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Neural Network ABAC with Dropout Layer for Activated Sludge System

Maimun Huja Husin, **Mohd Fua'ad Rahmat***, **Norhaliza Abdul Wahab** and **Mohamad Faizrizwan Mohd Sabri**

[1]Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, Malaysia.
[2]School of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.

*Corresponding author: fuaad@fke.utm.my, Tel: 607-5557216, Fax: 607-5566272

Abstract: Due to the expensive operation of the activated sludge process and more stringent effluent requirements of wastewater treatment plant (WWTP), the wastewater treatment operator has been forced to find an alternative to improve the current control strategy, especially for those operating using an activated sludge system. The study aims to reduce the energy usage of a WWTP and to increase the effluent quality to meet the requirements of state and national laws by using the aeration control technique. The goals are achieved by varying the dissolved oxygen concentration in the benchmark plant's fifth tank according to the real ammonium measurement, a technique known as Ammonium-based aeration control (ABAC), which produced less nitrogen, resulting in better effluent and lower energy consumption. The simulation model Benchmark Simulation Model No. 1 (BSM1) was used to analyze ABAC in this study. The neural network (NN) model is used to design the ABAC controller, and simulation results were compared to the Proportional Integral (PI) controller of the BSM1 and PI ABAC control configurations. A dropout layer was added during the training process to improve neural network generalization. The dropout layer in the NN ABAC has improved the performances in terms of total nitrogen effluent violations by 4 percent less than the PI-ABAC and by 36 percent less than the PI. The NN ABAC LM dropout has been proven to be more effective in terms of energy efficiency by significantly reduced by 25 percent, effluent quality by successfully improved by 1 percent, and successfully reduced the total overall cost index by 5 percent when compared to PI-ABAC control. The study has illustrated that the NN ABAC could be used to improve the performance of the activated sludge system.

Keywords: ABAC, activated sludge, aeration control, BSM1, wastewater.

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1. INTRODUCTION

Wastewater treatment plant (WWTP) is the key infrastructures for protecting public health by preserving water resources and protecting the environment for a sustainable future. It is frequently defined as a complex system with nonlinear dynamics and has strong interactions with the multivariable system [1]. The influent of the WWTP exhibits oscillating behavior which subjects to large disturbances in the flowrate and uncertainties concerning the composition of the influent, thus making them hard to control [2].

Studies have shown that the energy consumption in biological systems such as the ASP, biological trickling filters, and membrane bioreactors can be curbed through good control of the aeration system. The issue of energy consumption has been investigated by various researchers and the findings suggest that the aeration section which is needed in the WWTP to detract nitrogen and natural or inorganic carbon in the biological process, contributes to 50-90% of the overall energy requirement of the WWTP [3]–[5].

In the last decade, there have been various studies investigating the effectiveness of various controller designs utilizing dissolved oxygen (DO) control in lowering the aeration cost. This control configuration is the highlight during that time due to the availability of a DO sensor probe that can continuously measure the DO concentration in the tank. The fundamental of using the DO sensor probe is to control the DO supply according to the oxygen demand of the microorganism in the tank. However, this solution has weakness due to the difficulty in getting the exact value of the actual oxygen demand by the microorganism at a specific time, thus, most of the proposed DO control strategies implemented an elevated DO set point to avoid nitrification failure. The DO control strategy has been extensively studied and many viable solutions have been developed and proposed, for example, model predictive control (MPC) [6], [7], Proportional Integral Derivative (PID) [1], [8], [9], fuzzy and neural network (NN) control [10].

However, even with the DO control strategy, the aeration cost issues persist as DO control requires aerators and turbines which are operated by electrically powered motors that add extra cost to the system. This calls for a paradigm shift in the choice of methodology to solve the problems of energy consumption and the cost of aeration control. This issue was explored and it is suggested that the aeration process can be regulated either using the aeration concentration control or tweaking the DO setpoint level