The Design of Water Level Controller Using Fuzzy Logic Technique for Water Tank System

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Abstract

The measurement of liquid level is important in industrial plants. In most of the operations, the ability to conduct accurate level measurement is very crucial since that it can make a difference in making a profit or taking a loss. Therefore, inaccurate level measurement or failure to take measurement can and will cause serious results. This project is to design a valve controller to control the liquid inlet flow in the water level control system. The suitable type of controller has been identified to be using Fuzzy Logic technique, thus the proposed method could be used to solve the inaccurate level of measurement problem. This valve controller uses intelligent feedback control scheme to produce an ideal liquid level for the next process.

Keyword: Fuzzy Logic, Liquid Flow Valve, Membership Function, Rule Block.

1.0 Introduction

Measurement of liquid level in storage and processing vessels, tanks, wells and reservoirs is commonly needed. The most common way to control the liquid level is by controlling the flow of liquid through pipes and valves.

The liquid flow can be controlled by mechanical or electronic techniques. In this project, the liquid flow controls are depending on the water level in the tank. There are many types of level sensors that has been developed and different method to get the accurate measurement. This operation of the valve controller is controlled by the Fuzzy Logic technique that can control the fractional opening or closing of a valve [2]. The controller compares a measured value from water level with a reference rules and make a decision to open the liquid flow valve. The purpose of this project was to analyze the performances of the water level system by using Fuzzy Logic technique.

The main objective of this project is to understand the concept of the Fuzzy Logic and to design the program and developed the hardware for Fuzzy Logic controller to analyze the performance of the water level system. The project includes the integration of Fuzzy Logic water level control, the modification and improvement of the water level sensors as well as the designing and developing of Fuzzy Logic controller for the system.

2.0 Methodology

The overall operation of this project is shown in Figure 2.1, the output signal from the sensors is sent to the controller. The controller will decide the action to actuate the switching circuit to drive the valve to fully open or fully close. The FuzzyTECH software is being used to control the process. This project consists of two major parts which are hardware and software. The construction of hardware part will include the mechanical system.

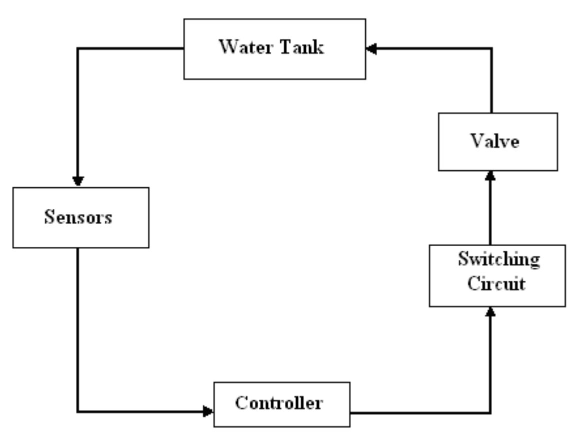

Figure 2.1: The Overall Process

2.1 Hardware Development

The hardware development has been divided to four main parts, the water level sensor, the microcontroller, switching circuit and the water flow valve.

The P1 LCW1 floatless level switch has been used as the water level sensors. The sensor used to achieve the project's objective i.e.; to send a signal to the controller.

Based on the intelligence Fuzzy Logic system, the microcontroller ATMEL AT89S52 was used. The FuzzyTECH software been downloaded to the chip to run the controller. This controller will function when it receive the signal from the sensor output. The signal then been processed according the rules and membership function. The output signal from this microcontroller will be sent to the switching circuit.

The switching circuit is a circuitry that switches the operation of liquid flow valve to fully open or fully closed. The type of relay that had been used is SRD-12VDC-SL-C with +12VDC supply. There are four relays used to actuate three valves and one motor pump.

