FUZZY LOGIC CONTROL OF A NONLINEAR PH-NEUTRALISATION IN WASTE WATER TREATMENT PLANT

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ABSTRACT

Industrial processes produce a variety of waste water pollutants, some are difficult and/or costly to treat. Waste water characteristics and level of pollutants vary significantly by industry. The task of various pH control system is to adjust the pH of the process stream into the defined acceptable discharge range. This study focuses on the control of highly nonlinear pH level of the waste water i.e. to obtain a natural solution (pH of 7). The pH level and the flow rate are taken as inputs and the acid and base flow rate as the outputs. Fuzzy control system has been implemented based on system model. A very fast response and stable operation have been observed for transient response. Fuzzy logic controller with 21 rules which shows the most remarkable result of maintaining the output pH to 7±1 which is the acceptable pH level for waste water.

Key words*: Waste water, pH, Fuzzy Control, Nonlinear Process*

INTRODUCTION

All waste waters are to be kept out of the rivers and other receiving waters and they must be unloaded from the transporting water at the terminus of the sewerage system which is call the sewage treatment plant. The significant of using pH value in the industrial processes as a measurement is mainly to sense the state of a reaction resides in the fact that several phenomena, as floating, the precipitation and the coagulation, produce themselves better to a certain value of pH.

Waste water is a big concern in industrial safety. pH is one of the waste water parameters that need to be controlled. Acidic or basic waste water is extremely dangerous. It could cause mutation to human cells, which usually called cancer in general term. Long-term exposure to acidic or basic environment can cause illness and unhealthy life to living creatures in the world. Control problems in the process industry are dominated by non-linear and time-varying behavior, many inner loops, and much interaction between the control loops.
Studies on dynamics and control of pH-neutralisation has been carried out since 70's [1-5]. Due to its highly nonlinear characteristic and uncertainty, studies are still reported by many researchers but using new emerging control strategies [6 - 12]. Attention is still given since pH process exist in many systems and industries and practical pH control has not yet been finally solved [11].

Fuzzy Logic Control (FLC) has in some cases nevertheless mimicked the control actions of a human operator. Therefore, fuzzy controllers have advantage of its flexibility on controlling this highly nonlinear process.

This simulation study investigates how different types of rule bases fuzzy logic control work on pH-neutralisation in waste water treatment plant. The pH is controlled by the addition of an acid (to lower the pH) and a base (to increase the pH). A typical fuzzy controller is composed of three basic parts: input signal fuzzification, a fuzzy engine that handles rule inference and defuzzification that generates continuous signals for actuators.

Three types of nonlinear control rule bases have been tested and compared between high frequency input and low frequency input.

pH PROCESS MODEL

The model consists of three valves: Acid Valve, Base Valve and Waste water Valve. There is a chemical reaction pool in the center of the model. The chemical reactions take part inside the reaction pool to produce a reasonable pH waste water. The value of pH is then sent to fuzzy logic controller. The fuzzy logic controller will decide whether acid valve or base valve will be opened. Fig. 1 shows the overview of the operation. The system model used in the simulation is shown in Fig. 2.

