REAL-TIME SIMULATION OF LIQUID PROCESS PLANT USING GENESIS SOFTWARE

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Abstract

This paper presents the development of a mathematical model of a multivariable liquid process plant. This multivariable liquid process rig incorporates two interacting loops; level control loop and temperature control loop. Based on the developed model, an experiment was conducted on the actual system for the purpose of real-time data collection and estimating the parameters of the model using a real-time software called GENESIS. This software is a real-time, multitasking software used in this work for running the actual plant and collecting the real data from the actual process. It is also used to perform a computer simulation study on the developed model to verify its performance. The simulation study was performed in terms of three case studies, that are, level control loop, temperature control loop and interaction loop respectively. The performance of each loop was investigated and the extent of the interaction effect between the two single loops was also highlighted.

Keywords

Modeling, Simulation, GENESIS Real-Time Software, and Process Control.

1. INTRODUCTION

As the industry develops steadily, the production scale becomes larger and in the meantime the process complexity grows. Especially, in some production processes, the controlled variables are related to each other. Hence, in such a case it is inevitable that interaction should be taken into consideration when some variables are under control. Because the interactions are mutual, so there must be some coupling channels among the single variable control systems [2,4]. Consequently, the control system being treated is no longer a single variable system. This multivariable theory has become a very important field in process control theory and by depth of its contents, it has been admitted in general, that it is one of the most difficult fields in process control theory.

The objective of this paper is to develop a mathematical model of a multivariable liquid process plant and then conduct a computer simulation study to verify its performance in comparison to the actual plant performance.

2. LIQUID PROCESS PLANT

In this Liquid Process Plant, there are two interacting loops, namely, level control loop and temperature control loop. Figure (1.0) shows the schematic diagram of the multivariable liquid process plant.

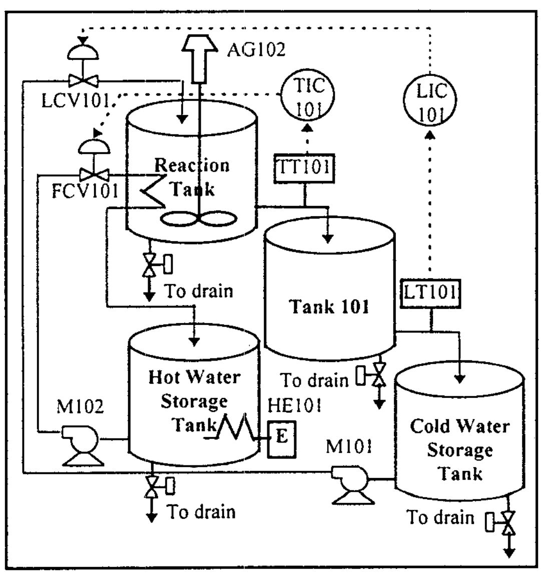

Fig. (1.0): Multivariable Liquid Process Plant.

In this section, we will describe the signal flow of the process and how the two single loops are interacting with each other. Firstly, the cold water is pumped from its storage tank into the reaction tank. Likewise, the hot water is also pumped from its storage tank to the reaction tank where the reaction takes place. The hot water flows through a coil inside the reaction tank. Therefore, the interaction between the two single loops occurred only in terms of the water temperature. However, the water level inside the reaction tank is only affected by the inlet and outlet flow of the cold water. After that, the hot water completes its loop and flows back into its storage tank. However, the cold water with its new temperature flows into tank 101 and considered as a final product. The main objective of this paper is to control the level and temperature of this product inside tank 101. Moreover, it is also aimed to evaluate the interaction between the two loops.

3. PLANT EQUATIONS

Based on some mass and energy balance equations assumptions, a mathematical model represents [5] , the actual process was developed. The transfer function matrix was derived using two methods; block diagram simplification, and solving the mathematical equations of the process. This model was used to construct the strategy during the performance of the simulation study, and its performance was also investigated in the simulation study later. The block diagram of the multivariable process is shown in Fig. (2.0) below:

