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CASCADE CONTROL STRATEGIES FOR INTERACTING TANKS IN SERIES

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ABSTRACT
Control systems are tightly intertwined in our daily lives so much that we take them for granted. In the processing industry, controllers play a crucial role in keeping our plants running- virtually everything from simply filling up a storage tank to complex separation process and chemical reactors. Most of the applications of industrial process control used simple feedback loops which regulated flows, temperature, pressures, levels and the like. The use of advanced regulatory control has given benefits such as a simply closer control of the process.

KEYWORDS: Control strategies, cascade, interacting tank

INTRODUCTION
Advanced regulatory control loops, including ratio, cascade and feedforward plus additional forms such as constraint (selector) control and decoupling could readily be implemented simply by configuring software function blocks. It will be made very clear that with basic regulatory for example feedback control, before control action can occur, there must be a deviation set point. This is called feedback penalty [1].
The objective of advanced regulatory control is to be able to take the control action without paying the feedback penalty. The reduction in feedback penalty may be stated in a variety ways, such as reduction of the maximum deviation from the set point, reduction of the standard deviation, or simply as reduction in the amount of off-spec product produced [2]. This can provide several forms of economic benefit, such as improvement of product quality, energy saving, increased throughput, longer equipment life and plenty more [3].
One of the example of advanced regulatory control is to research and study about the interaction of flow and level by following some method. This project is all about modeling and advanced regulatory control of a two interacting tank in a series. The equipment was water as the process medium [4]. The unit consists of a tank whose discharge can be either gravity or by pumped flow, thus demonstrating self-regulatory and non-self regulatory control. The total system consists of the level tank together with liquid sump, pumps and associated pipelines. The unit demonstrates the level control and flow control by manipulating the valve opening [5].
These can be studied independently before attempting the level–flow cascade control system. After all, simulation of this process will be done using MATLAB to look out for a different in the experimental data and the simulation of the process. Refer to Figure 1 which is the schematic diagram that shows the process [6].
Many times the liquids will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled, and the flow between tanks must be regulated [7]. Explicitly, the concern of this research is to conduct modeling work and analysis of the selected advanced process for two interacting tank in series. In detail, the concern is to simulate the dynamic control process by applying five methods of advanced control strategies from the existence model.

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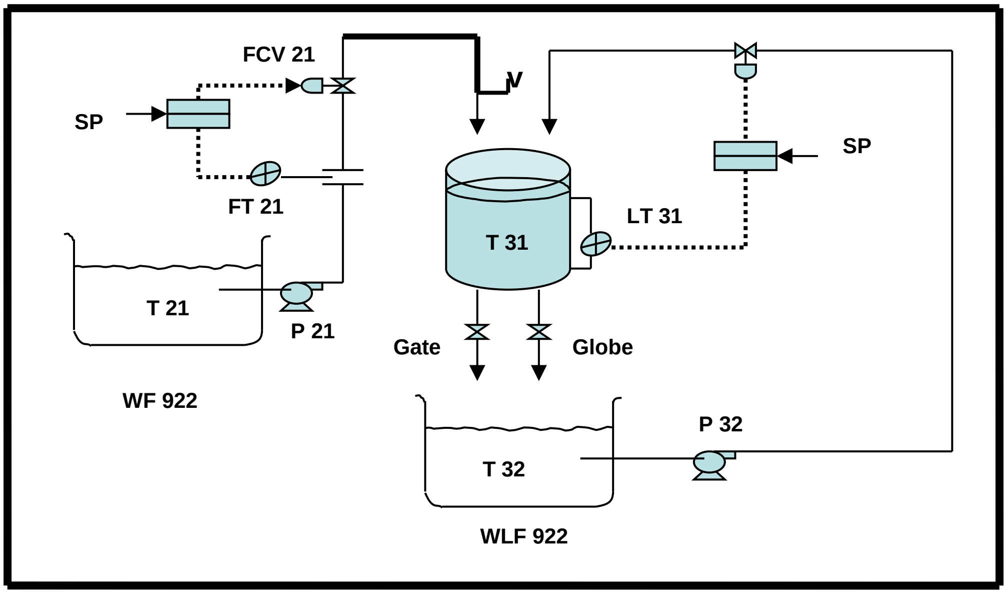