2.2 Software Development for Fuzzy Logic Control

FuzzyTECH Program has been used in this project, it provides with all the tools to design and test a Fuzzy Logic System. Design and implementation of a Fuzzy controller is conventionally divided into two basic steps: fuzzification, the application of knowledge base and defuzzification. Fuzzification transforms an objective term into a Fuzzy concept. The main parts in this program are the Input Output Variables, Membership Function and The Rule Block. The following Figure shows the Fuzzy Controller architecture.

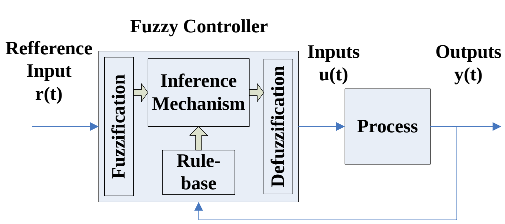

Figure 2.2: Fuzzy Controller Architecture

2.2.1 Input Output Variables

The structure of the Water Level Controller will appear in the project editor windows as shown in Figure 2.3**.** There are one input, one rule block and two output variables. The input block uses the interface type of 'Compute MBF' as input fuzzification while the output block uses Center of Maximum (CoM) type as output defuzzification.

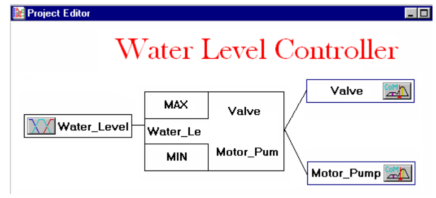

Figure 2.3: Input and Output Block diagram

2.2.2 Input and Output Membership Functions

For the Fuzzy Logic water level control, there are three membership functions for each of the input and output Fuzzy variable of the system. The inputs variables are water level and the outputs are valve and the motor pump. The linguistic variables are presented in Figure 2.4, 2.5 and 2.6.

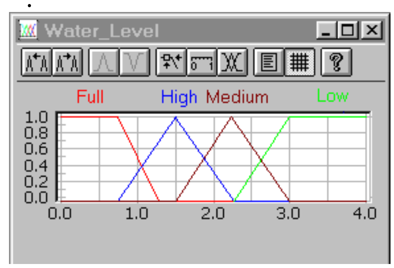

Figure 2.4: Membership Function of the Water Level

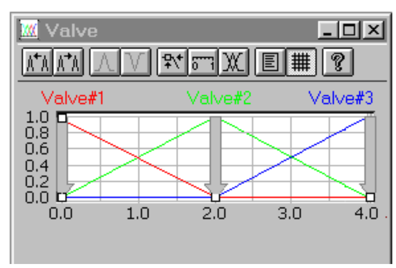

Figure 2.5: Membership Function of the Liquid Flow Valve

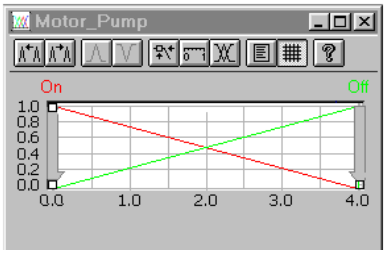

Figure 2.6: Membership Function of the Motor Pump

2.2.3 Rule Block

This Rule Block contains the rules of the system describing the control strategy. Each rule is a linguistic expression about the control action to have taken in response to a given set of process conditions [7]. The format of the rules involved is as Table 1. There are nineteen possible rules that been considered in this project.

Table 1: Rule Block

Spreadsheet Rule Editor - RB1

Matrix	IF	THEN			
Utilities	Water_L	DoS	Motor_P	Valve	
1	Full	1.00	Off	Off	OFF Conditions
2	High	1.00	On	Valve#1_C	Motor Pump ON, Valve Closed
3	High	1.00	On	Valve#2_C	
4	High	1.00	On	Valve#3_C	
5	Medium	1.00	On	Valve#1_C	
6	Medium	1.00	On	Valve#2_C	
7	Medium	1.00	On	Valve#3_C	
8	Low	1.00	On	Valve#1_C	
9	Low	1.00	On	Valve#2_C	
10	Low	1.00	On	Valve#3_C	
11	High	1.00	On	Valve#1_O	Motor Pump ON, Valve Opened
12	High	1.00	On	Valve#2_O	
13	High	1.00	On	Valve#3_O	
14	Medium	1.00	On	Valve#1_O	
15	Medium	1.00	On	Valve#2_O	
16	Medium	1.00	On	Valve#3_O	
17	Low	1.00	On	Valve#1_O	
18	Low	1.00	On	Valve#2_O	
19	Low	1.00	On	Valve#3_O	

