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A model free dissolved oxygen controller for industry effluent using hybrid variables measuring technique

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ABSTRACT

The present scenario of the world relays on water scarcity, enormous amount of water is needed for people but the world has pollution which makes a great effect. Water is polluted due to various reasons such as industrial waste, sewage, and global warming and oil pollution and mainly polluted due to industrial effluent waste water. The main objective of this paper is to control the dissolved oxygen of the industrial waste water by measuring turbidity and dissolved oxygen (DO). Turbidity is measured through the intensity of the light through the medium in Nephelometric unit (NTU) and dissolved oxygen is measured in PPM through amperometic electrode method. The controller is designed to improve the quality of the effluent water through the aeration process. The very low concentration of dissolved oxygen (DO) level is too harmful to the aquatic ecosystem and it pollutes the water to the maximum extent. This measurement method of turbidity has an enhanced idea which processed with the software and it is monitored. The controller is designed as such with the condition of inverse proportionality of water turbidity and dissolved oxygen, which contributes an additive advantage to the concept design.

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1. INTRODUCTION

The dissolved oxygen is very important factor in measuring the water quality. The dissolved oxygen level in the water should be moderate for the aquatic life in the water. The presence of dissolved oxygen is must for the aquatic level but the range should be in some certain level. Frequently varying amount of dissolved oxygen in the water level also harm the aquatic life and pollute the water nominal rate should be processed. Lower the amount of dissolved oxygen also causes water pollution. The cloudy appearance of the water caused the presence of suspended and colloidal matter. In the waterworks field, a turbidity measurement is used to indicate the clarity of water. An improvised model predictive control is being added to already develop PI control which utilizes dissolved oxygen concentration and the air pressure of the aeration system. [1]. Control of the DO concentration in the Benchmark Simulation Model No. 1 (BSM 1) was done using the proposed T-S fuzzy neural network. A fast and efficient real time control of DO concentration in the waste treatment plant is observed by adjusting the learning rate which in turn increases the convergence rate of the system [2]. In any waste water management system oxygen is a key variable that needs to be controlled beside other variables for the simulation prove that the expected level of DO for MPC can be achieved [3]. An increased accuracy is possible when the weak scattered light is measured using a single photon avalanche diode (SPAD) a resolution of 0.1 NTU can be measured within 1s [4]. The Simulations results in provided segment as well as comparison results against a well-known Lyapunov based controller and a classical PID controller [5]. The Nephelometric turbidity values ranges from 40 to 400 NTU.

In the activated sludge waste water treatment plant DO is a crucial factor which determines how efficiently the biological processes are taking place. Improvisation of the Direct Model Reference Adaptive control (DMRAC) is relation to DO tracking for the Sequencing Batch Reactor (SBR) is put forward [6]. The first step was to identify dissolved oxygen control loop at various operating points. By using simulation the gain scheduling control strategy of DO concentration was tested; an experimentally pilot plant is also presented in this paper [7]. The successful control strategies usually employ PI control for industry based applications. Effectiveness of GS-PI and MNC control methods are displayed using simulations performed on nonlinear model [8]. The process of sewage treatment is a convoluted biochemical process. The simulation results point out a better response speed, reduced overshoot and also a reduced static error is observed [9]. Waste Water treatment plant in general is a complicated, multivariable, time depended and enormous industrial system which is nonlinear. Air/Oxygen for the aerated tanks is obtained through the aeration system (blowers, pipes, diffusers). Investigation is being carried out for the nonlinear fuzzy PI control system [10]. The outcome of this study is the development of a PC based virtual (VI) system using LABVIEW, which automatically monitors and controls the Dissolved Oxygen concentration (DO). This drastically reduces business costs in terms of automation required and has higher effectiveness with lower electricity consumption [11]. The optimal set-point of dissolved oxygen affects both the batch time and energy savings. PC-based virtual instrument (VI) system using LabVIEW, which can monitor and control the dissolved oxygen (DO) concentration in an automated manner and the quality of DO is been analyzed [12]. The controllers are validated by simulation using real data sets and an ASM2d model of the biological reactor. On the consolatory aspect, three model predictive controllers (MPCs) are designed, tested and the results are compared with a PI controller. A well-established simulation benchmark is used as a test bench for this study [13]. Fuzzy logic based controlled was designed for aeration process [14]. The batch time and the energy savings are affected by the optimal set point of the parameter dissolved oxygen [15, 16]. An investigation is being carried out for the nonlinear model predictive controller and direct reference adaptive controller. Validation of the controller is done using simulated real data sets and an ASM2d model of a biological reactor [17-21]. Various model predictive controllers for dissolved oxygen in an activated sludge wastewater treatment plant (WWTP) are being discussed. This paper proposes a new system that measures turbidity and dissolved oxygen for designing an efficient DO controller. Because turbidity is inversely proportional to DO value of water. Therefore, measuring both variables and designing a controller makes the system output response better. This paper also contributes an enhanced approach of model free control for dissolved oxygen (DO).

