TO STUDY ON THE EFFECT OF TUNING RULES USED ON THE WATER LEVEL CONTROLLABILITY

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Abstract - The.purpose.of this research is to study on the effect of tuning rules used to recover from disturbances for the liquid level controllability. This research extract the information upon mostly primary sources including books, published journals, and experiments in laboratory. In the experiment, the time will indicate the respond of PV whether it is fast or slow if the controller output is changed. Time is observed by several tuning methods which are Ziegler-Nichol's tuning rule, tuning rule by Takahashi and tuning rule by Chien, Hrones and Reswick (CHR). The Water Level Control Using PID Controller is a design of an intelligent automatic level measurement system using PID controller. The system will allow users to measure and set the desired level of water with the PID controller controlling the process of water flowing into the tank. The system will be connected with a control valve and level sensor for the control section. The system is able to show the trend of water flowing into the tank and the responses of the measurements. The PID controller has the ability to control the trend and specific responses for a smooth transition of the water reaching the desired level point with the tunings and algorithm parameters entered by the handler (human) together with safety aspects monitored by the PID controller especially in hazardous plant.

I. INTRODUCTION

The Proportional-plus-Integral-plus-Derivative (PID) controllers have found wide acceptance and applications in the industries for the past few decades. It has a simple control structure which was understood by plant operators and which they found relatively easy to tune. In spite of the simple structures, PID controllers are proven to be sufficient for many practical control problems and hence are particularly appealing to practicing engineers. An abundant amount of research work has been reported in the past on the tuning of PID controllers. Ziegler Nichols tuning rule, tuning rule by Takahashi and tuning rule by Chien, Hrones and Reswick (CHR) are involve in this research.. "PID" means Proportional-Integral-Derivative, referring to the three terms operating on the error signal to produce a control signal. Since many control systems using PID control have proved satisfactory, it still has a wide range of applications in industrial control.

In this project, several useful PID Controller design techniques will be presented, and implementation issues for the algorithms will also be discussed. The PID Controller will be designed to control the liquid level at tank 1. In this project, the simulation of proportional, integral and derivative actions are explained in detail, and variations of the basic PID structure are also introduced. A graphical user interface (GUI) implementing of PID Controller tuning formulae will also be present at this project. Lastly, in this project, the method that gives best for level controllability will be identified.

Process Level Control illustrates the essential elements of a process. A level transmitter (LT), a level controller (LC) and a control valve (LV) are used to control the liquid level is a process tank. The purpose is to maintain the liquid level at some prescribed height (H) above the bottom of the tank. It is assumed that the rate of flow into the tank is random. The level transmitter is a device that measures the fluid level in the tank and converts it into a useful measurement signal, which is sent to a level controller. The level controller evaluates the measurement, compares it with a desired set point (SP) and produces a series of corrective actions that are sent to the control b\valve. The valve controls the flow of fluid in the outlet pipe to maintain a level in the tank.

II. METHODOLOGY

Delta V-Emerson software was used to control the process and observe the pattern of the process. Firstly, open loop test was done. The process was stabilized by manual (MAN) mode. Then, the initial value of manipulated variable in % was recorded. Next, step change was made by 10 % to the manipulated variable. From the process response, thee slope is calculated and after that the system was switched to AUTO mode. Then response curve was printed to calculate the response rate and time delay form the process using reformulated tangent method. Next, PI controller setting was determined using three tuning rules which are Ziegler-Nichol's tuning rule ,tuning rule by Takahashi and tuning rule by Chien, Hrones and Reswick (CHR).

After obtained the P and I value, then closed loop test was tested by inserting the values in the controller setting. Then, the process was tuned by dividing the value by 4 to achieve the stable condition. The optimum PI controller setting then was recorded.

Next, load disturbance test was test to observe how the process react towards any disturbances and how long the time taken for it to recover after being distracted from external or internal sources. Finally, set point test was done to discover how the process respond if the set point is change when the process is still running.