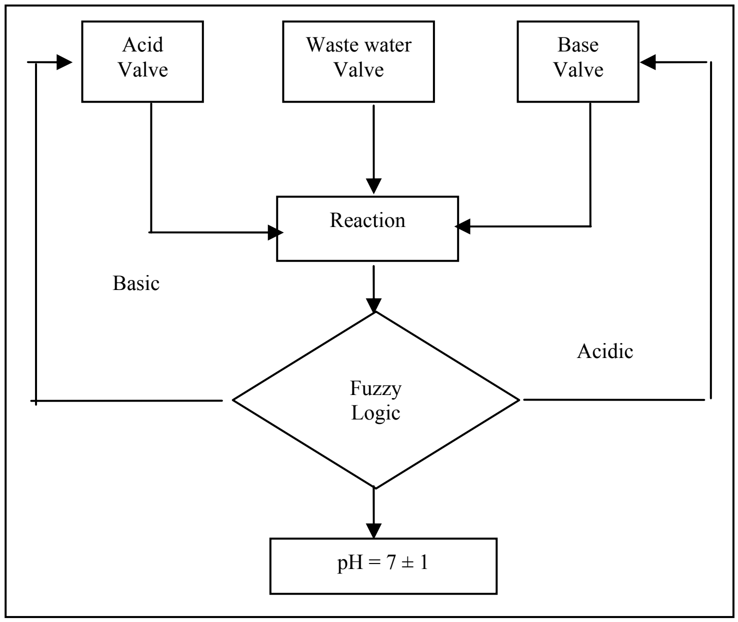

Figure 1: Model of the nuetralisation process

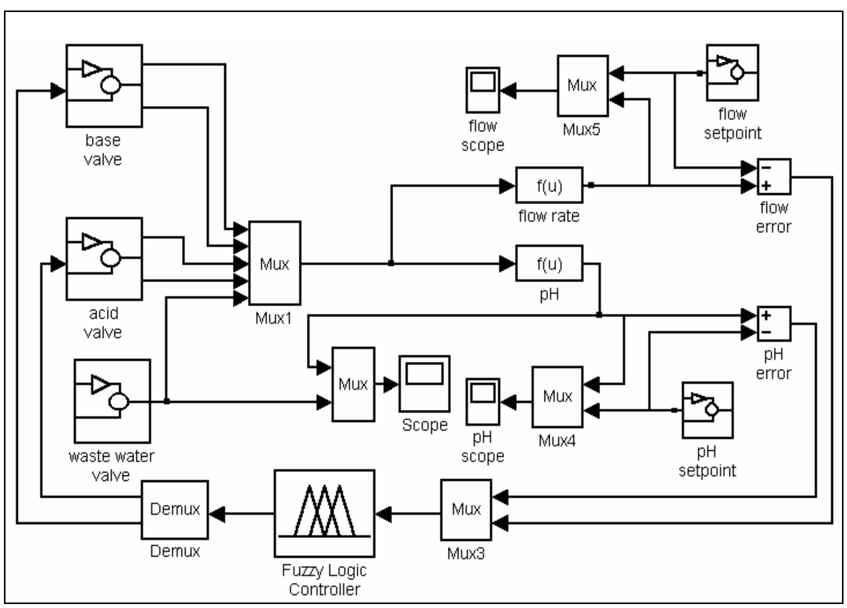

Figure 2: System Model

FUZZY CONTROLLER

A basic structure of a fuzzy controller is shown in Figure 3. There are four things that need to be defined i.e. the input membership function, the rules set, the inference engine and the output membership function.

Two inputs i.e. pH and waste water inflow have been used. These two inputs are the most important inputs of waste water treatment plant. Two outputs are signals to open and close the valves for the acid and base. These two valves will control the flow of the acid and the base so that maintain the value of pH after reaction with the waste water coming out of the plant at 7±1. If the waste water pH is below 6, then base valve will open while acid valve close. If the waste water pH is above 8, then acid valve will open while base valve close.

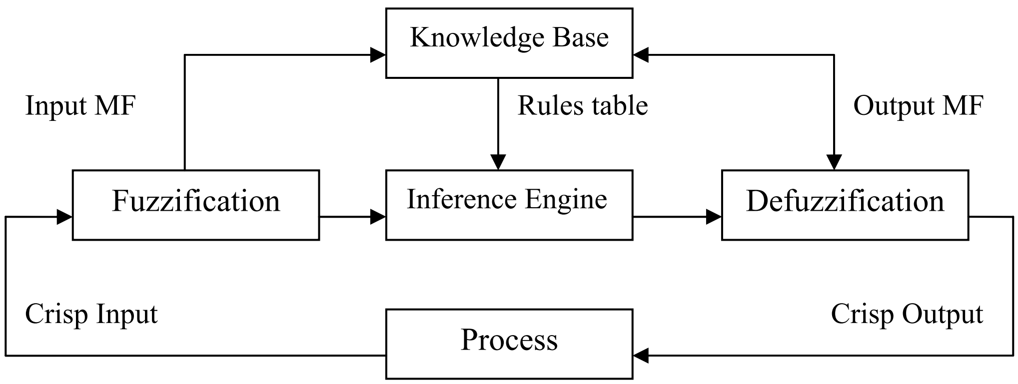

Figure 3: Basic Structure of the Fuzzy Logic Controller

Mamdani inference engine with different number of membership functions for the input has been used. Sugeno type has also been implemented for comparison with the best configuration of the Mamdani.

