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MODELING AND CONTROLOF LIQUIED LEVEL PROCESS WITH ARDUINO INTERFACING PLATFORM

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Abstract - The design of control algorithms for real time processes demands exact knowledge about the process. In this work, firstly a mathematical model of laboratory liquid level process based on experimental data is obtained using Arduino interfacing platform with system identification toolbox in MATLAB. The considered liquid level process consists of single input-single output (SISO) type, where liquid inlet flow is the input variable and liquid level of the tank is the output variable. As a result, process model is fit into first order with time delay model. For controlling the liquid level of the tank, two types of controllers are designed using classical PID and modern control theory. A continuous PID (Proportional Integral Derivative) controller is designed to control the plant with satisfactory output response and desired time constant. For the same control problem, a state controller is designed using Pole Placement method as well as LQR (Linear Quadratic Regulator) method. MATLAB simulations were carried out to showcase the effectiveness of the proposed control methods. Simulation study shows that LQR controller is capable of controlling the liquid level process effectively compared to PID controller.

1. INTRODUCTION

In many industries, controlling the level of the liquid column is a very important process. Many parameters are involved in the control of the liquid level process such as pumping the liquid from source tank to the process, draining the excess liquid into the drain tank, monitoring the input flow rate to the tank and output flow rate from the tank. Each of the following process has to be monitored and modeled correctly in order to maintain the proper level of the liquid column [1].

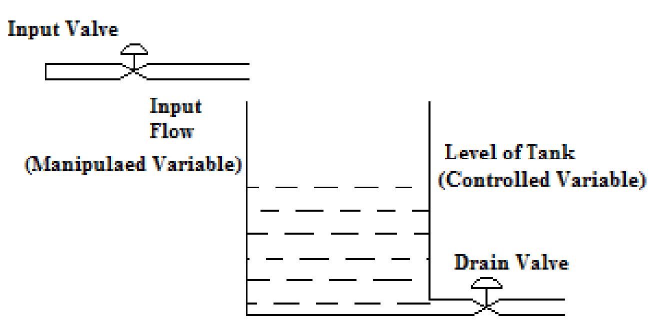

Fig.1. Liquid Column

It is very important to understand how the level of the tank is controlled and how the control problem can be handled. The main challenge is to design the controller for the process that has both ability to effectively control the process and robustness to eliminate the bounded disturbances. There are various methods to design the controller for the modeled process. Classical PID (Proportional Integral Derivative) can be designed to control the process with standard tuning methods which will improve the response time, steady state error in the system effectively. Modern control theory can also be applied to the same problem to control the plant with effective output response [2].

The physical process cannot be directly interfaced with the computer software such as MATLAB, SIMULINK etc. in order to interface the hardware model to computer, an interfacing platform is required. The Arduino hardware can be used to easily interface the hardware model to the SIMULINK software in MATLAB. The input readings can be directly taken from the Arduino into the MATLAB and can be processed in real time. At the same time, output response can also be given to the Arduino from MATLAB [3].

2. MODELING OF LIQUID PROCESS

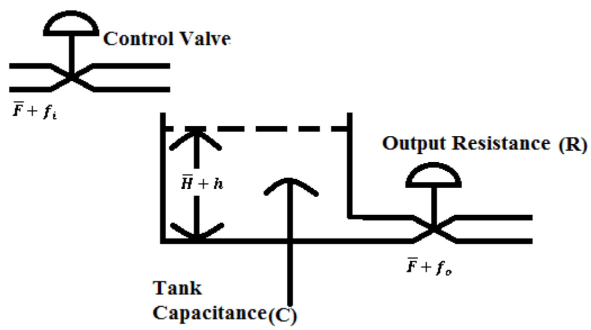

Fig.2. Variables associated with level of the tank.

Where,

F = steady state input flow rate,

H = steady state head,

$\bar{F}$= steady state input flow rate (before any change has occurred),

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f_i = inflow,

f_o = outflow,

h = change in head due from its steady state value.