III. RESULTS AND DISCUSSION

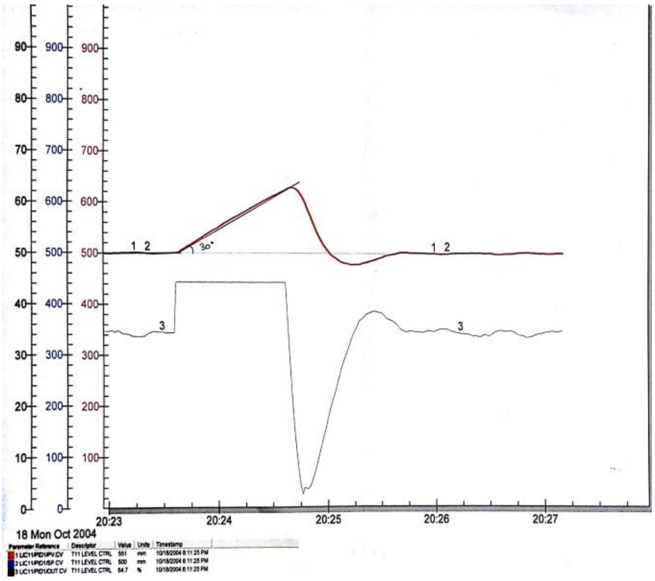

Figure 1 shows the open loop test

An open loop test has been performed to a water level control loop. The first graph shows the process response after a step test from MV_i = 34.6% to MV_f = 40.6% is made. Then, the response rate (RR) and the dead time (T_d) is calculated based on Reformulated Tangent Method. The response rate obtained is 0.0249 s^{-1} while the dead time (T_d) is 23.2 s^{-1}. Water level is known as a fast process, therefore a P+I mode has been chosen for mode control. But, in this study there are three tuning rules that has been chosen which are Ziegler-Nichol's tuning rule, Takahashi tuning rule and Chien, Hrones and Reswick tuning rule to calculate the optimum controller setting. Then, closed loop test is tested to observe which tuning rules can give the best outcome to achieve optimum setting during the process followed by load disturbance test and set point test.

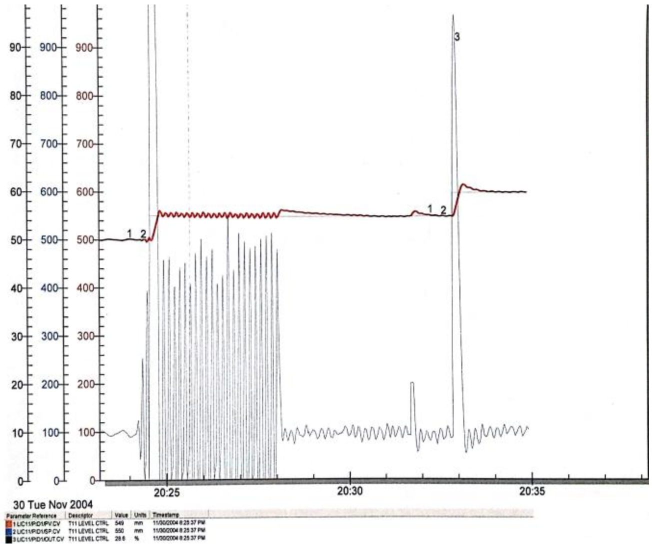

Figure 2 shows closed loop test, load disturbance test and set point test using Ziegler-Nichol's tuning rule

For the first tuning rule which is Ziegler-Nichol's tuning rule, they come out with equation P = 111.1RRT_d to obtain the proportional (P) value and I = 3.33 T_d to get the integral (I) value. The value of proportional (P) and integral (I) obtained are 64.18 % and 77.26 s respectively. Based on the graph, it takes short time which was about 1 s to stabilize the process but the valve was working rapidly by close and open to maintain at the set point. Therefore, this condition will make the valve easily to be broken or reduce the lifespan of the valve. So, this unsteady condition of the valve must be fix so that the process can be stable without using a lot of work from the valve. Therefore, the value of proportional (P) and integral (I) need to be tune by dividing it by 4. So, the new value for proportional (P) is 16.05 % and integral (I) is 19.32 s. Then by referring to the graph, it can be seen that the valve worked lesser to achieve the set point and stabilize the process. The time taken to stabilize the process is 3 s. Then, set point test was tested in the process and the time taken for it to achieve to the new set point is 3.75 s.

Table 1 Shows the P and I values after being tuned and their response time, T_R

Tuning rules	P (%)	I (s)	Time taken for the process to be stable, T_{Ro} (s)	First Tuning			Second Tuning		
				P (%)	I (s)	Time taken for the process to be stable, T_{R1} (s)	P (%)	I (s)	Time taken for the process to be stable after the second tuning, T_{R2} (s)
Ziegler-Nichol's tuning rule	64.18	77.26	1	16.05	19.32	3	-	-	-
Tuning rule by Takahashi	63.54	76.56	26	16.14	19.14	3.25	-	-	-
Tuning rule by Chien, Hrones and Reswick (CHR)	165.22	27.84	8.25	41.31	-	2.25	10.33	-	3

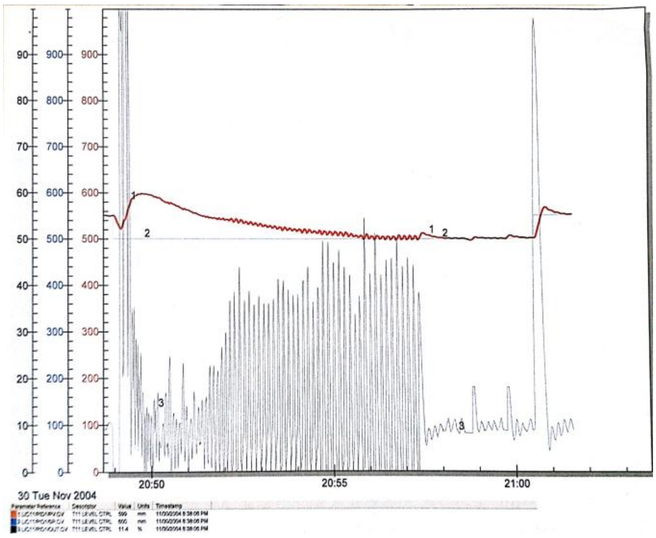

Figure 3 shows the closed loop test, load disturbance test and set point test using tuning rule by Takahashi