Figure 1 Schematic Diagram of Level Flow Process

MATERIALS AND METHODS

Start up procedure for model WF 922

T-21 is filled up with water form the water supply at the equipment itself

↓

A pipe was connected from T-21 to T-31

↓

P-21 was switched on so that water from T-21 could be pumped to T-32

↓

P-22A/B and P-21 were switched to OFF mode.

↓

"to WLF 922" and "from WT 922" valves were fully shut.

↓

The pressure was checked accordance to the pressure indicated at the air pressure regulator (IAS) and air regulator (AR31). It is a good practice to purge the air regulator (IAS) to remove any condensed water.

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Start up procedure for model WLF 922

T-32 is filled up with water form the water supply at the equipment itself

↓

P-32 was switched on so that water from T-32 could be pumped to T-31

↓

P-31 and P-33 were switched to OFF mode.

↓

"to WLF 922" valve was fully shut.

↓

The pressure was checked accordance to the pressure indicated at the air pressure regulator (IAS) and air regulator (AR31). It is a good practice to purge the air regulator (IAS) to remove any condensed water.

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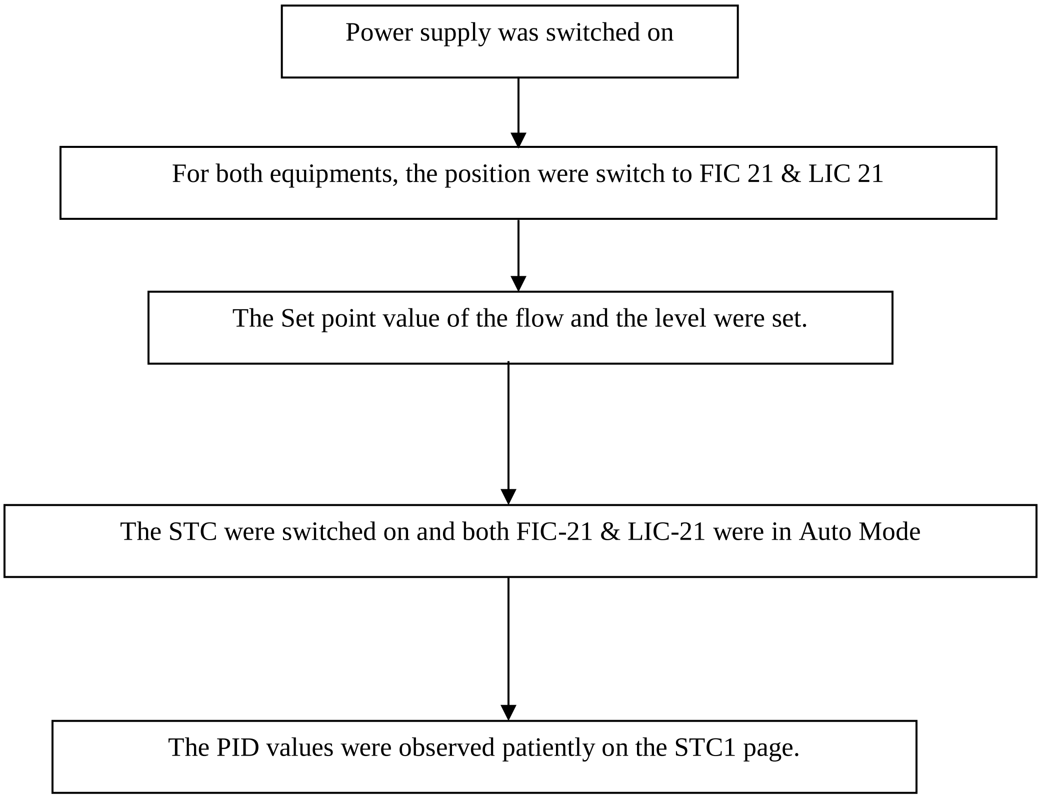
Self Tuning Control Experimental Procedure