For laminar flow, the resistance can be given as:

$$R_{laminar} = \frac{dH}{dF} = \frac{H}{F} \quad (1)$$

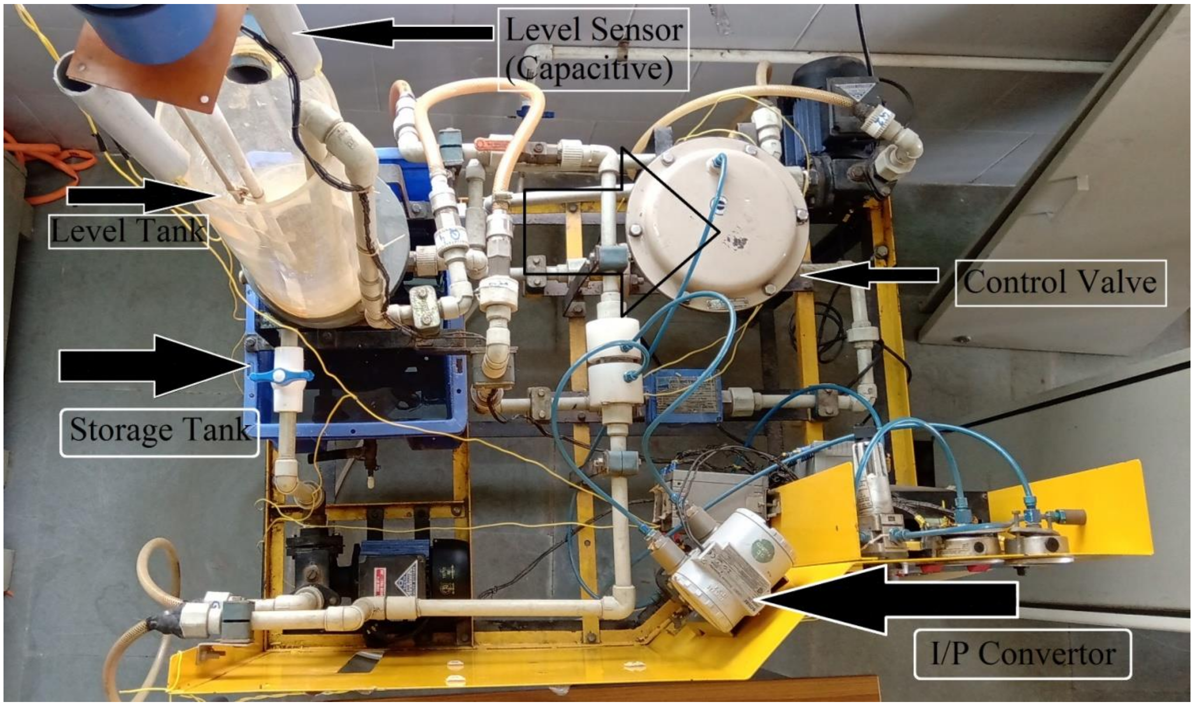

Fig.3. Liquid Level Control Process

The laminar flow resistance can be taken as electrical resistance as it remains constant [5]. The system can be considered linear if the flow is laminar. By flow balance equation, the equation to this system can be obtained as,

$$C\,dh = (f_i - f_o)dt \tag{2}$$

By ohms law, the f_o can be given as:

$$f_o = \frac{h}{R} \tag{3}$$

For a constant value of R, the differential equation becomes:

$$RC\frac{dh}{dt} + h = Rf_i \tag{4}$$

To obtain the transfer function of the system, we need to take Laplace transform of both sides of the equation:

$$(RCs + 1)H(s) = RF_i(s) \tag{5}$$

$F_i(s)$Is the input to the tank and $H(s)$ is the output of the system.

The transfer function is given by:

$$\frac{H(s)}{F_i(s)} = \frac{R}{RCs+1} \tag{6}$$

Transfer function of the model is extracted from System Identification Toolbox in MATLAB. Inputs and consecutive outputs were taken from the model and entered into command window. MATLAB command '*ident'* was used to get the transfer function of the model. The transfer function is in PID format:

$$G(s) = \frac{K_p}{T_{ps}+1} \times e^{-Tds} \tag{7}$$

Where,

K_p= proportional gain = 0.7034,

T_p= proportional time constant = 1.1781,

T_d= derivative time constant = 8.0141×10^{-10}.

$$G(s) = \frac{0.7034}{1.1781S+1} \tag{8}$$

3. CONTROL SYSTEM DESIGN

For comparison, two controllers are designed to control the plant. Using classical method, a PID controller is designed and using state space analysis, LQR controller is designed. Both controllers are designed using MATLAB's control system toolbox.

3.1. PID Controller

PID (Proportional Integral Derivative) controller is the most widely used controller in the industries, over 90% of the industries use PID controller in plant. PID is simple and easy to implement in practical applications.