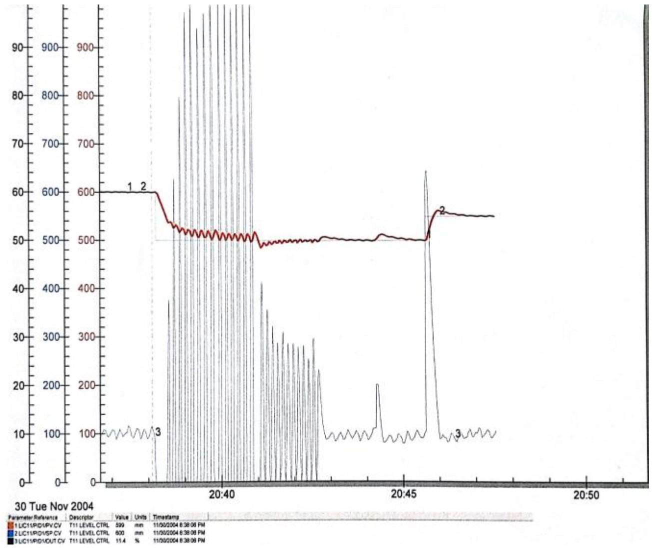

Figure 4 shows the closed loop test, load disturbance test and set point test using tuning rule by Chien, Hrones and Reswick (CHR)

Next, for the second tuning rule which is Takahashi tuning rule. The equation provided to get proportional (P) is P = 110 RR T_d and integral (I) is I = 3.3 T_d. So, after did the calculation the value of Proportional (P) and integral (I) obtained are 63.54 % and 76.56 s respectively. As shown in the graph, when the value of proportional (P) and integral (I) was insert in the controller setting for load disturbance test, the time taken to stabilize the process is quite longer than Ziegler-Nichol's tuning rule which is 26 s. Not only the time taken is longer, but the condition of the valve also not in very good as it also worked rapidly by close and open to stabilize the process. Therefore, for the first trial after the calculation using takahashi tuning rule, the process took longer time and the valve need to work rapidly to stabilize the process if there are any disturbances occur in the process.

Thus, the proportional (P) and integral (I) value is tuned by dividing it by 4 to reduce the time taken and the work load of the valve to stabilize the process. Then, the new calculated value of proportional (P) and integral (I) are 16.14 % and 19.14 s respectively. After obtained the new value, it is insert in the controller settings and the graph showed how it was response afterwards. The process become stable faster than before which is 3.25 s and it was not oscillate anymore which mean the valve worked properly. Then, set point test is run and the time taken for the process to achieve the new set point is 3.75 s which is more than Ziegler-Nichol's tuning rule. Therefore, by compare to the tuning rule before which is Ziegler-Nichol's tuning rule, Takahashi tuning rule is less suitable for water level control because the value for proportional (P) and integral (I) give longer time to stable and same pattern of oscillation.

Lastly, the tuning rule used is tuning rule by Chien, Hrones & Reswick (CHR). This tuning rule comes out with equation P = 286 RR T_d and I = 1.2 T_d to get the value of proportional (P) and integral (I). The value of proportional (P) is 165.22 where integral (I) is 27.84. Then, after inserted the obtained value of proportional (P) and integral (I) in the controller setting, the process slightly goes undershoot before it became stable. The time taken was 8.25 s. Then the value of proportional (P) is tuned for the first time by dividing it by 4 to overcome the problem. The new value of proportional (P) which is 41.31 is then inserted in the controller setting. The process then is stable and the time taken was 2.25 s but the graph is still oscillates which mean the valve is open and close very fast to stabilize the process. So, the valve has high potential to be broken very quick. Hence, the value of proportional (P) is tuned for the second time to fix the behavior of the valve by dividing it with 4. The new value is 10.33 and is inserted in the controller setting. Referring to the graph, it is not oscillates anymore which mean the valve is in good behavior and the time taken for the process to become stable is 3 s.

Then, the set point test taken place and the time taken for the process to achieve the new set point is 4.25 s. By overall, this tuning rule is the least effective to be used for the water level control. This is because when the first value obtained from this tuning rule's equation, the time taken for the process to stabilize has gone undershoot. This is mean, it needs two times to be tuned to stabilize the process and fix the behavior of the valve. The time taken also not very quick which is up to 8 seconds compared to the Ziegler-Nichol's tuning rule which not exceed than 7 seconds.

IV. Conclusion

It can be proved the Ziegler-Nichol's tuning rules is the best for water level controllability compared to tuning rule by Takahashi and tuning rule by Chien, Hrones and Reswich (CHR). Ziegler-Nichol's tuning rule only need one time tuning for the the process to achieved optimum setting if the is any disturbance in the process same as tuning by Takahashi. However, tuning rule by Chien, Hrone and Reswick (CHR) needed to be tuned by two times for the process to become stable. By comparing based on the time taken for the process to become stable. Ziegler-Nichol's tuning rule also gives the best result as it takes the fastest time for the process to recover the process which is 1 s and only need 3 s after the first tuning session.

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