2.3 Experimented Setup

The experiment setup demonstrates the hardware assemblies to get the expected result. All the hardware designed had been connected as Figure 2.7.

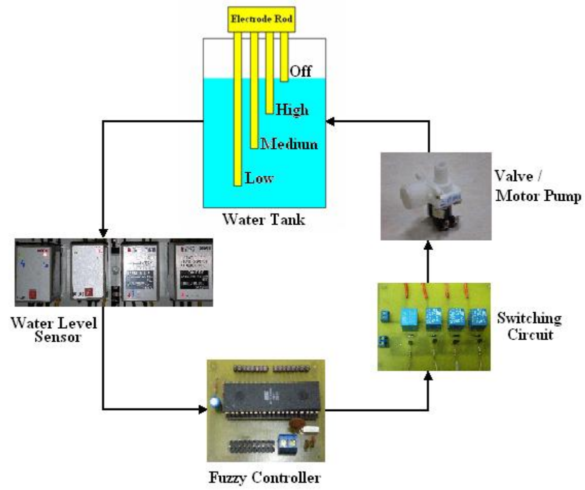

Figure 2.7: Flow chart of the overall operation

The input sensor is been placed into the water tank, any changes of the water level is measured. Then the output signal from the sensor is processed by the Fuzzy Controller.

The controller decides the task according to the rules and the membership that has been set. After the controller had made the decision, a signal will be sent to the switching circuit.

The switching circuit actuated the valve to let the liquid flow. The valves operate according to the output of the Fuzzy controller to fill up the water tank. This operation will stop when the water level reaches the point that had been set.

3.0 Result and Discussion

The water level control system has been tested to ensure that the system is reliable and consistence. This work is divided into two parts; hardware and software part. The most important criteria are to get the best quality of product produced.

3.1 Programming Result

The programming result can be obtained after enabling the 'Interactive Debug Mode'. Figure 3.1 shows the sample of Fuzzy output after defuzzification process. The sample result below shows that when the water level reaches the medium level, the motor pump is ON and two valves has been driven to fully open.

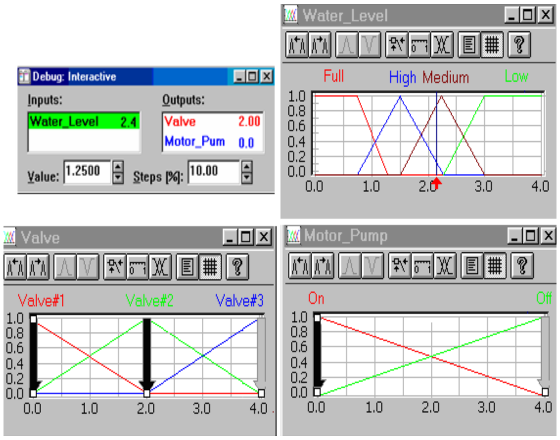

Figure3.1: Software output simulation result

Table 2 shows that the both side of the Degree of Support (DoS) for the medium level condition are displayed. According to the spreadsheet rule editor below, valve number one and valve number two are opened and valve number three is closed.

Table 2: Rule Block Table for the Medium Level.