Examples of the rules table is given in Table 1 for 9 rules i.e. pH below 6 is considered as acid and pH above 8 is considered as base. For 15 rules, the pH is defined into 2 categories of acid (strong acid for pH between 0 to 3 and acid for pH between 3 to 6) whereas base for pH between 8 to 11 and strong base for pH between 11 to 14. In addition, for 21 rules system, acid is divided into three categories i.e. very strong acid (pH of 0 to 2), strong acid (pH of 2 to 4) and acid (pH of 4 to 6) whilst base is divided into three categories as well i.e. base (pH of 8 to 10), strong base (pH of 10 to 12) and very strong base (pH of 12 to 14).

In the two cases (5 and 7 membership functions of pH), the membership functions for flowrate, acid valve and base valve remained three. Similar tables were constructed for these cases.

Table 1: If-Then rules for the controller for 9 rules

IF	pH	AND	Flow Rate	THEN	Acid Valve	AND	Base Valve
IF	Acid	AND	Low	THEN	Close	AND	LittleOpen
IF	Acid	AND	Medium	THEN	Close	AND	HalfOpen
IF	Acid	AND	High	THEN	Close	AND	FullOpen
IF	Good	AND	Low	THEN	Close	AND	Close
IF	Good	AND	Medium	THEN	Close	AND	Close
IF	Good	AND	High	THEN	Close	AND	Close
IF	Base	AND	Low	THEN	LittleOpen	AND	Close
IF	Base	AND	Medium	THEN	HalfOpen	AND	Close
IF	Base	AND	High	THEN	FullOpen	AND	Close

RESULTS AND DISCUSSION

A random square wave signal has been used as the waste water inlet flow with two different frequencies (0.05 Hz and 0.1 Hz) which mimic the fast dynamic of the pH value. The value between 0 to 14 was chosen so that it covers all possibilities i.e very acidic and very strong base. The high frequency response is also used in comparing Mamdani and Sugeno model. The square signal used as input here emulate digitised measurement of pH of the waste water.

Low Frequency Response

Input signal with is used as low frequency response input. This input has the range of 13.4506 pH, which is sufficient for simulation purpose. The input is a random square signal. The input signal is shown in Fig. 4.5. The output with 9 rules is shown in Fig. 4.6. It shows that the output is definitely higher than the limit of 6 to 8 pH. This is not a good result. The output with 15 rules is shown in Fig 4.7. It shows that the output is slightly higher than the limit of 6 to 8 pH. This is a moderate result. Fig. 4.8 shows that the output with 21 rules is controlled within the limit 6 to 8 pH. This is the best result obtained from the simulation. It meets the requirement of environment safety and health. The 21 rules FIS fulfill the objective of the project.

High Frequency Response

Input signal with is used as high frequency response input. This input has the range of 13.8569 pH, which is sufficient for simulation purpose. The input is a random square signal. The input signal is shown in Fig. 4.1. The output with 9 rules is shown in Fig. 4.2. It shows that the output is definitely higher than the limit of 6 to 8 pH. This is not a good result. The output with 15 rules is shown in Fig 4.3. It shows that the output is slightly higher than the limit of 6 to 8 pH. This is a moderate result. Fig. 4.4 shows that the output with 21 rules is controlled within the limit 6 to 8 pH. This is the best result obtained from the simulation. It meets the requirement of environment safety and health.

In both cases, 15 rules would be enough if the range of pH value for the waste water is between 1 and 13. Visual inspection of the responses between low and high frequency inputs shows no visible difference. However, in Table 2 the pH errors computed for different fuzzy controller configurations shows that, the controller performed better for low frequency input. It is also clear that, fuzzy control with 21 rules satisfies the requirement of maintaining the pH between 6 and 8.

Table 2: Comparison between low and high frequency response of the system with Mamdani inference system.

	pH Error (Low Frequency)	pH Error (High Frequency)
9 Rules	4.4835	4.6190
15 Rules	2.2417	2.3094
21 Rules	1.4945	1.5397

Figure 10 shows high frequency response of Fuzzy control with Sugeno inference system with 5 membership function of the pH input (15 rules). There is no significant difference in the performance between Mamdani dan Sugeno inference system.

