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EMPIRICAL MODELLING AND CONTROLLER DESIGN FOR TITO LEVEL SYSTEM

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ABSTRACT
A model is a mathematical representation of a physical, biological and information about the system. Model allows to make predictions about a system's behaviour. It is also possible to obtain models of system dynamics from experiments on the process. The empirical process model provides the ability to control and manipulate the variables based upon the environment knowledge from the Two Input Two Output interacting level system. In this paper, transfer function of TITO system is obtained via experimental modelling for tanks in interacting mode. Based on the empirical model, controller for the process is designed. The basic control objective of the TITO system is to maintain a constant level of the liquid in the tanks. The controller designed using the obtained model, gives the satisfactory control of level under servo and regulatory operations in real time.

KEYWORDS: Interacting level system, Experimental modelling, PI controller.

INTRODUCTION
The models are restricted to input/output models since only these signals are accessible to experiments, but modelling from experiments can also be combined with modelling from physics through the use of feedback and interconnection. In general modelling is obtained by either experimental or analytical. A mathematical model will not take into account the physical system, biotic or a biotic conditions that prevail in any particular region or country. Secondly the formulas or rules that are applied to find a conclusion out of an impending situation may not give the actual scenario and only provide factual data. This leads to a situation where many points are either missed or are overlooked and ultimately leads to wrong conclusion. TO overcome this, empirical processes promote sustainable development. The users should be able to maintain their plans with evidence of progress so that corrective action can be taken as soon as possible. Persistent relationships are considered as equivalent to indivisible links between phenomena in the real world. Any definition can be modified at run time a completely open ended method of interaction. The present work is on experimental model for interacting tank process with disturbances.

EXPERIMENTAL SETUP OF THE PROCESS
The three tank system consists of cascaded three tank system in series manner. The inflow for these tanks is regulated by two pumps. Here the objective is to maintain the level of the tank1 and tank2. The level of the water in the tanks is quantified by means of the Differential Pressure Transmitter (DPT). Fig 1 shows the experimental setup of the process.

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Fig. 1 Experimental setup of TITO system

The Fig. 2 shows the closed loop control block diagram for two input two output system.The quantified level of water in the form of current in the range of (4-20) mA is sent to the Data Acquisition system (DAQ) in which Analog to Digital Converter (ADC) converts the analog data to digital data and feed it to the PC.The PC acts as the controller and data logger. The controller considers the process variable as feedback signal and finds the manipulated variable as the output based on the predefined set point The DAC module of the DAQ converts this manipulated variable to analog form into 4-20 mA current signals. The I/V converter converts the current signal to voltage signal, which regulates the motorized control valves to make flow of water into the three tanks based on the set point of the tank.