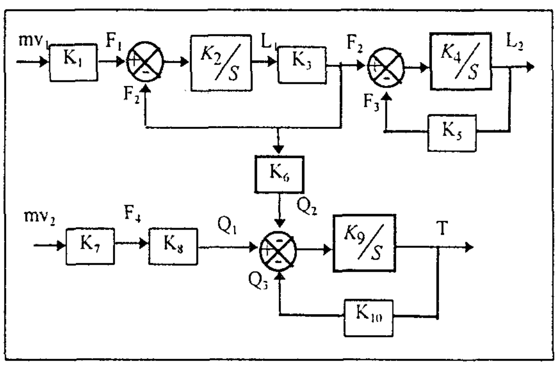

Figure (2.0): B. D. of 2×2 Multivariable Control Loop

From the block diagram shown in Fig. (2.0), a closed loop transfer function of the whole process was obtained by solving the equations of each single loop separately. Firstly, the transfer function of the level control loop is obtained as in equation (1.0):

$$L_2 = \left\{ mv_1 \left(\frac{k_1 k_2 k_3 k_4}{(s + k_2 k_3)(s + k_4 k_5)} \right) \right\} \qquad (1.0)$$

Secondly, the transfer function of the temperature control loop is stated in equation (2.0) as follows:

$$T = \left\{ \begin{array}{c} -mv_1 \left(\dfrac{k_1 k_2 k_3 k_6 k_9}{(s + k_2 k_3)(s + k_9 k_{10})} \right) \\ + mv_2 \left(\dfrac{k_7 k_8 k_9}{(s + k_9 k_{10})} \right) \end{array} \right\} \qquad (2.0)$$

Equations (1.0) and (2.0) can be written in the transfer function matrix form as follows:

$$\begin{bmatrix} L_2 \\ T \end{bmatrix} = \left\{ \begin{bmatrix} \left(\dfrac{k_1 k_2 k_3 k_4}{(s+k_2 k_3)(s+k_4 k_5)} \right) & 0 \\ -\left(\dfrac{k_1 k_2 k_3 k_6 k_9}{(s+k_2 k_3)(s+k_9 k_{10})} \right) & \left(\dfrac{k_7 k_8 k_9}{(s+k_9 k_{10})} \right) \end{bmatrix} \begin{bmatrix} mv_1 \\ mv \end{bmatrix} \right\} \qquad (3.0)$$

4. COMPUTER SYSTEM & PLANT INTERFACE

4.1 GENESIS Software

GENESIS software used in this work is a real-time software developed by ICONICS, Inc. It consists of three modules; Strategy Builder, Graphics Builder and Runtime module.

The GENESIS Runtime system is a real-time, multitasking environment that allows us to run and control the strategy created in the Strategy Builder using built in commands and a graphic interface [1]. It also allows us to use the graphic displays created in the Graphics Builder to assist our operators. It is used to run the actual process for the purpose of real data collection from the actual rig and estimation of system parameters.

4.2 Plant Interface

The actual process was connected with the host through an intelligent digital and analog I/O device called OPTOMUX [3]. It is a 4,8 or 16 point rack that accommodates photo-isolated analog or digital power I/O modules. Each OPTOMUX unit consists of a removal brain board and an I/O mounting rack. OPTOMUX units communicate with the host computer over an RS-422/485 communications link. It is possible to communicate with up to 256 individual units on a single serial link for a total of 4096 digital and/or analog I/O. The connections between the host computer and OPTOMUX units is illustrated in Fig. (3.0). OPTOMUX units can be located where the actual control is needed (in the process field).