2. METHODOLOGY

2.1. Turbidity measurement

The turbidity values are measured in NTU (Nephelometric Unit). Earlier concepts measured turbidity based on the amount of light scattered through the sample medium. Instead of measuring scattered rays of light, the other method is suggested to measure the intensity of light transmitted through the sample. It consists of a light source, which is a LASER emitting diode at a wavelength of 670 nm. The light from the LASER passes through the turbid solution and falls on a photo detector. The output signal from the photo detector is given as analog input to the embedded system, where it is processed and the given analog input is calibrated Nephelometric turbidity unit and which is reported in Table 1. This turbidity measurement values are compared with standard turbidity measuring instrument. Figure 1 shows the process to measure the turbidity. Turbidity of the sample considered is inversely proportional to dissolved oxygen concentration. This turbidity measurement helps in designing efficient controller. Different known samples were prepared to calibrate turbidity meter.

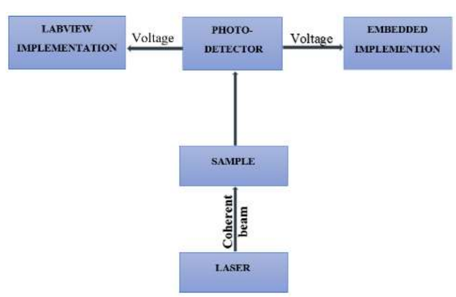

Figure 1. Turbidity measurement process

Table 1. Min and max output voltage value

SOLUTION (NTU)	VOLTAGE (volts)
40	0.3
400	4.6

2.2. Solution preparation

In order to calibrate the turbidity measuring system the standard formazin (heterocyclic polymer) is prepared by three step processes [20].

Step 1 - Preparation of solution A: Dissolving 1 gm of Hydrazine sulphates in 50ml of water and dilute to 100ml by using distilled water.

Step 2 - Preparation of solution B: Dissolving 10 gm of Hexamine in 50ml of distilled water and dilute to 100ml in distilled water.

Step 3 - Formazin Preparation: Take 5ml of solution A and it mix with 5ml of solution B and allow to stand 24 hours at 25º C to 30º C temperature and dilute to 100ml of distill water to attain a standard formazin turbid solution of 400NTU. The stock samples were analyzed and tested to calibrate the measuring system. The chemical reactions are shown in Figure 2.

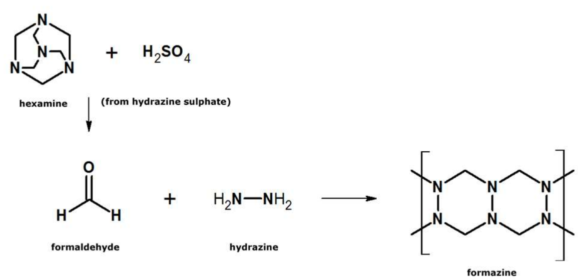

Figure 2. Three steps of solution preparation

2.3. Dissolved oxygen control

Based on literature survey most of the industry effluent waste waters have very low dissolved oxygen. Figure 3 shows about the overall block diagram of Dissolved oxygen aeration process control in effluent waste water.

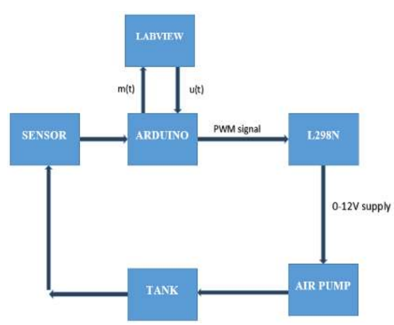

Figure 3. Block diagram of dissolved oxygen aeration process control

Dissolved oxygen sensor works based on the amperometric method. Current flow in between the electrodes is proportional to the dissolved oxygen concentration in the water. Analog output from dissolved oxygen sensor is interfaced with Arduino. To acquire the data using LabVIEW, there is an additional Arduino tool installed. The analog signal from the dissolved oxygen sensor is given to the Arduino and it is directly read through LabVIEW without any specialized data acquisition hardware. The air pump is used as actuator device to adjust the DO level in the waste water by varying the input voltage of the pump range from 0-12v.