Spreadsheet Rule Editor - RB1

Matrix	IF	THEN		
Utilities	Water_L	DoS	Motor_P	Valve
1	Full	1.00	Off	Off
2	High	1.00	On	Valve#1_C
3	High	1.00	On	Valve#2_C
4	High	1.00	On	Valve#3_C
5	Medium	1.00	On	Valve#1_C
6	Medium	1.00	On	Valve#2_C
7	Medium	1.00	On	Valve#3_C
8	Low	1.00	On	Valve#1_C
9	Low	1.00	On	Valve#2_C
10	Low	1.00	On	Valve#3_C
11	High	1.00	On	Valve#1_O
12	High	1.00	On	Valve#2_O
13	High	1.00	On	Valve#3_O
14	Medium	1.00	On	Valve#1_O
15	Medium	1.00	On	Valve#2_O
16	Medium	1.00	On	Valve#3_O
17	Low	1.00	On	Valve#1_O
18	Low	1.00	On	Valve#2_O
19	Low	1.00	On	Valve#3_O

OFF Conditions (row 1)

Motor Pump ON, Valve Closed (rows 2–10)

Motor Pump ON, Valve Opened (rows 11–19)

3.2 Experimental Result

There are a few experiments that had been conducted in order to analyze the performance of the system. The experiment involved four level of water conditions which are full level, high level, medium level and low level.

The first experiment is to test the full water level condition; at this condition there are no output signal from the sensor to enable the valve and the motor pump as shown in Table 3.

Table 3: Full Level Condition Test

SENSORS (V)		RELAY (V)		MOTOR PUMP/ VALVE	
S1	0.00	**R1**	0.00	**Motor**	OFF
S2	0.00	**R2**	0.00	**Valve 1**	Close
S3	0.00	**R3**	0.00	**Valve 2**	Close
S4	0.00	**R4**	0.00	**Valve 3**	Close

In the second experiment which is for high level condition, the water level sensors sent 4.7V signal to the Fuzzy controller to turn ON the motor pump and enabled the first valve. From Table 4 below shows the result for high level condition.

Table 4: High Level Condition Test

SENSORS		RELAY (V)		MOTOR PUMP/ VALVE	
S1	4.70V	**R1**	11.00	**Motor**	ON
S2	4.65V	**R2**	10.80	**Valve 1**	Enable
S3	0.00	**R3**	0.00	**Valve 2**	Close
S4	0.00	**R4**	0.00	**Valve 3**	Close

Consequently, for medium water level in the third experiment, the sensor sent 4.35V signal to the controller to open the second valve. The following table is for medium level condition result, where the motor pump and two valves been enabled.

Table 5: Medium Level Condition Test

SENSORS		RELAY (V)		MOTOR PUMP/ VALVE	
S1	4.60V	**R1**	10.70	**Motor**	ON
S2	4.50V	**R2**	10.50	**Valve 1**	Enable
S3	4.35V	**R3**	10.00	**Valve 2**	Enable
S4	0.00	**R4**	0.00	**Valve 3**	Close

The final experiments are low water level condition. At this level, the sensors sent the 4.00V signal to the Fuzzy controller and then the controller actuated the switching circuit and drive all the valve. The results are shown in table 6.

Table 6: Low Level Condition Test

SENSORS		RELAY (V)		MOTOR PUMP/ VALVE	
S1	4.50V	**R1**	10.60	**Motor**	ON
S2	4.30V	**R2**	10.30	**Valve 1**	Enable
S3	4.20V	**R3**	9.80	**Valve 2**	Enable
S4	4.00V	**R4**	9.75	**Valve 3**	Enable

Table 3 to table 6 indicates the performance of the water level control system. Overall, the system is 98% successful.

4.0 CONCLUSION

The water level controller system using Fuzzy logic has been successfully implemented in this project. It can operate the opening and closing of valve according to the changes of water level in the water tank. The purposed measurements have been implemented and performance of the system discussed. The applications of the FuzzyTECH software to program the microcontroller ATMEL 89S52 are successful.

5.0 FUTURE DEVELOPMENT

It is recommended to use the pressure transducer as an input sensors and the proportional valve to increase the accuracy and to improve the system. This Fuzzy Logic method could also be applied in varies industry process.

6.0 ACKNOWLEDGEMENT

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