Fuzzy Logic Based Aeration Control System for Contaminated Water

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Abstract: The waste water which are the outcomes of processing liquids cannot be used further without proper treatment so the water has to be treated and handled in order to elude the contamination that deteriorates the quality of the atmosphere. Although the biological methods can be utilized for treating the wastes in the water by decomposing the bacteria, it is biased by various causes such as the impurity level, the oxygen available, the dirt type etc. But the standard methodology like aeration utilizes the biological and the chemical oxygen demand reduction termed BO and CO respectively to treat the waste water, the conventional aeration process is performed manually causing enormous usage of electrical energy. So the paper elaborates the scheme of a fuzzy logic based aerator control system (FLACS) for the waste water. The essential equipment of the proposed system are the sensors providing the particulars of the chemical and the biological oxygen demand as input, the microcontroller (Arduino UNO) and other electrical and electronic equipment's that controls the working of the aerator. The analysis performed on the proffered model indicates the performance improvement of the FLACS in terms of the electrical energy utilization and duration of working hours.

Keywords: FLACS, Arduino UNO, Fuzzy Logic, Aerator Control System, Demand in Biological Oxygen and Chemical Oxygen

1. Introduction

The increase in the population has not only caused the increase for daily essential but has increased the amount of waste generation, one such waste is the water wastes, the waste waters that could be reused without treating, are produced from both the industrial areas as well as from the domestic areas. These liquid wastes generated influences the quality of atmosphere. So it is compulsory that these wastes are to

be treated to avoid the contamination of the environment. The treatment plant for the waste water is encompassed of two ponds one for the process of aeration and the other for the sedimentation. The process of aeration is done to minimize the required land area so as to enhance the speed in the process and evade the bad odors that results due to the flawed oxidation procedures.

The aeration process is the fabricator of oxygen in the form of air-bubbles combined with water, "it is an aerobic process for minimizing the chemical and the biological O_2 requirement". But the Conventional ACS functioned manually for very long hours to retreat the waste water. This long hours functioning in turn consumes large amount of electrical power. "To meet the oxygen requirements that are in accordance with the characteristic of the treated waste input, strategies that are intelligent are required to manage the aerators working time so as to minimize the electricity usage enhancing the rate of treatment."

So to reduce the electrical energy consumption of the modern control technology were devised to enhance the performance of the aeration system. "The fuzzy rule based system that is effective with the capability of linguistic reasoning, eluding the necessity of the complicated mathematical models is used in the proposed method as the development for the conventional schemes followed for controlling had restrictions in managing the "nonlinear process" Based on the definition of the context above, the paper puts forth the smart aerator design based on fuzzy logic with the duration (hours) of aerator work observed as output and the attributes of the liquid waste as input (demand in BO and CO). So the proposed method uses a one input one out fuzzy logic to devise the smart aerator controller that is managed by the Arduino UNO.

The key objective of the proposed system is to minimize the electrical energy usage of the aerator control system and "by setting the time of the aerator operation and to work according to the attributes of the water waste input BO and CO" .The remaining of the paper is organized with the related works on section 2 and the proposed design on section 3, the observed results on section 4 and the conclusion on section 5.

2. Related works

Exploration on the waste water treatment form the industries with a aeration cycle shows the optimal bacterial growth with an aeration time of 8 hours according to Wagini, et al [1] An expert arrangement structure was developed based on fuzzy rule system by the author.Kaya, et al [2] and Atia, Doaa M et al [3] to analyze and regulate the wastewater treatment systems that were designed ideally to attain the results aimed through the research.

The author Harrington et al [4] preformed experiments so as to reduce the level of biological oxygen demand and enhancing he PH and the nitrite levels to retain the bacterial progress and in the retreating

process. Linda,et al [5] elaborates the study on the controls that are based on the models that utilize modern algorithms to identify the solutions for minimizing the energy consumption. Tirtowiyadi et al [6] conducted the research with the aerator controller by incorporating it with the PI controller so as to regulate the level of oxygen and in turn to regulate the oxygen level required for the breaking down the contaminants.Estydyah et al [7] disclosed his research performed on the ACS to effectually minimize the chemical oxygen demand.Ross et al [8] presented the overview of the ACS with the FL to regulate the limitations in successfully managing the nonlinear process utilizing the simulation structures that examine the algorithms in the integrated environments that are complicated.Åmand, L. et al [9] summarizes the research that has been performed on the waste water treatment, the review in the paper discusses the complexity degree that is demanded by the ACS and examines the "regulating strategies in the full-scale pilot scale and simulations."