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RESULTS AND DISCUSSION

Automatic Tuning Open-loop Test

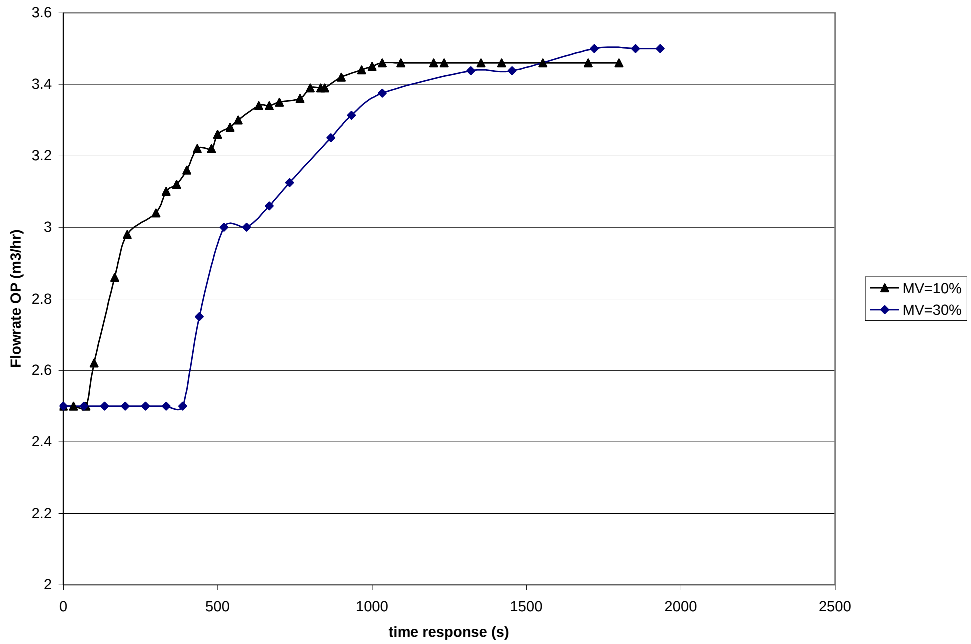

Figure 2: Graph of Automatic Tuning of Flow Control

The graph on Figure 2 shows the response showed when we used the PID values of Tank 1 (Kc=0.143867, τ_I =53.11 for MV=10% and Kc=0.101738, τ_I =54.61 for MV=30%) which did show a slow response, The PID values for Tank 2 was not been used as it is far beyond the range. Therefore we then proceed with the Self Tuning Control (STC) to find the best tuning value for both tanks and below are the result obtained.

Table 1. Self Tuning Data Collected for WF922

Set Value, SV	Valve Opening, MV	PB	τ_I
2.50	56.4	485.2%	2s
3.00	58.9	242.6%	3s
3.50	65.4	174.7%	2s

Table 2. Self Tuning Data Collected for WLF922

Set Value, SV	Valve Opening, MV	PB	τ_I
550mmH_2o	66.7	16.2%	35s
600 mmH_2o	68.8	15.7%	18s
650 mmH_2o	69.9	13%	12s

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Three parameter values are required;

- Process gain, Kp
- Dead Time (delay), τ_D
- Process time constant, τ_C

This parameters are obtained by the simulation done on the SIMULINK based from the dynamic equation from the experiment data. The equation is then modeled in the MATLAB SIMULINK as a subsystem. The subsystem is next put under masked.
The data such as the control valve value (Cv), the flow rate from the first and second tank were modeled as constant value inside the masked subsystem.