Equation for the control law of PID controller is:

$$u(t) = K_p e(t) + K_i \int_0^t e(t)d(t) + K_d \frac{de(t)}{d(t)} \tag{9}$$

Where, K_p is proportional gain, K_i is integral gain, K_d is derivative gain.

$$e(t) = c(t) - u(t) \tag{10}$$

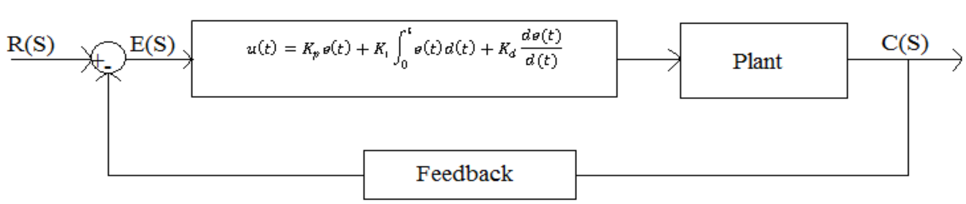

Fig.4. Block diagram of PID controller

3.2. LQR Controller

The Linear Quadratic Regulator (LQR) technique is a controller design technique based on state space representation. In state space, instead of taking the output of the system and feeding back to input to generate the error signal, the states of the system are monitored and given to the input via feedback gain matrix K. We can obtain the state space model from the transfer function directly by using *'tf2ss(num, den)'* command. The state space models are represented by state equations:

$$\dot{x} = Ax + Bu \quad (11)$$

$$y = Cx + Du \quad (12)$$

Where, x is state vector, u is input, y is output, A is state matrix, B is input matrix, C is output matrix, D is transmission matrix.

The input to the plant is:

$$u = -Kx \quad (13)$$

Where, K is feedback gain vector.

To minimize the performance index:

$$J = \int_0^{\infty} (x * Qx + u * Ru)dt \quad (14)$$

Where, Q is positive definite real symmetrical matrix, R is positive definite real symmetrical matrix.

The conversion of transfer function into state space gives:

$$A = \begin{bmatrix} 0 & 1 \\ 0 & -0.8488 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \quad C = [0.5971 \quad 0], \quad D = [0]$$

Feedback gain matrix for following state space model is:

$$K = [16 \quad 3.1512]$$

4. SIMULATION RESULTS

Step input is given to both controllers; the following graph shows comparative response of PID controller with LQR controller:

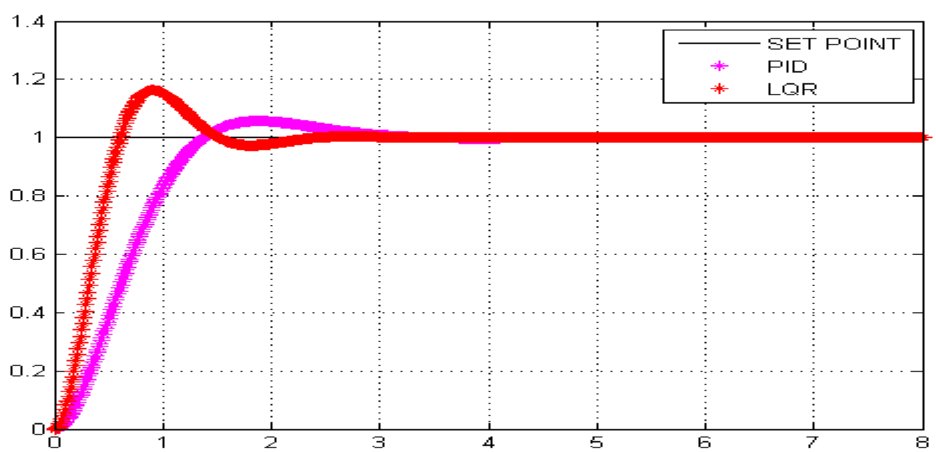

Fig.5. Step Response of LQR vs. PID Controller

LQR is more aggressive than PID controller and reaches to reference value much faster than the PID controller. PID takes more time to reach to reference at first interval than LQR. This comparison shows speed of response of both controllers.

5. CONCLUSION

In this paper, two controllers are designed. The performance of these two controllers is compared on the basis of the simulation results obtained from the MATLAB/SIMULINK software. It is been concluded that both the control methods are capable of controlling the plant effectively with satisfactory time response. Simulation study shows that LQR controller has better performance than PID controller for controlling the modeled first order liquid level system. LQR has faster response time than PID whereas PID's overshoot is significantly less than LQR control method. The LQR control algorithm is more robust than PID controller. PID control method cannot be applied non-linear systems with large disturbances. LQR is much more robust and can be applied to non linear systems.

6. REFERENCES

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