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Liquid Level Control Interface Design on Simulink External Mode with Raspberry Pi

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Abstract – Liquid level control in industrial applications is one of the classical control problems. The dynamic structure of two couple tank systems resembles many real systems such as boilers and oil refineries. It is the most controlled problem due to its non-linear structure and continuously changing phase properties. The liquid level of the tank is controlled by using a PI controller. The desired level is adjusted by using an ultrasonic sensor on the tank. The closed-loop system is operated by using a control interface designed by the Simulink program. The program prepared by Simulink is downloaded to Raspberry Pi over the Wi-Fi. The experimental input-output data of the system is provided by the external mode of Simulink. The user can adjust the speed of the fluid using the designed interface without a controller or control the liquid level by activating the controller on the same interface. This study provides great convenience to users to control and monitor the liquid level remotely.

Keywords – Liquid level control, Raspberry Pi, Simulink, External mode, PID control

I. INTRODUCTION

Since the last two decades, the control of two coupled tanks' liquid-level systems attracted the attention of many researchers around the world. This system is a multi-input and multi-output system. The control voltage is the input, and the water level is the output. There are a lot of studies about the system and controller design in the literature.

Sekban et al. applied the backstepping and conventional PI controllers to the coupled tank liquid level system [1]. They analyzed the controller performances.

Yılmaz et al. applied the PI+FF control to control the liquid level in the tanks. The feed-forward control is used to cancel the disturbance [2].

Fellani and Gabaj present the development of PID controller for controlling the desired liquid level of the tank. Simulation is made by MATLAB environment to verify the performances of the system in terms of Rise Time, Settling Time, Steady State Error, and Overshoot. They said that the PID controller is the most effective controller for fast response [3].

Govinda Kumar and Arunshankar presented a modified sliding mode controller (SMC) with a fractional-order PID (FOPID) based sliding surface for liquid level control of two-tanks system. A simulation study is executed. Proposed SMC with modified sliding surface shows better performance than the traditional SMCs [4].

Hashim et al. studied an active disturbance rejection control (ADRC) on a nonlinear quadruple tank system. They aim to control the liquid levels of lower two tanks. Genetic algorithm is used in optimization process of the system. The robustness of the proposed method is proven by simulation results [5].

Mahapatro et al. proposed an adaptive fuzzy sliding mode controller (AFSMC) for control the liquid level in coupled tank system. To reduce the chattering, they used fuzzy based sliding surface. The success of the proposed method is shown on the experimental results [6].

Arivalahan et al. presented a level control study for two tanks spherical interacting system. They proposed a FOPID controller to control the liquid level of this system. They used MATLAB/Simulink program for this study. Settling time, rise time, overshoot etc. performance indices are analyzed according to obtained data [7].

The experimental set-up consists of two couple tanks and two DC motors as liquid pumps in the laboratory. The liquid level is controlled Programmable Logic Controller (PLC) in the Laboratory. PLC is a good solution for industrial applications. But it is expensive for simple and small systems. In contrary to this, microcontroller-based systems [8–12] are cheap and sufficient for small systems. Therefore, Raspberry Pi is used for controlling the system [13]. Simulink is used for preparing the control algorithm and programming the Raspberry Pi [14,15]. This system is a good opportunity to develop some advanced controllers and implement them in real-time. An interface is designed on the computer for users to access the experimental setup consisting of two couple tanks. The aim of this study is to maintain the liquid level at the desired reference level by controlling the liquid pumps on the system via Raspberry Pi.

II. Liquid Level System

Liquid level system is designed to control the actual level at desired value by using PID controller. Block diagram of liquid level system is presented in Fig. 1. PID controller equation can be defined as follows [16,17].

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_d e(t)\frac{d}{dt} \qquad (1)$$

Here $u(t)$ is controller output, $e(t)$ is the error function. K_p, K_i and K_d are proportional, integral, and derivative gains of PID controller, respectively.

In Fig. 1, h_r is the reference liquid level, h is the actual liquid level, e is the error between h_r and h. Experimental setup is given in Fig. 2.