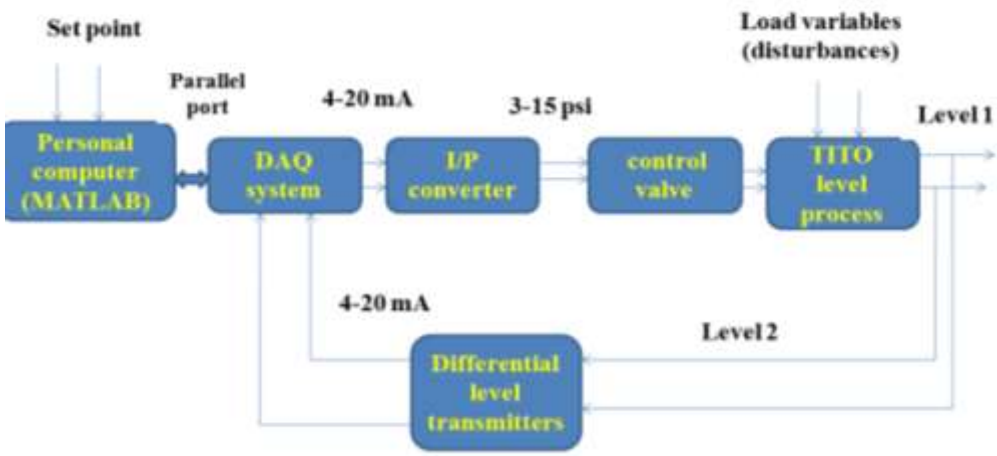

Fig 2. Closed loop control block diagram for two input two output system

Empirical modelling refers to any kind of computer modelling based on empirical observations rather than on mathematically describe relationships of the system modelled. It is a knowledge derived from investigation, observation, experimentation. For TITO system experimental model is obtained from it's open loop response. System identification tool will give proper model by using various approximation and linearization techniques.

3.1 TITO system configuration

The fig.3 shows the schematic diagram of three tank system. Coupling between tank 1 and tank 2 is to be controlled.

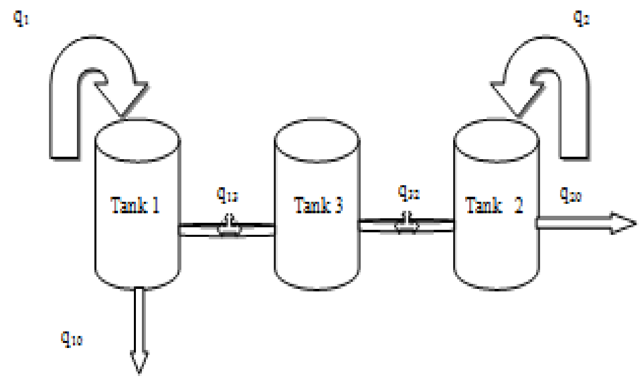

Fig.3 Schematic diagram of three tank system

The volumetric flow into tank1 = $q_1 m^3/s$
The volumetric flow into tank 2 = $q_2\, m^3/s$
The volumetric flow rate from tank 1 to tank 3 =$q_{13}\, m^3/s$
The volumetric flow rate from tank 3 to tank 2 =$q_{32}\, m^3/s$
The volumetric flow rate from tank 1 =$q_{10}\, m^3/s$
The volumetric flow rate from tank 2 =$q_{20}\, m^3/s$
The height of the liquid level in tank 1 = h1(cm)
The height of the liquid level in tank 2 = h2(cm)
The height of the liquid level in tank 3 = h3(cm)

For obtaining responses from the TITO system it is necessary to keep the constrains in a stable condition. Since TITO is a interacting level process, it should be noted that constrains include valve settings also. Table 2 shows the valve position for the taking open loop and closed loop response from the system. It should be maintain constant throughout the process. These constrains are very important while performing the experimental model.If the constrains are changed it will directly impact the effect on closed loop system.

Table 2 Valve Positions for Open and Closed Loop

Test	Response	q_1	q_2	q_{10}	q_{20}	q_{13}	q_{32}
Open loop	T_1	open	close	Partially open	Close	close	close
Open loop	T_2	close	open	close	Partially open	close	close
Open loop	T_{12}	close	open	Partially open	Partially open	Partially open	Partially open
Open loop	T_{21}	Open	close	Partially open	Partially open	Partially open	Partially open
Closed loop	T_1 & T_2	open	open	Partially open	Partially open	Partially open	Partially open

System transfer function $= \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix}$

- G_{11} is obtained by giving input to tank 1 and then getting response from tank 1.
- G_{12} is obtained by giving input to tank 2 and then getting response from tank 1.
- G_{21} is obtained by giving input to tank 1 and then getting response from tank 2.
- G_{22} is obtained by giving input to tank 2 and then getting response from tank 2.