Cascade Control
Cascade control system in water level control is designed to handle a total flow rate of water effectively. The same procedure as others were applied for this controller. Figure 3 and Figure 4 below illustrate the block diagram for cascade control loop and the response respectively.

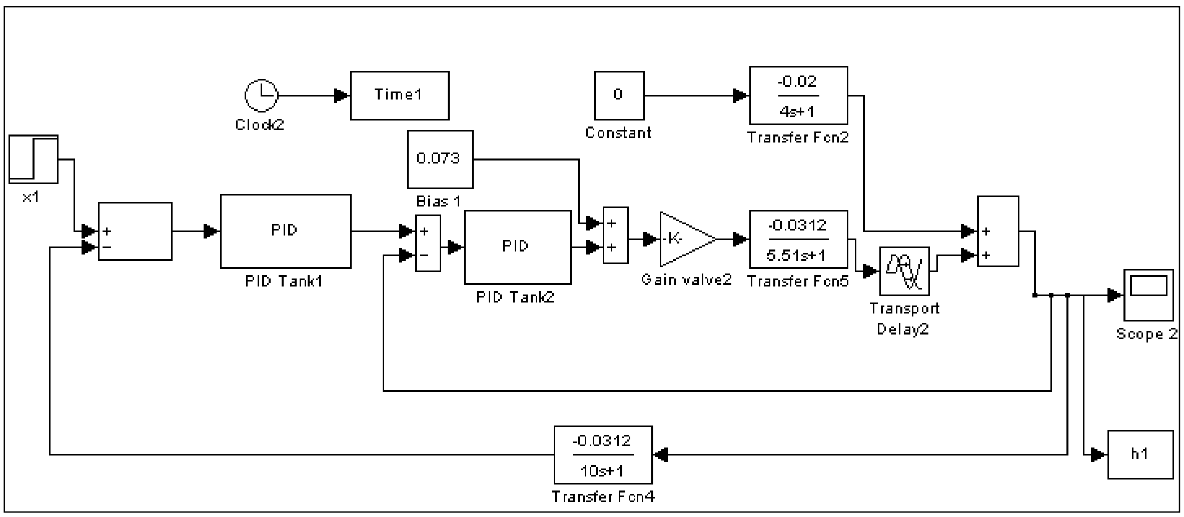

Figure 3: Block diagram of Cascade Control loop

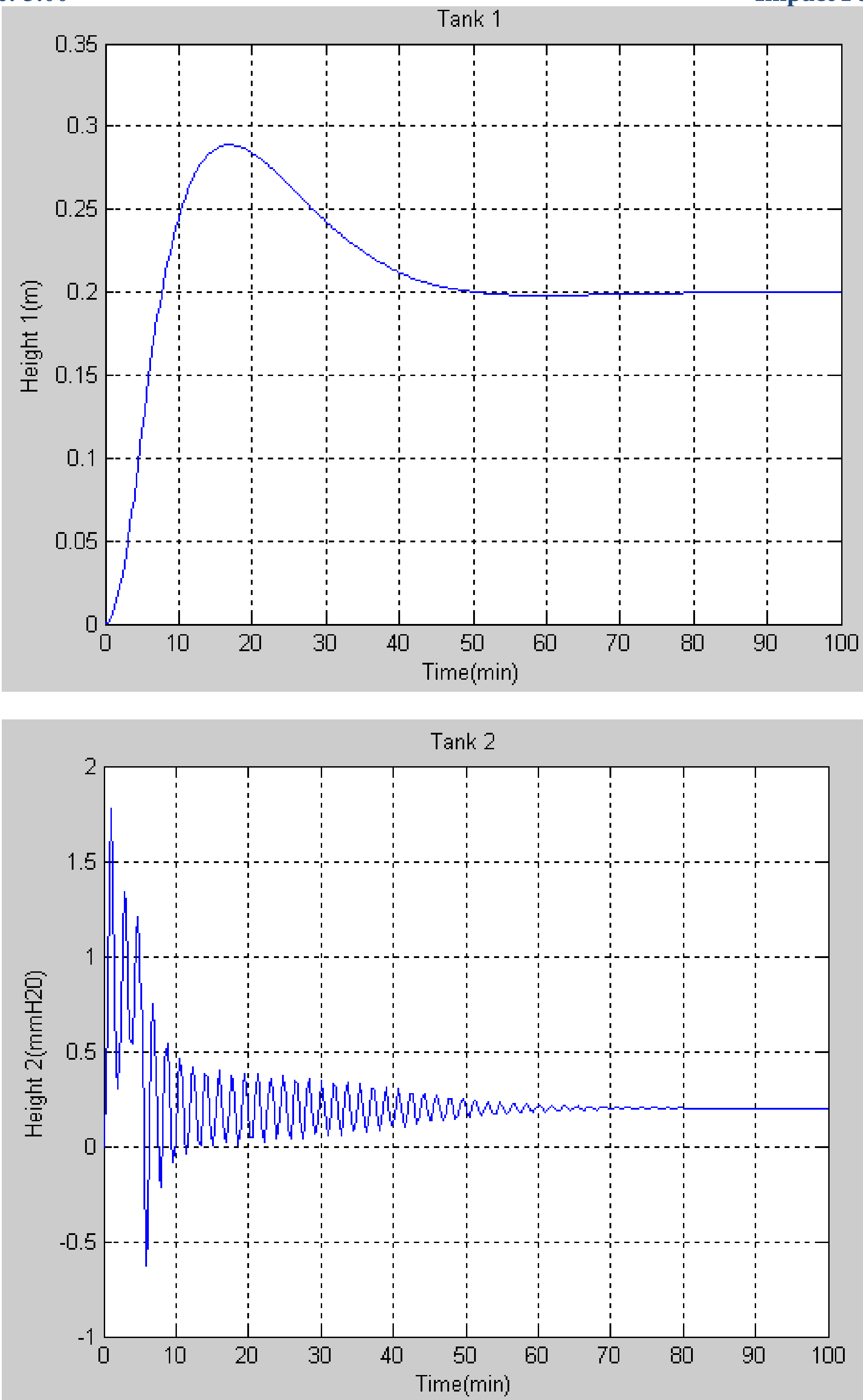

Figure 4: Response graph of Cascade Control Loop

A secondary loop is used to adjust the regulating valve and thus manipulate the total flowrate of water. The primary loop sends its signal in term of desired level to the secondary loop which is flow controller by valve. In essence, the signal from the primary loop is the set pint of the secondary controller.
Based from the response for tank 1, the response has an overshoot which settles at a desired value at a very short time; 50 minutes. This controller provides the best controller for water level of tank 1. This we could see from the response itself where the area under the graph (which represents the error) is the smallest among all the controls. The summary results from the response are shown below. The response for tank 2 shows fluctuation in the beginning before it settles at 0.25 mmH_20 in 80 minutes. Although the time taken for the level of tank 2 to be stable is rather quick, the height for it to settle is rather very low. The summary results from the response are shown below.

Table 3: Summary result of cascade control response

Controller	% Valve Opening	Transfer Function	Area under the graph
Cascade	0.5 (Tank 1)	$\frac{0.0033319}{2616.3s^2+110.7s+1}$	21.45
	0.2 (Tank 2)	$\frac{0.0032934}{0.0000011s^2+52.1s+1}$	23.32

CONCLUSION
Cascade control manages to minimize error the best and has a faster rate of settling time for both tanks. Furthermore, the error was the lowest by comparing the area under the graph. The instability of the level in tank 2 is acceptable as it is in a small range of height.
It is recommended that this project will be extended to a greater scope of experimental value in order to have a wide range of control strategies. Other than that, it is suggested that the data to be simulated is taken from the equipment which is being proper fabricate

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