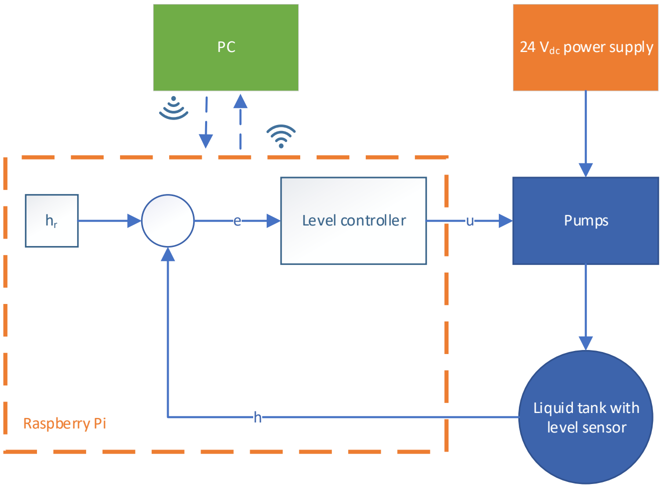

Fig. 1 Block diagram of liquid level system

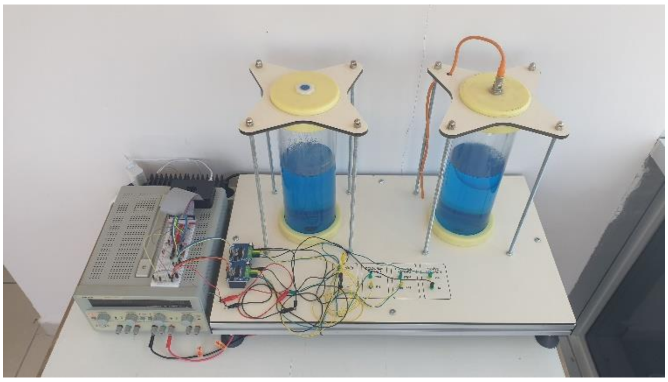

Fig. 2 Experimental setup

In Fig. 2, experimental setup consists of a 24 Vdc power supply, 2 liquid pumps for filling and drain the liquid, 1 tank with ultrasonic level sensor, 1 tank for drain the liquid, a Raspberry Pi 4B board, MCP3008 integrated circuit as ADC unit to measure the liquid level, and a PC for monitoring and control the system.

III. Control Interface Design

Simulink Support Package for Raspberry Pi hardware tool of MATLAB [18] is used for preparing the codes and programming the device directly on Simulink. The prepared block diagram is illustrated in Fig. 3.

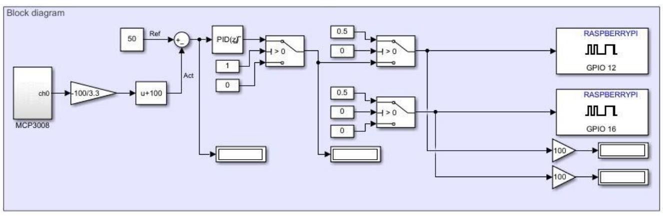

Fig. 3 Simulink block diagram

In Fig. 3, liquid level is measured by using MCP3008 because of Raspberry Pi board does not have any ADC unit. Measured level data is converted to percent unit and compare with reference level. The error is used in PID input. PID period is choosed 10 ms. GPIO 12 and 16 pins are configured as 1 kHz PWM outputs to control filling and drain pumps. Designed control panel for liquid level system is demonstrated in Fig. 4.

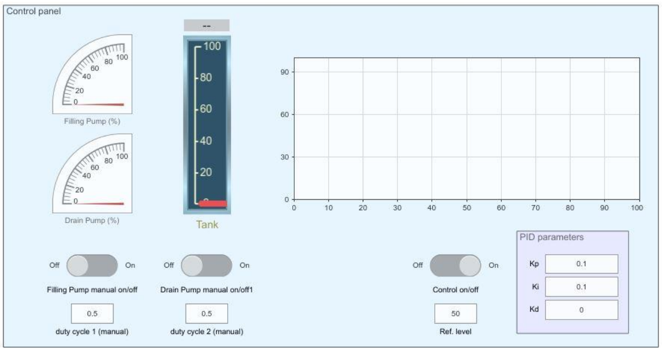

Fig. 4 Simulink control panel

In Fig. 4, system can be run either manual or PID controlled via slider switches. Duty cycle value of each pump is illustrated in quarter circular gauges. Liquid level is shown on vertical gauge. Actual and reference liquid levels are presented on dashboard scope in real-time. PID parameters K_p, K_i and K_d can be changed while system is running.

IV. Experimental Results

Designed control block is downloaded to Raspberry Pi and the control panel is connected the device in real-time. The system is tested on external mode. System test result is demonstrated in Fig. 5.

When Fig. 5 is examined, it seen that the connection between PC and Raspberry Pi via external mode is realized successfully. Reference level is changed while running and the response of the controller is seen in scope. Also, all gauges are correctly show the values.

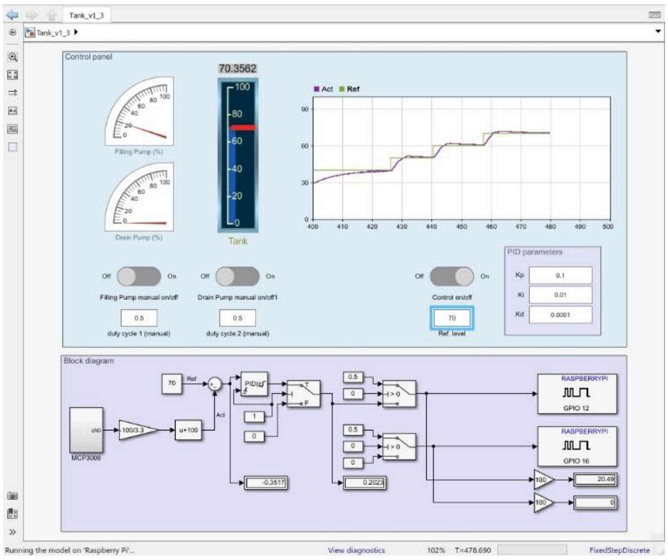

Fig. 5 Test result

V. Conclusion

Liquid-level control systems are widely used in the chemical industry in the world. The controller design and closed-loop control techniques are very important for this system. In some processes, such as mixed liquids, remote control and monitoring of system output is vital to avoid harming the environment and living things. The control panel is created by Simulink on the PC as open-loop and closed-loop for users. The control of the liquid level experimental set is carried out easily by designing basic controllers such as on-off and PI on the panel. The system can be run in the MATLAB/Simulink environment as well as embedded in the Raspberry Pi. The speed of liquid can be controlled by users on the control panel by adjusting duty rate manual. Graphics and values of the desired parameters can be recorded and tracked on the PC. The graphics can be analysed in more detail with the tools available in the interface. This method can be applied to complex and big systems because of its simple structure and is cheap for industrial applications.

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