3.2 Open loop response for tank 12 (Interaction in tank 1 by tank2)

By giving set point to tank 1 as 12 mA and tank 2 as zero. Interaction valves are partially opened. The open loop response for tank 2 and it's interaction in tank 1 is shown in figure 3.2

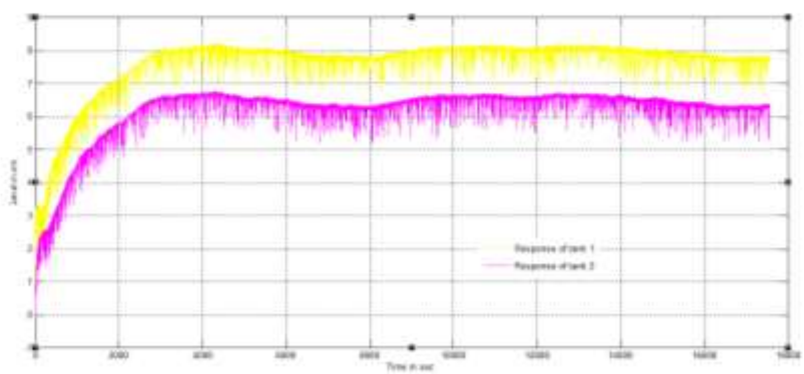

Figure 3.2 Open loop response for tank 12(Interaction in tank1 by tank2)

3.3 Open loop response for tank 21 (Interaction in tank 2 by tank 1)

By giving set point to tank 2 as 12 mA and tank 1 as zero. Interaction valves are partially opened. The open loop response for tank 1 and it's interaction in tank 2 is shown in figure 3.3

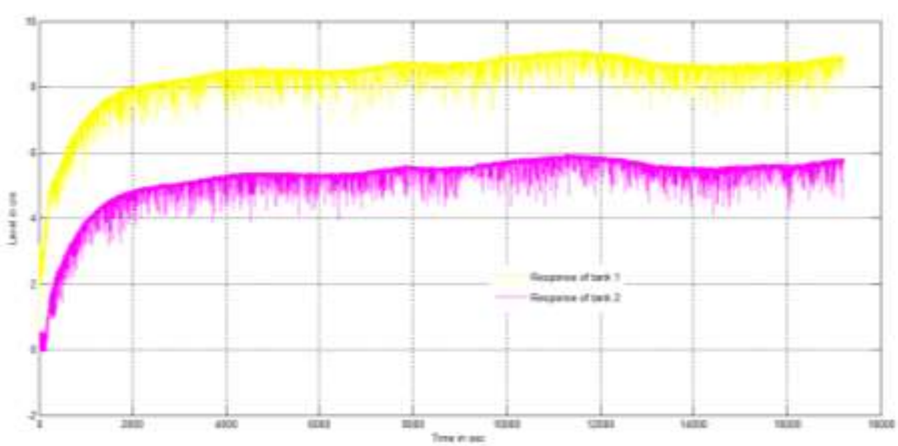

Figure 3.2 Open loop response for tank 21(Interaction in tank2 by tank1)

From the open loop responses , corresponding data collected and given to system identification tool.

3.4 Model identification and validation

The data observed in previous stage has been used to construct the appropriate model for further analysing. Among the different identification procedure,black box identification is considered for model identification. Major key factor in black box modelling is start time and sampling time which has the potential to avry the model parameters.Hence it

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is selected properly from open loop data. Simply Least Square Estimation (LSE) has been followed and part of the data is estimated to obtain the model. The method of least squares is about estimating parameters by minimizing the squared discrepancies between observed data.

- To obtain transfer function G_{11},input is imported as data given to tank 1(mA data corresponds to set point of tank 1)and output is imported as data collected from tank 1.
- To obtain transfer function G_{21},input is imported as data given to tank 1(mA data which corresponds to the set point of tank 1)and output is imported as data collected from tank 2.This transfer function shows the interaction in tank 2 by tank 1.
- To obtain transfer function G_{22},input is imported as data given to tank 2(mA data corresponds to set point of tank 2)and output is imported as data collected from tank 2.
- To obtain transfer function G12,input is imported as data given to tank 2(mA data corresponds to set point of tank 2)and output is imported as data collected from tank 1.This transfer function shows the interaction in tank 1 by tank 2.