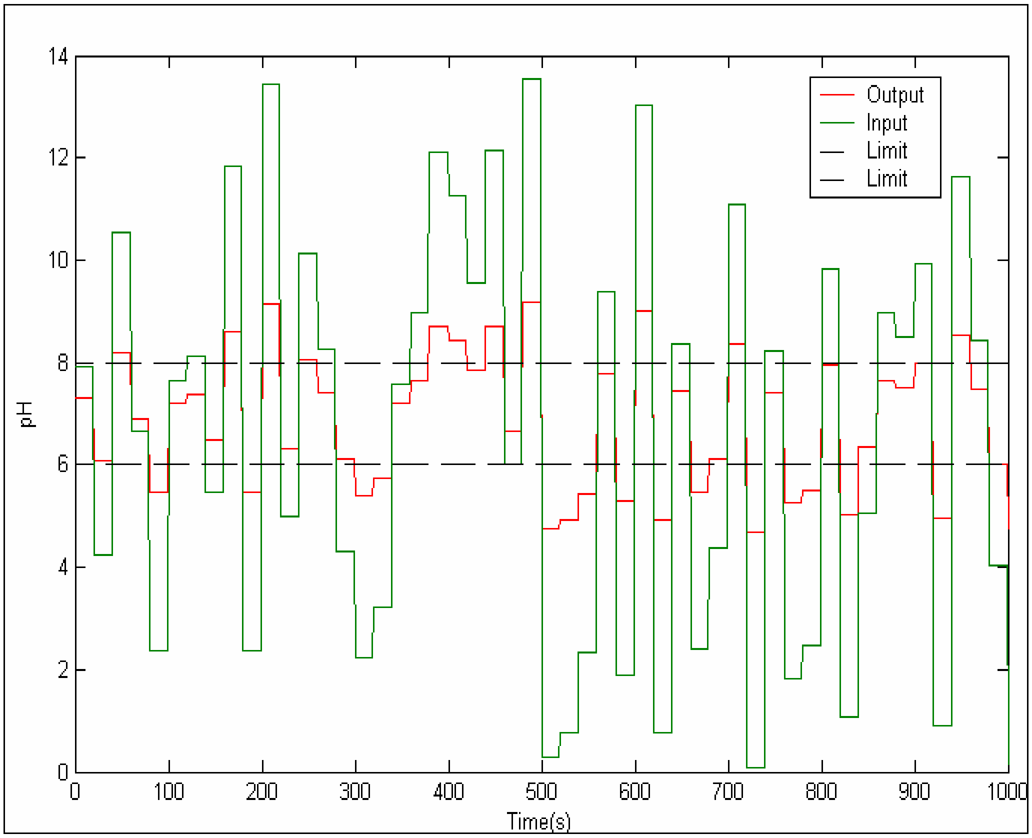

Figure 4: Simulation Output with 9 Rules under Low Frequency

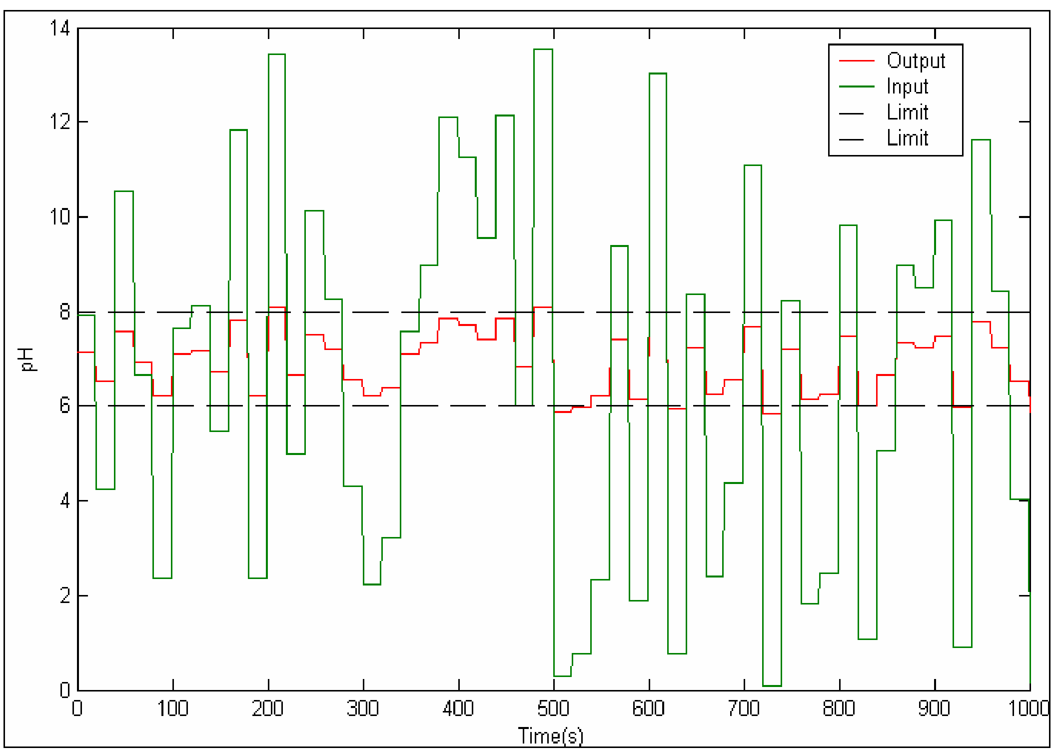

Figure 5: Simulation Output with 15 Rules under Low Frequency

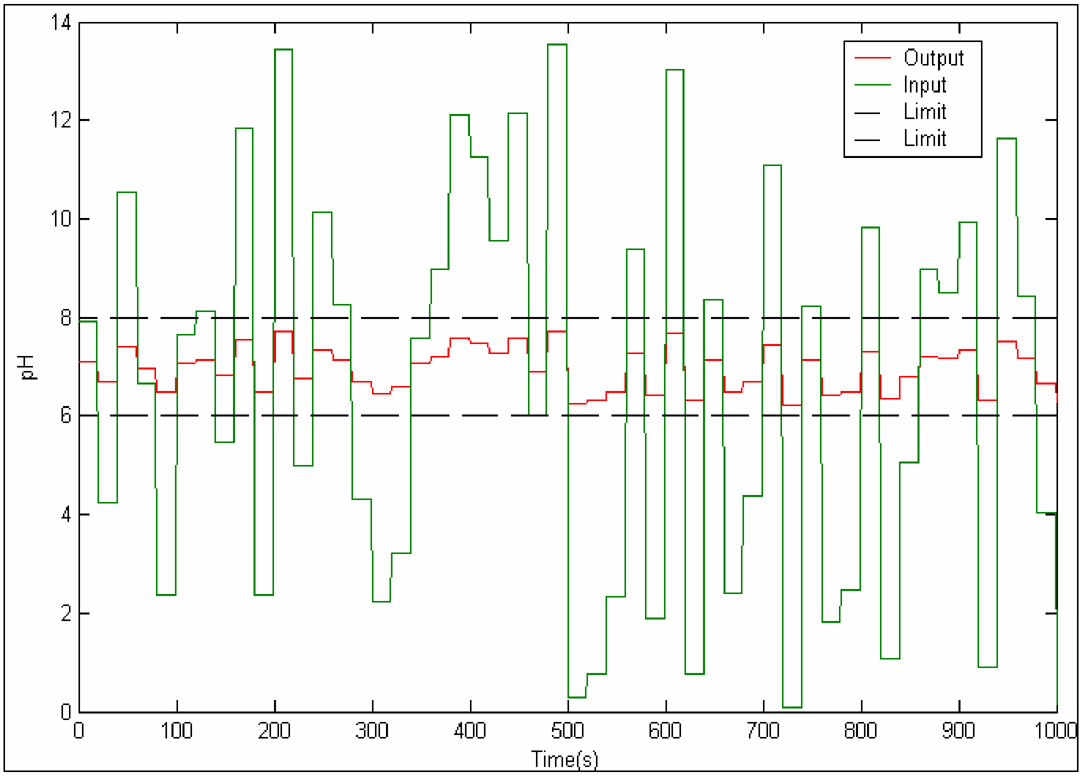

Figure 6: Simulation Output with 21 Rules under Low Frequency

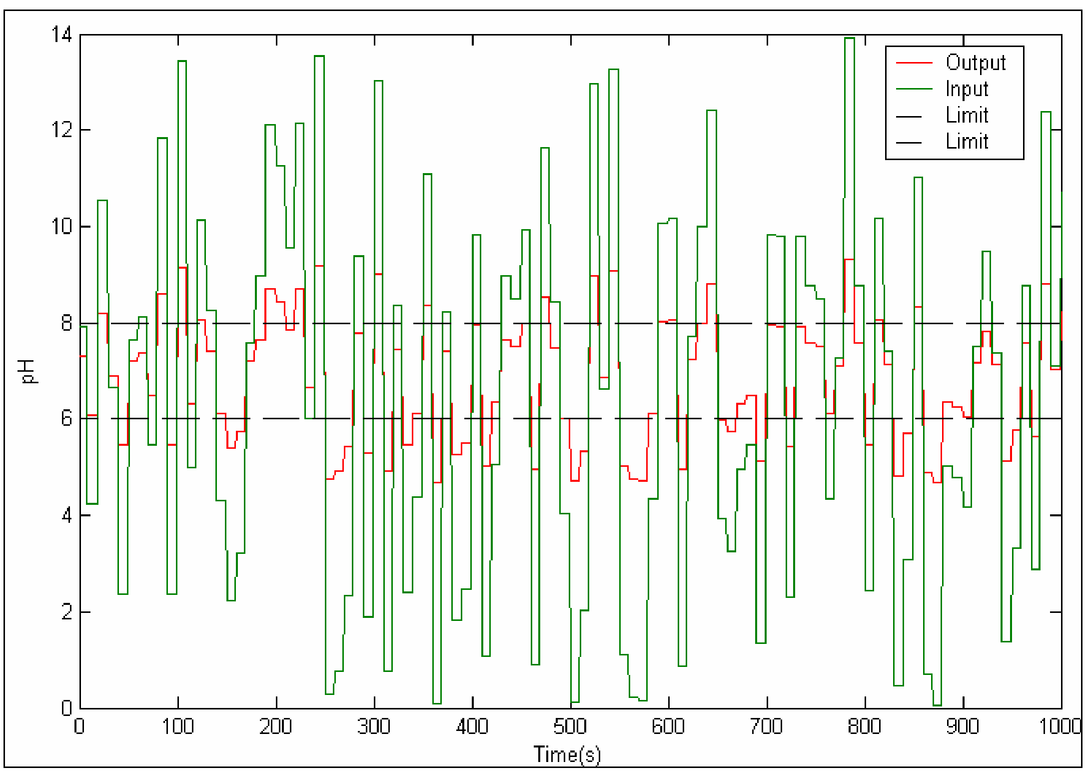