Filali, A et al [10] conducted a research examining the performance of the "Aeration control in a full-scale activated sludge wastewater treatment plan" in terms of power consumption as well as N2O emission Bengt Carlsson et al [11] performed experiments to identify the optimal aeration control for the proper nitrification of the sludge process. R. Vinothkanna et al [12] has utilized the grove sensors and the unibots configuration along with the Beagelbone black processor to sense the activities taking place in and around the home by connecting the things around using the internet of things. Pandian, A. Pasumpon. et al [13] in his paper devise the smart logistics employing the sensors, tag readers and the bar code scanners and the artificial intelligence to develop an automated storage and the retrieval using the IOT devices. Raj, Jennifer S.,et al [14] has devised the automated greenhouse using the sensors to gather the information on the prevailing, moisture, temperature and humidity in turn to enhance the production level of the agriculture, following the aforementioned projects, the proposed methods also devises an aerator control system with the sensors to identify the level of biological and the chemical oxygen demand thereby set the duration of the aerator based on the level of biological and the chemical oxygen demand estimated using the fuzzy along with the microcontroller to regulate the activities of the aerator.

3. Proposed Work

The proposed model designed by replacing the existing controller with the Arduino-UNO controller, and the sensors are used to gather the demand of the biological oxygen and the demand for the chemical oxygen is estimated as shown in the equation 1

$$Demand_{\,Chemical\,Oxygen} = \left(Demand_{\,biological\,oxygen} * 1.64\right) + 11.360 \qquad (1)$$

The digital temperature sensor is utilized in the proposed frame work to gather the temperature in the aeration and it is converted into the biological oxygen demand and converted into chemical oxygen demand

according to equation 1, this given as input to the controller where value obtained are transformed to fuzzy sets using the fuzzy rule based controller and once de-fuzzyfied at the output.

The software design for the proposed model is done using the fuzzy rule system based on the Mamdani type fuzzy interference that generates fuzzy sets output. The input to the system is fed in the form of demand of biological oxygen and the aerator operation is obtained as output. The input values given are fuzzified using the trapezoidal member functions as defined in equation 2

$$\tilde{T}(x) = \begin{cases} \frac{x-l}{a_1-l} & l \leq x \leq a_1 \\ 1 & a_1 \leq x \leq a_2 \\ \frac{u-x}{u-a_2} & a_2 \leq x \leq u \\ 0 & other\ wise \end{cases} \tag{2}$$
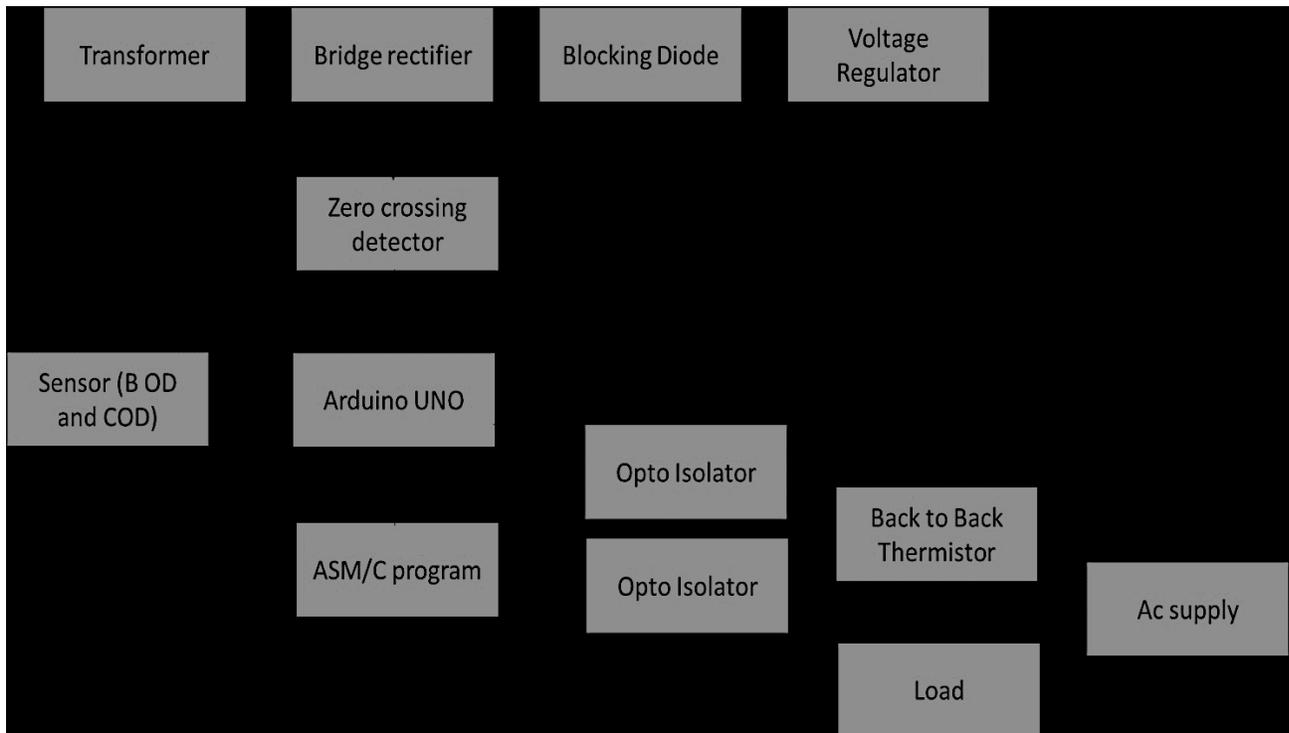

Figure.1 Proposed Design for FLACS

The Figure.1 shows the FLACS proposed design. The based on the input given three rules are designed and the operation duration of the aeration control system is set accordingly. The table.1 below shows the rule and the duration of the ACS operation.

