, the responsiveness of a controller towards an error value may also be smaller. When a proportional integral mode is added to the control loop, the controller output will be accelerated and attains a steady state set point by removing the errors of Proportional mode and improve the responsiveness of an overall system. The PI-mode gives the faster response but give a larger amount of oscillations and greater time to reach the set point value [3].

To remove the overshoot and to control errors, PID-mode is used. The PID-mode adjusts the overshoot of controller output in comparison to the given set point. It recommends for the slower processes as these are very sensitive to faster process and may become unresponsive. However, in case of closed loop performance the PID controller tuning is very much difficult and cannot be understood by the Engineers and operators. They use PID-mode default settings with the conventional method of tuning [4].

II. Experimental

A. Apparatus

The control loop of flow controller is shown in Fig. 1. A centrifugal pump is connected to pump water from a storage tank. An orifice unit is connected to measure the flow rate of water from the pump. A magnetic flow transmitter FT-2 is connected with the pump which transmits a signal of flow rate to the flow controller FC-1. The Positioner LC opens the control valve by pneumatic air depending upon the set point configuration. When the set point is achieved the Positioner automatically shuts off the control valve. In this control loop a

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digital signal of controller output is displayed at a control panel and pump flow rate is detected manually by the magnetic flow transmitter. The controller configuration has three built in modes i.e. P-mode, PI-mode and PID-mode. Further experimentation of controller output is discussed in experimental studies.

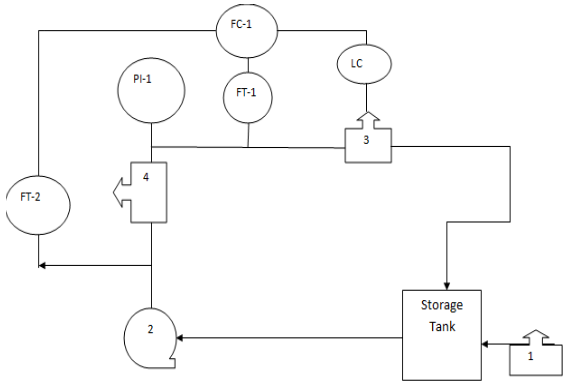

Fig. 1 Control loop for flow controller 1. Bottom Valve, 2. Centrifugal Pump, 3. Pneumatic Control Valve, 4 Restriction valve FT-1 (flow transmitter) FT-2 (Magnetic flow transmitter) FC-1 (Flow controller) LC (Positioner) PI-1 (Pressure gauge)

B. Experimental Studies

The experimentation was conducted for three built in tuning modes i.e. P, PI and PID-mode. The set point of 30% for each mode was selected. The controller output was measured at a time interval of 10 seconds. The P-mode of tuning was selected from a control panel and the value of proportional gain was selected by increasing/decreasing keys. The proportional gain was selected as 0.6. The pump was started from control panel and immediately noted the reading of magnetic flow transmitter and the reading of controller output at a time interval of 10 seconds. The pump was stopped as the set point value was obtained. The above procedure was repeated for the proportional gain values of 1 and 1.6. Now PI-mode of tuning was selected from a panel and the value of integral time was adjusted as 0.1, 0.15 and 0.5. Again the pump was started, took down the reading of controller output for changing values of integral time with respect to stop watch time for every 10 seconds. The pump was switched off after 100 seconds interval. Finally, the PID-mode was selected for a set point of 30%. The values of rate minute were taken as 1, 2 and 3. The pump was again turned on to note down the readings of controller output for every 10 seconds. The controller output in all three modes discussed above is tabulated in results and discussions [5].

III. Results and Discussion

The responses of controller output for P-mode, PI-mode and PID-mode were monitored. The typical effects of parameters like gain, integral time and rate minute for a set point of 30% are presented in Figs. 2 – 4.

A. Effect of Gain on Controller Output for Propotional-Mode

In case of changing values of steady state gain in Proportional mode, the controller output also alters. In this case by increasing the gain the controller output has more stable values and reaches the required set point more frequently. But the fluctuations in this mode remain significant. This might be happen due to greater oscillations and slower response in case of P-mode. The slower response is due to more steady state errors.

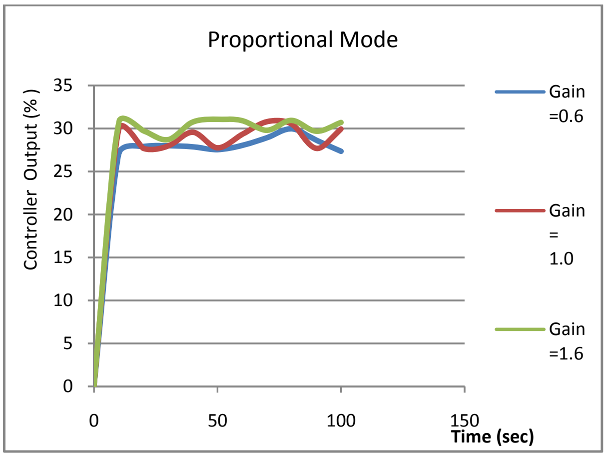

Fig. 2 Effect of gain on controller output for P-mode

The effects of increasing gain on controller output for proportional mode with respect to time is plotted in Fig. 2. At selected values of gain i.e. 0.6, 1.0 and 1.6 the controller output is found to be different at each value of gain. The values of output of controller at gain of 0.6 never reach the set point. This might be due to greater oscillations and greater errors. When the value of gain is increased to 1.6, the controller output is also reached the set point more frequently.