Figure 7: Simulation Output with 9 Rules under High Frequency

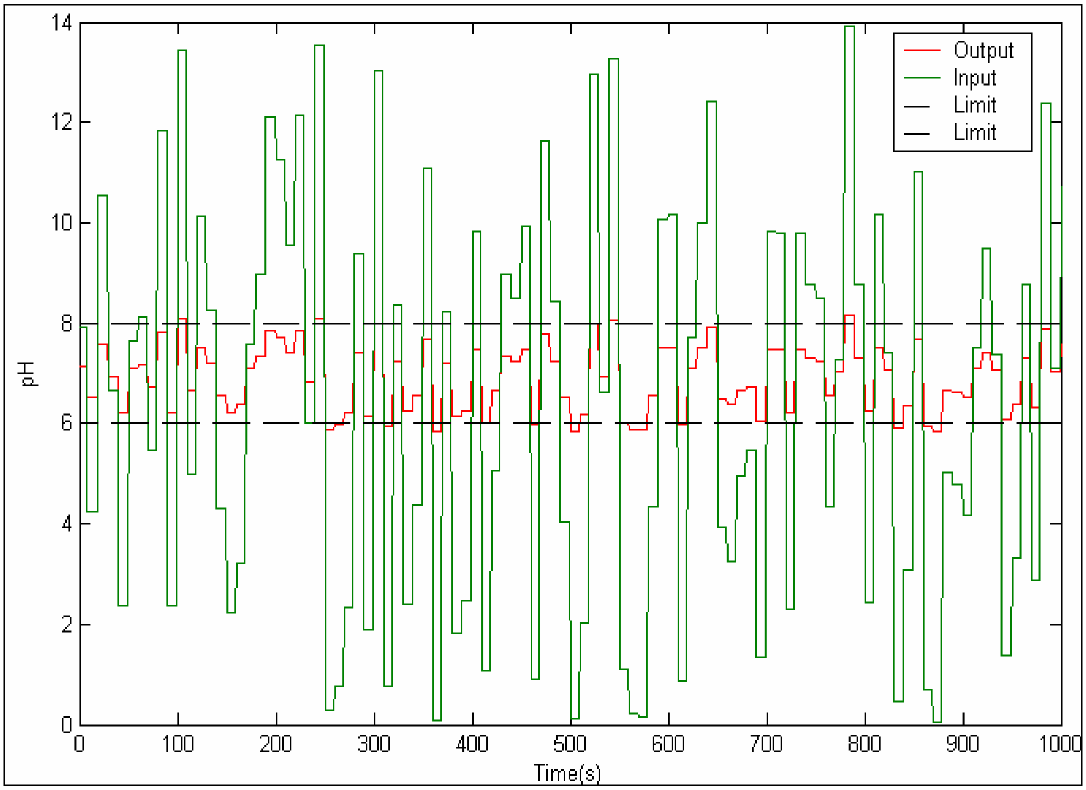

Figure 8: Simulation Output wit 15 Rules under High Frequency

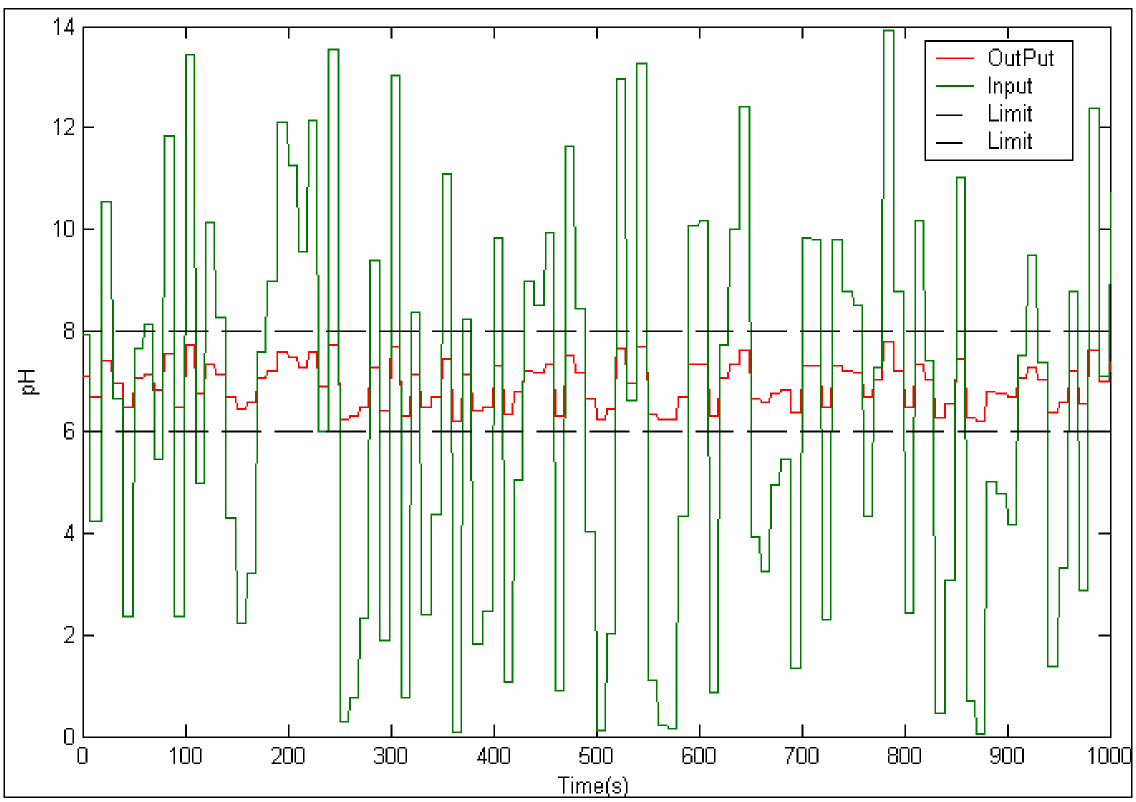

Figure 9: Simulation Output with 21 Rules under High Frequency

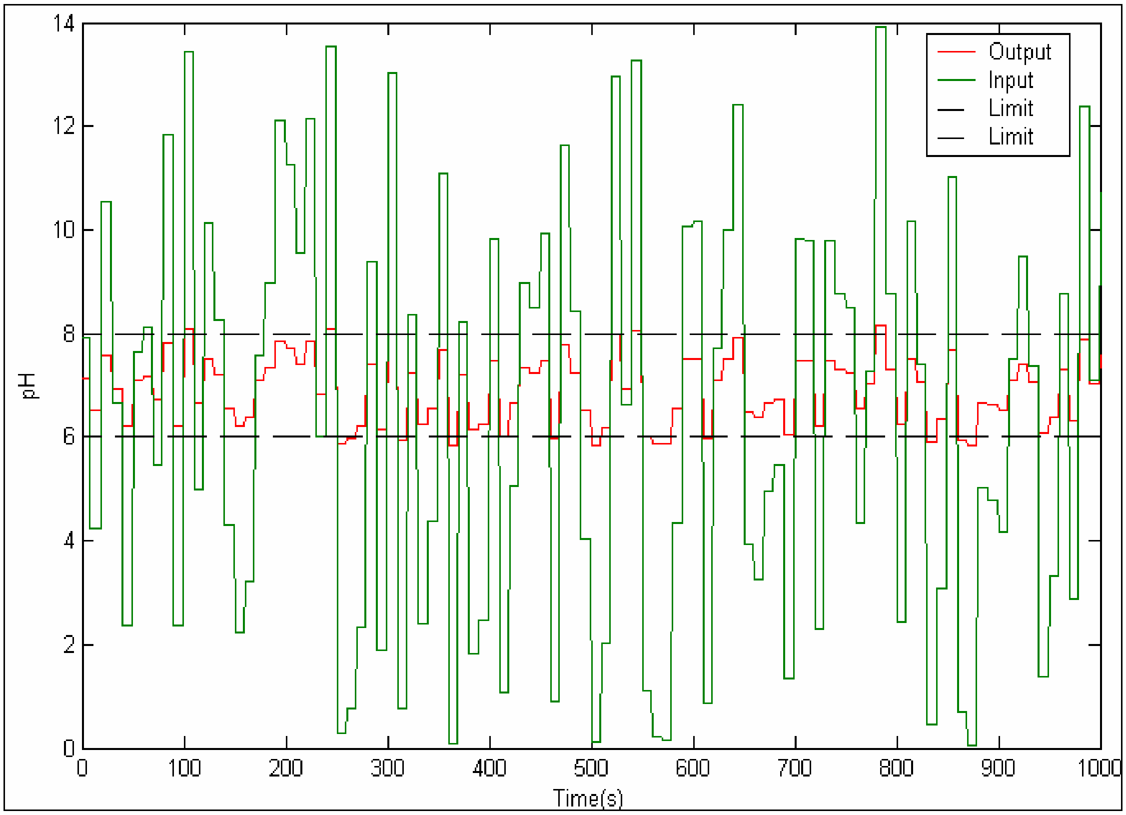

Figure 10: Simulation of pH neutralisation under Sugeno-type Fuzzy control with 15 rules

CONCLUSION

A simulation study of pH neutralisation process control has been carried out succesfully using Matlab. It has been demonstrated that fuzzy logic control performed well to control the highly nonlinear pH neutralization process within the defined range.

The results obtained from the simulation show that 9 rules fuzzy logic controller is not sufficient to obtain a good pH of waste water. Although 15 rules fuzzy logic controller able to control the pH of waste water, but 21 rules fuzzy logic controller is more effectively maintain the pH of waste water at 7±1.

A *sugeno system* is also used to compare with the *mamdani system.* The results show that there is no different between two systems and therefore *Mamdani system* is recommended because it is easier to be compute.

ACKNOWLEDGMENT

The authors wish to acknowledge the authorities of Universiti Putra Malaysia and Ministry of Science, Technology and Innovation, Government of Malaysia for the help and grant provided for carrying out the research (Project Code: 09-02-04-0826-EA0001)

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