Since the process is TITO system, there is two input and two output in the process. Also we have to find system transfer function which will be 2*2 matrix. From the open loop data ,TITO system transfer function is obtained as

$$G = \begin{bmatrix} \frac{0.72339e^{-0.9s}}{1002.7s+1} & \frac{0.54054e^{-0.9s}}{956.98s+1} \\ \frac{0.46088e^{-0.2s}}{1034s+1} & \frac{00.66231e^{-0.00012s}}{960.67s+1} \end{bmatrix}$$

Verification of a model is the process of confirming that it is correctly implemented with respect to the conceptual model. Comparison of real time open loop response and the simulated responses is done. From the real time open loop response the system model is obtained using system identification tool in MATLAB. This model is simulated in MATLAB/Simulink environment with the same constrains which is used in real time. Following figures 3.8 and 3.9 shows the validated model for TITO system.

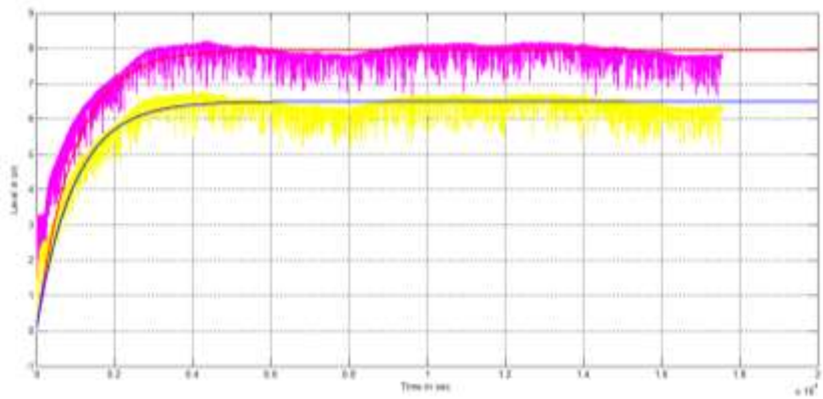

Figure 3.8 Validated response of tank 1 with the influence of tank 2

Figure 3.8 ,shows the response of tank 1 with the influence of tank 2.Here input is given to tank 2 alone. In real time tank 2 input is given as 75.In simulation corresponding current value (12 mA) is given for tank 1. In figure 3.8 ,pink line shows the open loop response for tank2 .Yellow line shows the open loop response for tank 1.This yellow line shows the influence of tank 2 in tank 1.Pink and Yellow line shows the real time response of tank 1 with the influence of tank 2. Red line shows the simulation response of tank 2 and blue line shows the simulation response of tank 1 with the influence of tank 2.

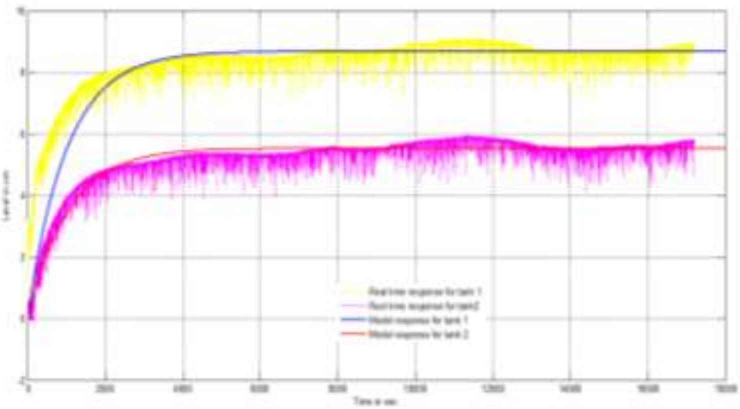

Figure 3.9 Validated response of tank 2 with the influence of tank 1

Figure 3.9 ,shows the response of tank 2 with the influence of tank 1.Here input is given to tank 1 alone. In real time tank 1 input is given as 75.In simulation corresponding current value (12 mA) is given for tank 1. In figure 3.9 ,pink line shows the open loop response for tank2 .Yellow line shows the open loop response for tank 1.This pink line shows the influence of tank 1 in tank 2.Yellow and pink line shows the real time response of tank 2 with the influence of tank 1. Red line shows the simulation response of tank 2 with the influence of tank 1and blue line shows the simulation response of tank 1.