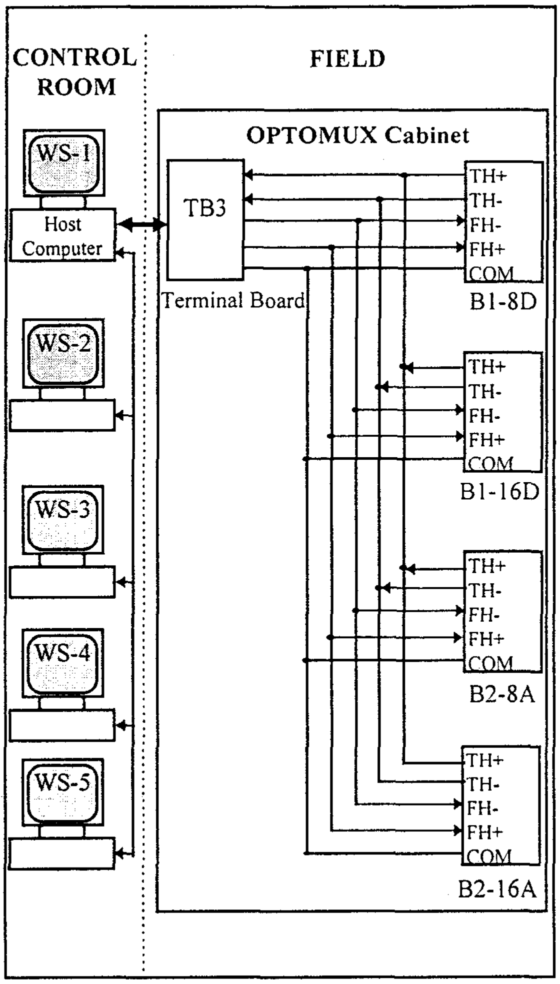

Fig. (3.0): Host Comp. and OPTOMUX connection.

The host computer issues instructions to OPTOMUX by sending messages over the serial communications link. OPTOMUX is capable of using two types of message protocols. The first protocol is 2-pass protocol which is used during normal operation. The other one is 4-pass protocol. This protocol is sometimes useful during initial setup and installation because it allows the host to examine and display the command massage that OPTOMUX received.

4.3 System Parameters Data Collection

There are ten parameters involved in the whole liquid process plant. The level control loop has five gains, (k_1, k_2, k_3, k_4, and k_5), while the temperature control loop involves four gains (k_7, k_8, k_9, and k_{10}). K_6 represents the interaction between level control loop and temperature control loop. The values of these parameters were obtained by experimental study conducted on the actual process. The final values of the system parameters are listed in table (1.0).

Table (1.0): List of the system parameters values

gain	k_1	k_2 k_3	k_4	k_5	k_6	$k_7 k_8$	k_9	k_{10}
val.	3.5	0.15	0.4	-0.6	-.02	0.37	0.3	-0.8

GENESIS was also used to perform the simulation study on the developed strategy. For instance, in the first case study, Algorithm Blocks that run level process were created in the Strategy Builder. Each algorithm block of the strategy performs a preprogrammed function. After that, graphic displays were created in the Graphics Builder to enter and display information for monitoring and controlling the level control strategy. Then a system simulation was performed in the runtime mode using the combination of strategy and graphics. A similar procedure is done for constructing the other two case studies using the corresponding strategy. For the three case studies, the developed strategies of level, temperature and 2×2 multivariable control loops are shown in Fig. (4.0), (5.0) and (6.0) respectively.

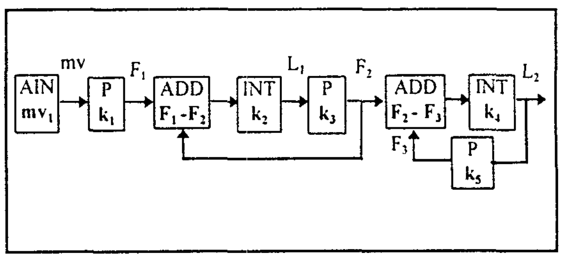

Fig. (4.0): The Strategy of Level Control Loop.

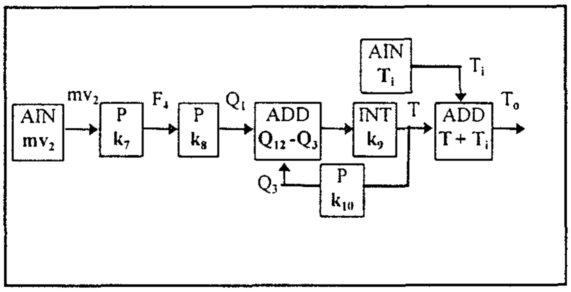

Fig. (5.0): Temperature Control Loop Strategy.

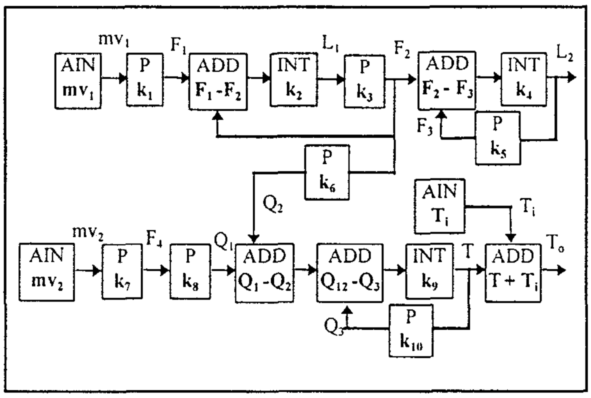

Fig. (6.0): Multivariable Control Loop Strategy.