Figure 4 epics the variation in the DO concentration during the aeration process by varying the pump voltage in range of 2V, 4V and 10V. By changing the pump input voltage, data's are collected and used for designing gain values of PID controller.

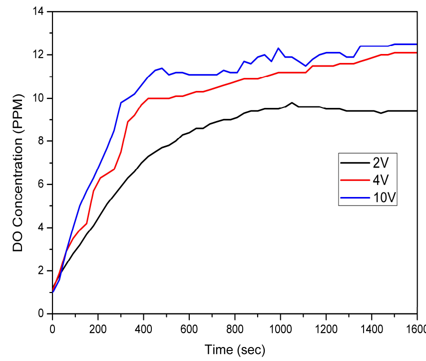

Figure 4. Input voltage to pump

3. RESULTS AND DISCUSSION

3.1. Experimental results for turbidity measurement

The results have obtained from the turbidity sensor using the known samples which were prepared. The analog voltage from the turbidity sensor (L14G1) is fed as variable input through the DAQ in LabVIEW to the formula node. The formula node computes the turbidity value and which is displayed on the front panel. The results were shown in embedded LED display as well as in LabVIEW. Using formula node, DAQ and While loop in LabVIEW is used to convert the LED voltage (0-5V) output to Nephelometric (40-400 NTU) Unit. Figure 5 shows the LabVIEW design for calibrating the voltage value from phototransistor into NTU. The output voltage for various values of 10 samples with different turbidity ranges are shown in Figure 6.

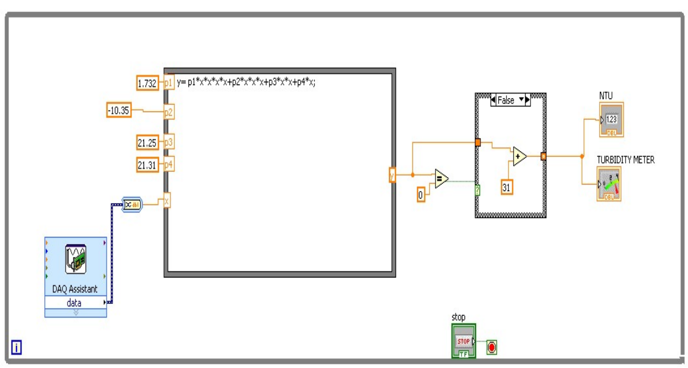

Figure 5. LabVIEW for converting voltage to NTU

Higher order polynomial equation can improve the curve fitting relation between the input (voltage) and the output (turbidity). Therefore 4th degree linear polynomial formula which is used to convert voltage into turbidity as follows:

$Y = q1*x^4 + q2*x^3 + q3*x^2 + q4*x + q5;$
$q1 = 1.732$
$q2 = -10.35$
$q3 = 21.25$
$q4 = 21.31$
$q5 = 31$

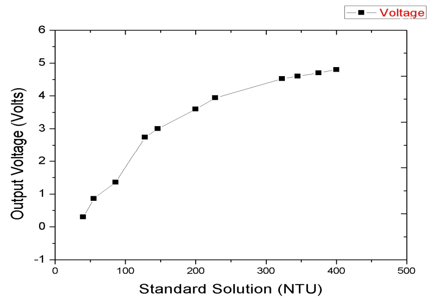

Figure 6. Samples solution vs output voltage

3.2. PID controller design for DO

Thus the real time PID controller is implemented in LabVIEW. The set point of 5 PPM is taken to the three samples, the PID controls the process, the steady state is obtained at various load changes of each samples. The PID Controller designed using LabVIEW, is tuned using Ziegler Nicholes method and the gain is changed by noting the response of the system.

Figure 7 shows the design of LabVIEW program to control DO level. Design of controllers are always different in real time implementation. Therefore PID controller gain values are selected from trial and error method also and its suits for DO concentration set point tracking. Proportional & Integral controllers are used frequently in automation industry, especially when quickness of the response is not a matter. A control without Derivative mode is used when fast response of the system is not required and great disturbances and noise are existing during operation of the process. As the aeration process makes the DO to change quickly, Proportional, Integral and derivative gain very much need for this process.