Input level	Rule Devised	Operation duration
L:ow	IF I/P is low O/P is short	Less
High	IF I/P is High O/P is Long	More
Moderate	IF I/P id moderate O/P is Normal	Moderate

Table.1 Fuzzy rules

The de-fuzzing process in order to obtain the real number is obtained by the following relation showed in the equation 3

$$real_{number} = \frac{2l + 7a_1 + 7a_2 + 2u}{18} \qquad (3)$$

4. Experimental Analysis

The experimental analysis of the FLACS frame work is done at the waste water treatment plant for a duration of 12 months and the data such the demands on the BO and the CO, the volume of waste acquired from the liquid and the duration the aerator operates were observed. Apart from this the specifications of the aerator, its working time and its corresponding everyday energy depletion where observed. The table.2 shows the data collected and their units.

Data Collected	Units
BOD and COD	Mg/L
Aerator Specification Data	KVA
Aerator Working Hours	Hours/Day
No.of Aerators working	Units/Day

Table.2 Data Collected

The BOD observations are done initially with the scope of determining the aerator controller operations prior to the application of the definite conditions. The data from the aerator is collected for every two hours forty minutes. The following table.3 shows the results observed per day on the application of the fuzzy and the Arduino-UNO.

Parameters	Analysis Results /Day									
	1	2	3	4	5	6	7	8	9	10
BOD (1) mg/L	115	133	131	145	45	231	231	69	133	131
Operation Duration (1) in hours	7	9	9	9	5	9	9	5	9	9
Energy Consumed (1) KWh	800	100	100	100	500	100	100	1	100	100
BOD (2) mg/L	105	19	31	36	69	55	149	55	58	26
Operation Duration (2) in hours	5.5	5	5	5	5	5	7	5	5	4
Energy Consumed (2) KWh	600	0.2	0.1	0.1	0.1	65	0.1	600	0.1	0.1
BOD (3) mg/L	131	129	121	85	131	115	97	109	57	59
Operation Duration (3) in hours	9	9	9	8	9	8	6	7	5	5
Energy consumed (3) KWh	100	64	60	60	100	60	100	50	.1	.1

Table.3 Results Observed On the Energy Consumed and the Operation Duration on Single Day

Form the results observed it was noted that the average energy consumption for (1) was estimated as 27,600 KWh, the energy observation for (2) was observed as 20,100 KWh and the energy utilization for the (3) was noted down as 20,450 KWh. The results in the figure.2 shows the energy consumed using the fuzzy logic and the conventional method.
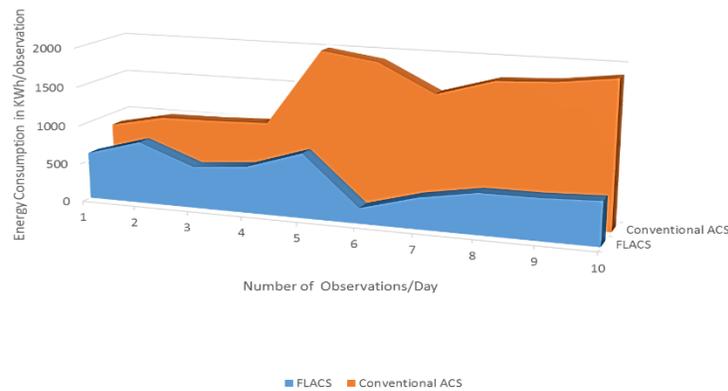

Figure.2 Energy Consumed

The results on figure.2 shows the FLACS has reduced a considerable amount of energy usage by minimizing the duration of the aerator operation by sensing the level of the demand of the chemical and the biological oxygen. The energy wasted by the conventional aeration control system is totally eliminated by the proposed framer work.

5. Conclusion

The aerator system designed by the substituting the current controller with the Arduino-UNO microcontroller and the sensor to sense the level of the demand in the biological and the chemical oxygen The sensed information's are is fed as input to the fuzzy controller fuzzified using the trapezoidal member ship function, to obtain the duration for ACS operation. By this process the duration of the ACS is limited and the energy wastage is also considerably reduced. The experimental analysis performed over the FLACS operation on single day records the operation duration as well as the energy consumption and comparison of the FLACS results with the Conventional-ACS shows the proposed system outperforms the conventional in terms of energy consumption.

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