5. PLANT SIMULATION AND RESULTS

Based on the mathematical model which was developed earlier, a system simulation study has been performed to verify the performance of that mathematical model. This simulation study was performed using GENESIS software in terms of three case studies; two single loop case studies, and one multivariable loop case study. In system simulation study, the time scale was 30 min. : 3 hours. In every case study, a suitable strategy to run the process was built in the Strategy Builder. After that, a corresponding static and dynamic displays were created in the Graphics Builder in order to enter and display information for monitoring and controlling the process. Then, the developed strategy was run and monitored in the Runtime module. The responses of the two single loops (level and temperature) are shown in Fig. (7.0) and (8.0). The response of the multivariable control loop is illustrated in Fig. (9.0). From the obtained results it is noted that both level and temperature responses were obtained and reached the desired values. Finally, the interaction effect between the two control loops (level and temperature) is shown in Fig. (10.0). From this figure, it can be shown that as we increase the cold water inlet to the reaction tank, the level inside tank101 increases, however, the temperature decreases. This is considered as a clear indication of the interaction between the two interacting loops.

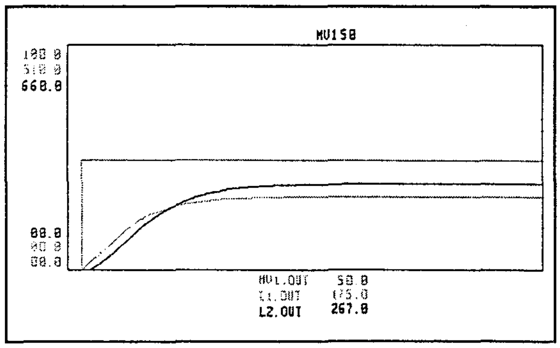

Fig. (7.0): Response of the 2×2 Multivariable Loop.

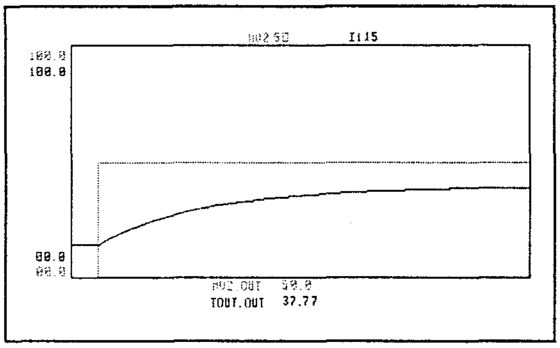

Fig.(8.0): Response of the Multivariable Loop.

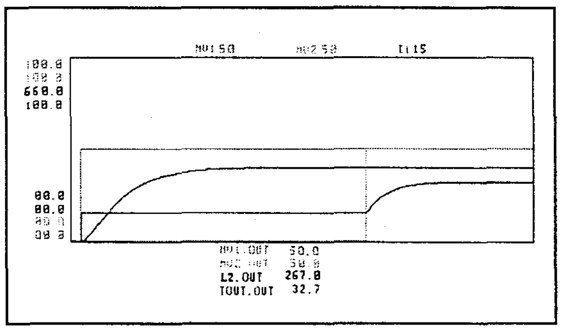

Fig. (9.0): Response of the 2×2 Multivariable Loop.

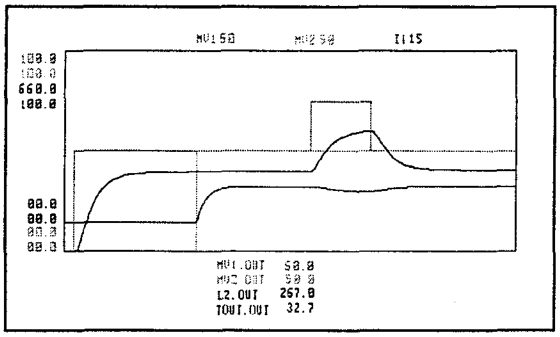

Fig. (10): Interaction Effect on the Multivariable Loop.

6. CONCLUSION

In this paper, a mathematical model that represents the actual multivariable liquid process rig was developed and a closed loop transfer function matrix was obtained. As a result of the conducted simulation study, the developed strategy performed well and showed a satisfactory results. The interaction between the two interacting loops was also demonstrated as shown in Fig. (10.0).

7. REFERENCES

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