AERATION SYSTEM CONTROL OF A WASTE-WATER TREATMENT PLANT, MODEL SELECTION

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ABSTRACT

This work is concentrated on blowers operation of aeration system on the waste-water treatment plant. There are several approaches of aeration modes described. In the next part there is a real system identified and then there is corresponding model designed. Finally there is algorithm for blowers suggested and applied to PLC for the real waste-water treatment plant.

1. INTRODUCTION

One of the ecological questions is how to handle with waste. And because the water is one of basic conditions of human survival it is very important to save water sources from pollution. People should also realise that only 1 % of water supplies on Earth is usable for all living creatures. Waste-water recycling (waste-water cleaning) should be prior because of this fact.

Waste water has different characters (industrial and agricultural waste-water, sewage water and rainfall waste-water).

Waste-water treatment is passing through dynamic progress either from the technological or legislative point of view. The main purpose of this article is to make identification of a real biological waste-water treatment system and to make a model of this system. The second part is devoted to the algorithm for PLC implemented to blowers in aeration part of this waste-water treatment. Algorithm is designed according to modern procedures of nitrification and denitrification.

Blowers are not overloaded (overheated), they are running on lower frequencies and there is no need of often maintenance. All this is because of these modern procedures of nitrification and denitrification.

2. CONTROL MODES OF NITRIFICATION AND DENITRIFICATION

There are two different ways of nitrification and denitrification control. The first one is fixed time intervals controlling (time control) and the second one is by the dissolved amount of oxygen in activation tank (dynamic control).

2.1. TIME CONTROL

Nitrification and denitrification time is set exactly by the technological design calculations. This time can be calculated as:

$$t_{tot} = \frac{V_{ACT}}{Q_h \cdot \left(\frac{m_{N-NO3,out}}{m_{N-Nitr.}} \right)}, \quad (1)$$

where V_{ACT} is activation tank capacity [m^3],

Q_h is max. hour flow [$m^3 \cdot h^{-1}$],

$m_{N-NO3,\,out}$ is $N - NO_3$ amount per day outwards [$kg \cdot d^{-1}$],

$m_{N-Nitr.}$ is amount of nitrogen which has to be nitrificated [$kg \cdot d^{-1}$].

Then it is possible to calculate the time of nitrification (t_N) and the time of denitrification (t_D):

$$t_D = t_{tot} \cdot f_D, \quad (2)$$

$$t_N = t_{tot} - t_D. \quad (3)$$

where f_D is the sediment part of denitrification in all the sediment.

2.2. DYNAMIC CONTROL

It is possible to adapt nitrification and denitrification time corresponding to the current waste-water treatment plant load. The data for both nitrification and denitrification are collected from oxidation and ORP (redox) probe.

Nitrification

Nitrification has its own maximal and minimal duration. It is set that nitrification should not exceed 60 minutes but it is possible to cancel it earlier after previous evaluation.

- Nitrification cancelling due to exceeding the upper limit

  $N\text{-}NH_4$ concentration is reaching 0 $mg \cdot l^{-1}$ step by step, blower works with minimal frequency and oxygen consumption is still rising. Nitrification is cancelled after upper limit exceeding for oxygen concentration or after time limit exceeding (see fig. 1).

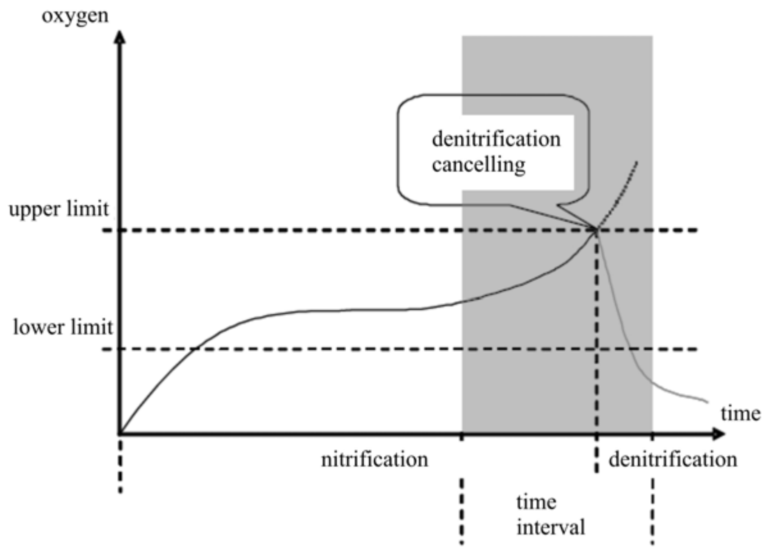

Figure 1: Nitrification cancelling after upper limit exceeding.

- Nitrification cancelling according to the oxygen consumption speed for frequency converter controlled blowers

  The blower is stopped (in minimal speed) and system counts off-time after the upper limit oxygen concentration is exceeded. This time equals to the oxygen consumption speed in denitrification tank. Blower is switched on again after the lower limit exceeding. If the blower off-time is longer than the set h_{max} value blower is also switched on (see fig. 2).

