Liquid Level Control of Single & Coupled Tank using PID & Fuzzy Controller

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Abstract— Coupled Tank system used for liquid level control is a model of plant that has usually been used in industries especially chemical process industries. Level control is also very important for mixing reactant process. The basic control principle of the coupled-tank system is to maintain a constant level of the liquid in the tank when there is an inflow and outflow of water in the tank and outflow of water out of the tank respectively. In order to control the level of the liquid automatically, a controller is needed. In this project, the various controller techniques have been studied which are used for controlling the level & flow of Coupled Tank system. The main objective of this project is to determine the mathematical model of a Coupled Tank system using these techniques. It follows by designing a controller consists of a PI, PID and a Fuzzy Logic controllers for the system.

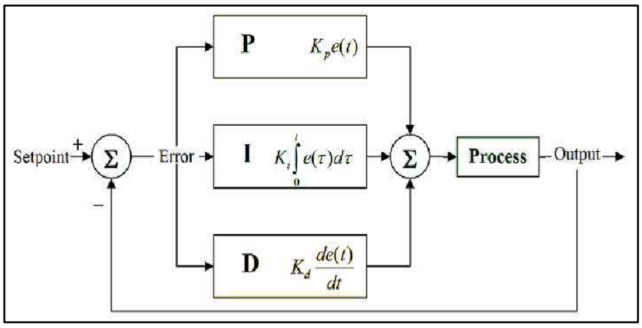
Keywords: Coupled Tank System, PI, PID and a Fuzzy Logic Controllers

I. CONTROLLER METHODOLOGY

It is a robust easily understood algorithm that can provide excellent control performance despite the varied dynamic characteristics of process plant. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. In the absence of knowledge of the underlying process, PID controllers are the best controllers. However, for best performance, the PID parameters used in the calculation must be tuned according to the nature of the system- while the design is generic. The PID controller calculation involves three separate parameters and is accordingly sometimes called three term control: the Proportional, the Integral and the Derivative values. The proportional value determines the reaction to the current error, the integral value determines the reaction based on the sum of recent error, and derivative value determines the reaction based on the rate at which the error has been changing. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve or the power supply of heating element.

MATLAB software was used to implement the required designs. The command window, Simulink feature as well as M-file facilitated the construction of the FUZZY model and PID controllers.

PID Controller had been successfully designed to controlled liquid level at tank on single tank system and at tank2 on coupled tank system using simulation and implementation. Among Different types of controller the matlab simulation technique is applied where PI shows higher accuracy and much high speed of response than P type of controller.



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$$u(t) = K_P e(t) + K_I \int e(t)dt + K_D \frac{d}{dx} e(t)$$

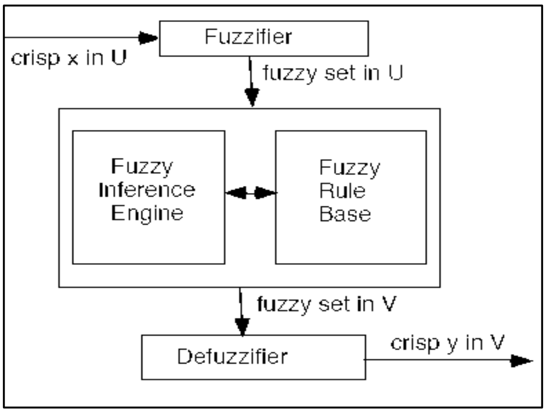
With the PID Control Transfer Function is

$$C(s) = K_P + K_I \frac{1}{s} + K_D s$$

Intelligent controller methodology (FUZZY LOGIC CONTROLLER) which includes human knowledge in the form of his/her experience. In the fuzzy logic controller better fuzzy control behavior and performance can be by the combination of:

– Redefining existing membership functions.
– Refining existing rule.
– Adding new membership functions and new rules.

Fuzzy logic control systems usually consist from four major parts: Fuzzification interface, Fuzzy rule-base, Fuzzy inference machine and Defuzzification interface.



Industrial applications of liquid level control abound, e.g., in food processing, beverage, dairy, filtration, effluent treatment, and nuclear power generation plants; pharmaceutical industries; water purification systems; industrial chemical processing and spray coating; boilers; and automatic liquid dispensing and replenishment devices. The level in twin tank control can be controlled by the variation techniques.

II. MAMDANI -TYPE FUZZY INFERENCE SYSTEM

Mamdani FIS type was proposed as the first attempt to solve control problems by a set of linguistic rules obtained from experienced human operators. The main feature of such type of FIS is that both the antecedents and the consequents of the rules are expressed as linguistic constraints. Mamdani FIS can provide a highly intuitive knowledge base that is easy to understand and maintain, though its rule formalization requires a time consuming defuzzification procedure. For such reasons, Mamdani type FISs can be used as valid supports in all such fields – like Medicine, Economics, etc.

A. *Fuzzy Logic Tool Box:*

In this section the Fuzzy Logic Toolbox graphical user interface (GUI) tools to build a Fuzzy Inference System (FIS) for any system is described [21]. There are generally five primary GUI tools for building, editing, and observing fuzzy inference systems in the toolbox:

- Fuzzy Inference System (FIS) Editor
- Membership Function Editor
- Rule Editor
- Rule Viewer
- Surface Viewer

1) Fuzzy Controller for Single Tank System

In this phase we implement the fuzzy logic controller for single tank system to obtain the desired response. Firstly we take the 3-Rules implementation for single tank system.

