IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Journal Européen des Systèmes Automatisés
Vol. 53, No. 5, October, 2020, pp. 671-679
Journal homepage: http://iieta.org/journals/jesa

Auto-Control Technique Using Gradient Method Based on Radial Basis Function Neural Networks to Control of an Activated Sludge Process of Wastewater Treatment

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https://doi.org/10.18280/jesa.530510

Received: 20 December 2019
Accepted: 13 September 2020

Keywords:
activated sludge process, wastewater treatment, gradient descent algorithm, RBF neural network, PI control

ABSTRACT

Dissolved oxygen (DO) concentration is a key variable in the activated sludge wastewater treatment processes. In this paper, an auto control strategy based on Euler method and gradient method with radial basis function (RBF) neural networks (NNs) is proposed to solve the DO concentration control problem in an activated sludge process of wastewater treatment. The control purpose is to maintain the dissolved oxygen concentration in the aerated tank for having the substrate concentration within the standard limits established by legislation of wastewater treatment. For that reason, a new proposed control strategy based on gradient descent method and RBF neural network has been used. Compared with RBF neural network PI control, the obtained results show the effectiveness in terms of both transient and steady performances of proposed control method for dissolved oxygen control in the activated sludge wastewater treatment processes.

1. INTRODUCTION

The wastewater treatment process is a very complex process; it presents strong nonlinearity and uncertainties regarding to its parameters. The wastewater treatment comprises various steps used for reducing the contaminants in the wastewater which are: pretreatment, primary treatment, secondary treatment [1, 2]. The pretreatment has the objective of removing solid objects, and to skimming off floating greases and oils. Without passing the wastewater through the pretreatment, these objects may cause block and damage the equipment and the other steps of treatments. The primary treatment removes the remaining suspended and dissolved solids.

The secondary or biological treatment is the most important step of wastewater treatment. It aims to add microorganisms to reduce the organic matter, nitrogen and phosphorus from the wastewater. There are different methods used in the wastewater treatment process, but the most used and popular one is the activated sludge process (ASP) [3, 4].

In the last years, varieties of researches have been conducted about the control of the level of dissolved oxygen to enhance the process. In general, improvements are related to the controlling techniques. A linear proportional integral (PI) controller with feedforward from the flow rate and the respiration rate has been shown as a basic strategy [4]. Because of the PID controller limitation, the classical method of proportional integral derivative (PID) has been attempted, and the controlling effect of the dissolved oxygen is not satisfactory enough. However, the controllers are normally designed for the particular operational conditions because of the scarcity of sufficient hard or soft sensors and the nonlinear features of the bioprocesses [5]. In recent times, scholars have begun to study the artificial intelligence (AI) technologies which can be widely implemented in numerous areas, including chemical and biochemical processes and. Due to its great capabilities and adaptabilities of nonlinear modelling, the most prevalent AI controlling strategies are neural network and fuzzy network, which are usually integrated with the PID control. A fuzzy method to the control of dissolved oxygen in the process of aeration was studied by Man et al. [6]. An adaptive fuzzy control strategy for dissolved oxygen concentration was used to control of an activated sludge process Liu et al. [7]. In the paper [8] an adaptive fuzzy neural network-based model predictive control (AFNN-MPC) is proposed for the control problem of DO concentration. Piotrowski proposed a supervisory heuristic fuzzy control system applied to a Sequencing Batch Reactor (SBR) in the Wastewater Treatment Plant (WWTP) [9]. Lin and Luo [10] developed an adaptive neural technique using a disturbance observer to solve the dissolved oxygen concentration control problem. An improved multi objective optimal control (MOOC) strategy is developed to improve the operational efficiency, satisfy the effluent quality (EQ) and reduce the energy consumption (EC) in wastewater treatment process [11]. Mirghasemi proposed a robust adaptive neural network control strategy and used it to control the dissolved oxygen in activated sludge process application [12].

In this paper, a control strategy based on Euler method and gradient method with RBF neural network is proposed to control the dissolved oxygen concentration in an activated sludge process of wastewater treatment. The Euler is a numerical method that is used to approximate the solution of a nonlinear differential equation (nonlinear system), and the gradient descent algorithm and the RBF neural network are used to find the values of a function's parameters (coefficients) that minimize a performance function as possible. The performance of the proposed control strategies laws is