B. Effect of Integral Time on Output of Controller for Pi-Mode

The PI-mode has an effect on controller output by varying the integral time with respect to time. The integral time is changed and ultimately it directly affects the output of the controller. The values of integral time have taken as 0.1, 0.15, and 0.5. As the integral time was increased the controller output was also changed with respect to time. This might be due higher oscillations and lesser smoothness in case of PI-mode. The PI-mode also reaches the steady state set point slowly.

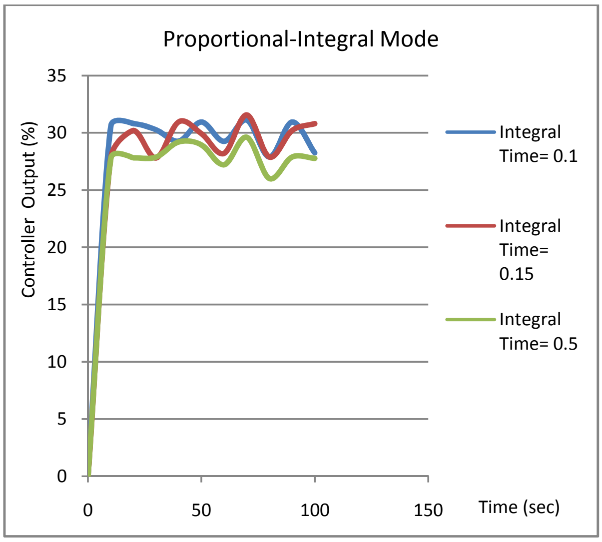

Fig. 3 Effect of Integral time on output of controller for PI-mode

The results are plotted in Fig. 3 for the effect of integral time on output of the controller. It is clear from the figure that by increasing the integral time the output of the controller decreases. This is due to the oscillations in case of PI-mode and lower smoothness. For integral time of 0.1, the controller output more frequently reaches the set point. When the integral time is further increased to 0.5 the response output of the controller is slower. So in that case, it reflects the properties of greater transitions and it has also showed maximum overshoot.

C. Effect of Rate Minute on Controller Output in Case of Pid-Mode

The PID-mode has direct effect upon the controller output by changing the rate minute with respect to time. The selected rate minutes are 1, 2 and 3. As the rate minute is increased from 1 to 3 the controller output has shown fluctuations with respect to noted time. The rate minute directly affects the output of the controller for PID-mode. The reason behind that response is lower oscillations and smoothness of PID-mode as compared to other two modes. The PID-mode also reaches the set point more frequently.

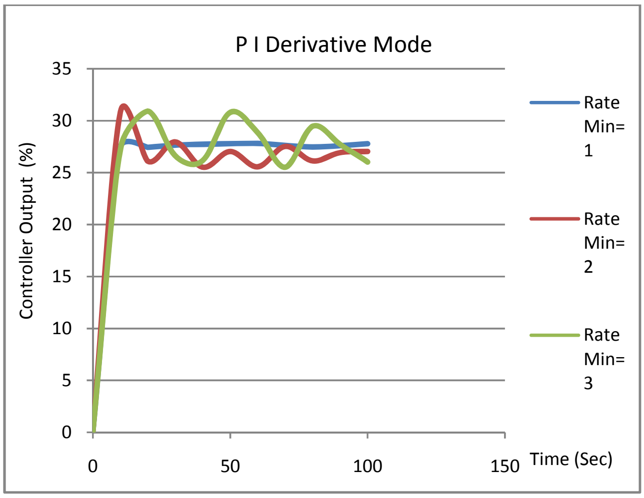

Fig. 4 Effect of rate minute on controller output in case of PID-mode

The results are shown for the effect of rate minute on controller output in case of PID-mode in Fig. 4. In this mode, the controller output more frequently reaches the set point. At rate minute value of 3, the output can be characterized in a manner of lower transition and output reaches the steady state many times. The derivative mode also controls the overshoot in the said case.

IV. Conclusion

Research work has been conducted to find out the controller outputs for the three modes i.e. P-mode, PI-mode and PID-mode. In all cases the response time of controller is compared with set point of 30%. The P-mode has reached near the set point in larger time due to the reason that it has more oscillations. The PI-mode has reached near the set point at slower rate. This is due to the fact that the overall smoothness is lesser and disturbances also affect the performance of controller output for PI-mode. PID-mode has reached near the set point in smaller time due to smoothness and controlling of overshoot by the introduction of derivative gain. This study demonstrates that PID-mode has greater response and performance characteristics in comparison to P-mode as well as PI-mode for controller output.

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