1) Case I: FC with 3 Rules:
1) Rule 1: IF level is okay, THEN valve is no change.
2) Rule 2: IF level is low, THEN valve is open fast.
3) Rule 3: IF level is high, THEN valve is close fast.

Since there is only one input [level] & one output [valve] for SISO system so therefore, two membership have been defined in terms of low , high & okay for LEVEL and also close fast , no change & open fast for valve control signal.

2) Rules Implementation for Single Tank System:

Similarly as previous case is implemented, we can easily implement it with the help of 5 Rules for simple tank system. FC with 5 Rules:

1) Rule 1: IF level is okay, THEN valve is no change.
2) Rule 2: IF level is low, THEN valve is open fast.
3) Rule 3: IF level is high, THEN valve is close fast.
4) Rule 4: IF level is okay AND rate is negative, THEN valve is open slow.
5) Rule 5: IF level is okay AND rate is positive, THEN valve is close slow.

3) First Tuning:

1) The membership functions of the water level's rate are named falling, steady, and rising.
2) Two membership functions close slowly and open slowly are added to the output of the system.
3) Two rules are added:

a) If Level is okay and rate is falling then valve is open slowly.
b) If Level is okay and rate is rising then valve is close slowly.

In this case the controller shows a better response with less overshoot.

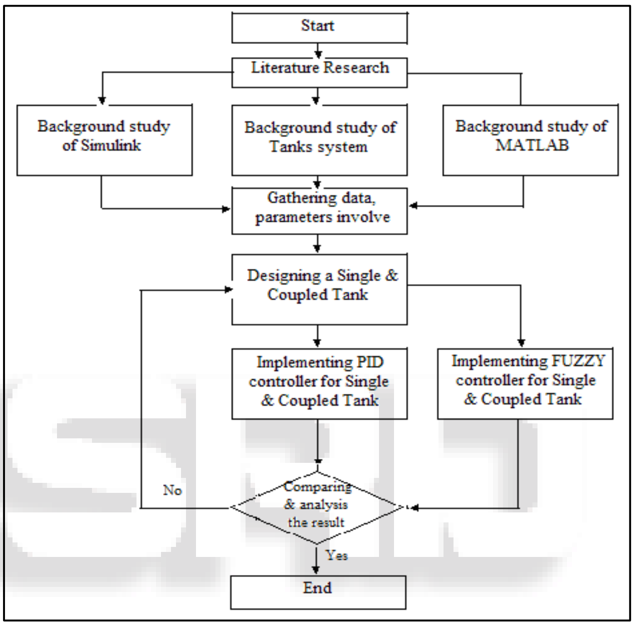
4) Second Tuning:

Changes made in water level are input to broaden up the range of high and low. The system's rise time is slightly improved; however overshoot occurs due to the Changes. The system is further fine tuned in the next phase.

5) Defuzzification Methods

Defuzzification is a process to select a representative element from the fuzzy output C inferred from the fuzzy control algorithm.

III. HIERARCHICAL PROCESS FLOW



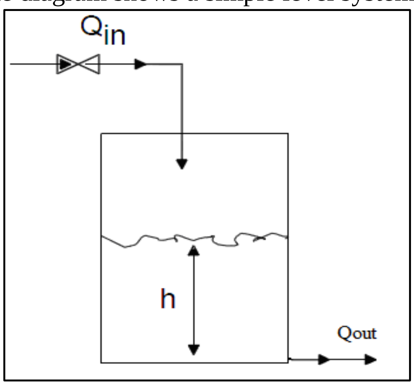
IV. MATHEMATICAL MODELLING

System modelling is a very important part in control system analysis. Before modelling of the split coupled tanks, a model is made for the single tank. This will facilitate the modelling and simulation on the split coupled tanks as well as the controlling of flow

A. *Single Tank System*

1) Non- Linear Behaviour

The system model is determined by relating the flow Qin into the tank to the flow Qout leaving through the valve at the tank bottom. The diagram shows a simple level system



2) Linear or Linearized Behaviour:

The linearized approximation for this nonlinear system or model by using Taylor series.

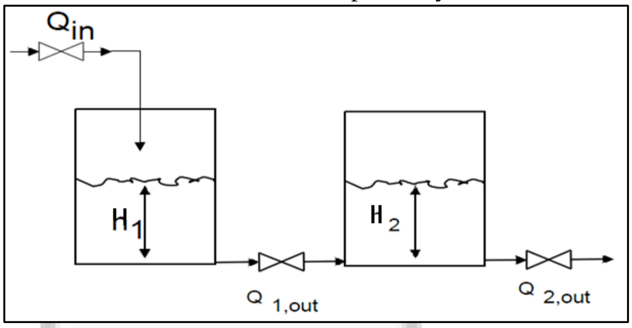
Transfer Function formula is:

$$\frac{h\ (s)}{q\ (s)} = \frac{0.76495}{1 + 24.4785s}$$

B. Coupled Tank System

1) Non- Linear Behaviour

Similar to the single tank system is the split coupled tank i.e. nonlinear system, the equations of flows in the coupled tank can be determined where the system states here are the liquid levels H1 and H2 in corresponding tanks. The mass balance for the first and second tank is respectively:



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