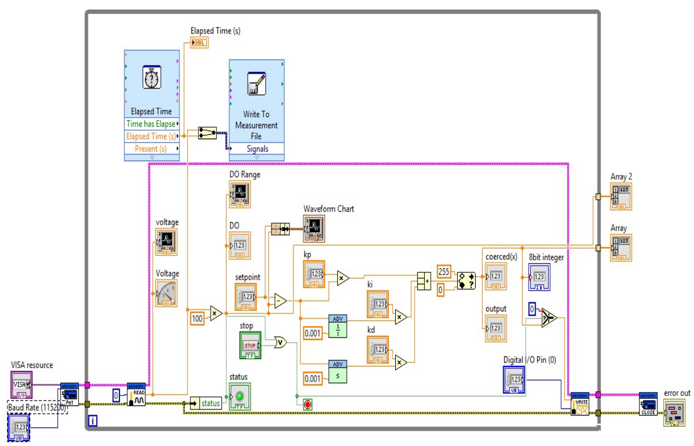

Figure 7. LabVIEW program to control DO level using PID controller

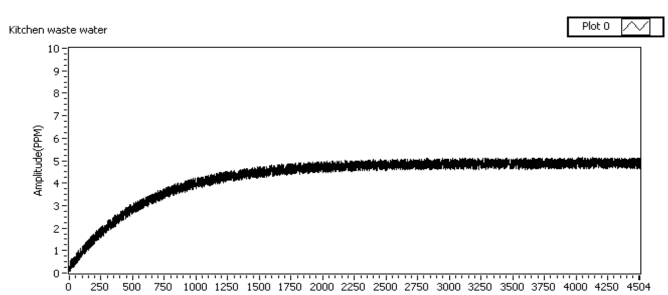

Figure 8. PID controller response for domestic wastewater

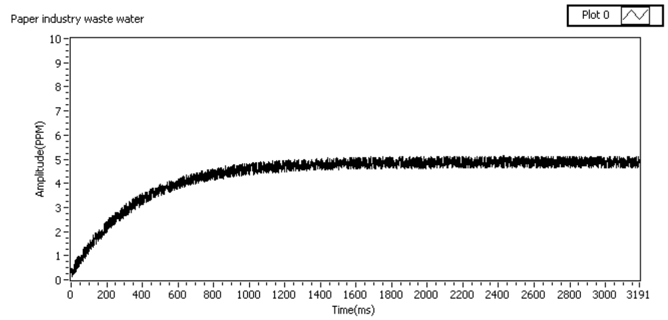

Figure 9. PID controller response for paper industry wastewater

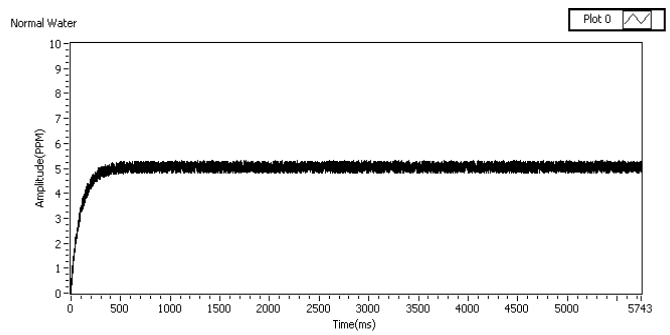

Figure 10. PID controller response for normal water

Figure 8 demonstrates the DO Control in domestic waste water. The waste water must have a minimum of 5 PPM level of DO concentration as per the literature survey. Therefore set point of 5PPM was taken to control the concentration of DO. Figure 9 indicates the DO control for paper industry waste water, the PID controller was able to achieve to the set point value of 5 PPM within 1000 milli-seconds. These experiments are tested with 30L water. The DO control for normal water is shown in Figure 10. The comparing all these three results, normal water reacts quickly to reach the set point of 5 PPM. And these experiments were performed multiple times with fresh waters in the setup. The designed controller responses shows that the controller is able to track DO concentration effectively using hybrid variables rather than measuring single variable based DO control. Through this hybrid variables based automation process, much amount of energy can be saved.

4. CONCLUSION

In industrial effluent and domestic waste water have measured in terms of turbidity and DO concentration. The turbidity sensor and DO sensor were calibrated with help of standard solution. The designed turbidity measurement is another method which is useful to measure colloidal particles of water in fields with a lesser conceptual cost aspect. Many phototransistors were used to improve the sensitivity of measuring turbidity values. The model free controller is designed to control the DO concentration effectively using both variables namely turbidity and DO concentration. The controlling of DO level concentration reduces the risk of polluting the land and can cut down many harmful factors too. The output responses of PID controllers with DO concentration level for domestic waste water; industrial effluent and drinking water were shown. From the responses it was understood the controller is effectively controlling the DO concentration without any overshoot and under shoot. The real time PID controller was successfully implemented in the pilot plant. The adaptive controller will be proposed to reduce the settling time of the process.

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