CONTROLLER IMPLEMENTATION

A controller is a device, historically using mechanical, hydraulic, pneumatic or electronic techniques often in combination, but more recently in the form of a microprocessor or computer, which monitors and physically alters the operating conditions of a given dynamical system.. It is a combination of proportional and an integral controller the output (also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyze proportional and integral controller mathematically. As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal, writing this mathematically we have,

$$A(t) = K_i \int_0^t e(t)dt + K_p e(t) \qquad (1)$$

Where K_i and k_p proportional constant and integral constant respectively.By using obtained model from experimental data,model based tuning is done. Model-Based Tuning Methods for PID Controllers, discusses the qualities required for the " good" dynamic data and methods for modeling the dynamic data for controller design. Parameters from the dynamic model are not only used in correlations to compute tuning values, but also provide insight into controller design parameters such as loop sample time and whether dead time presents a performance challenge. It is becoming increasingly common for dynamic studies to be performed with the controller in automatic (closed loop). The following values for the PI tuning parameters obtained by IMC-PI tuning formulas which is given by Equations (2) and (3)

$$k_c = \frac{\tau_p}{k_p \lambda} \qquad (2)$$

$$\tau_I = \tau_P \qquad (3)$$

By using these tuning formulas ,proper tuning values are obtained .When λ = 2000,the response of TITO system for PI controller is shown in Figure 4.1'

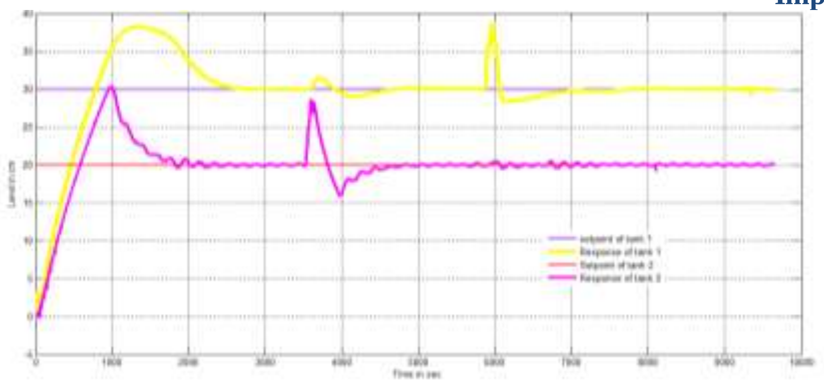

Figure 4.1 Response of TITO system PI controller

Set point of tank 1 is given as 30 cm and for tank 2 is given as 20 cm. In figure 4.1 ,Yellow and pink line shows the response of tank 1 and tank 2.Blue and Red line shows the set point for tank 1and tank 2.Yellow peak at 6000 sec and pink peak at 3500 sec shows the disturbance added in tank 1 and tank 2. Yellow peak at 3500 sec in tank 1 shows the interaction in tank 1 by tank 2.Pink peak at 6000 sec shows the interaction in tank 2 by tank 1.

CONCLUSION AND FUTURE SCOPE

Two input two output (TITO) interacting level system is analyzed in this work. Experimental model is obtained. Controller implementation also done based on the model obtained from real time experimental data. Satisfactory performance of the controller is proved through real time implementation.

Table 1.Performance indice sof TITO system

PERFORMNCE INDICES	TANK 1	TANK 2
Rise time (t_r)	800 sec	500 sec
Settling time(t_s)	2500 sec	2100 sec
Overshoot(%)	28.3	50
IAE	73.9	47.5

Since it is a two input two output interacting level system, this work is further extended to decoupler implementation. Mathematical modelling may also be carried out for perfect control action. Different controller tuning may be done to improve the controller response. Some advanced controller techniques such as MPC,MRAC can also be implemented.

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