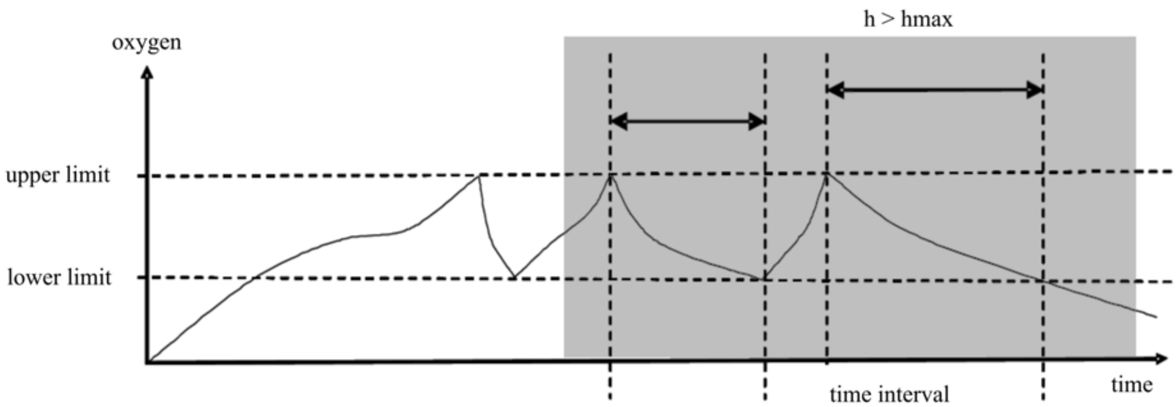

Figure 2: Nitrification cancelling according to the oxygen consumption speed.

Denitrification

Denitrification has also its own minimal and maximal time. It is set that the time of the whole process should not be longer than 60 minutes.

It is possible to cancel denitrification according to the data from ORP probe. As the concentration of $N\text{-}NO_3$ is slowly reaching 5 $mg \cdot l^{-1}$ ORP drop is slowing down and denitrification is cancelled according to the set difference ORP value (see fig. 3).

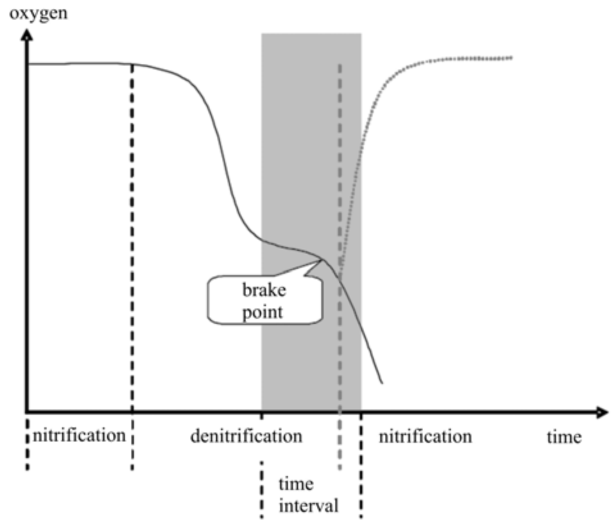

Figure 3: Denitrification cancelling.

3. MODEL SELECTION

There was a model of water treatment plant made. It was based on the real system identification in Matlab software. There were no other influences on the system (activation tank was covered by a roof and provided with heating to keep constant temperature). Model was made by pole-placement method (model was chosen from 20 models identified by various methods). The result is this system:

$$y = G\_1(s) \cdot u1 + G\_2(s) \cdot u2\,. \tag{4}$$

System has two transfer functions:

$$G\_1(s) = 0.24046 \cdot \frac{1 + 1.2743 \cdot 10^5 \cdot \mathrm{s}}{\left(1 + 1.8142\mathrm{e} \cdot 10^5 \cdot \mathrm{s}\right) \cdot \left(1 + 2670.4 \cdot \mathrm{s}\right)} \cdot e^{-2.8213 \cdot \mathrm{s}} \tag{5}$$

$$G\_2(s) = -0.68865 \cdot \frac{1 + 862.87 \cdot \mathrm{s}}{\left(1 + 2669.1 \cdot \mathrm{s}\right) \cdot \left(1 + 3513.8 \cdot \mathrm{s}\right)} \cdot e^{-7.4062 \cdot \mathrm{s}} \tag{6}$$

Constants are not able to be rounded because of the fact that the biological system is a very slow process.

4. CONCLUSION

There was a model of biological system (waste-water treatment – activation tank) made and there was also an algorithm designed. Majority of blowers are controlled in time mode which leads to short maintenance of blowers and large electricity consumption because of bad activation process.

Algorithm was designed to improve aeration mode to dynamic. This algorithm was implemented into PLC system on waste-water treatment plant. The result was that the aeration process was very effective and so the consumption of electricity was lower and the maintenance time lowered almost three times.

Fig. 4 and fig. 5 show the difference in oxygen concentration between time mode and dynamic mode

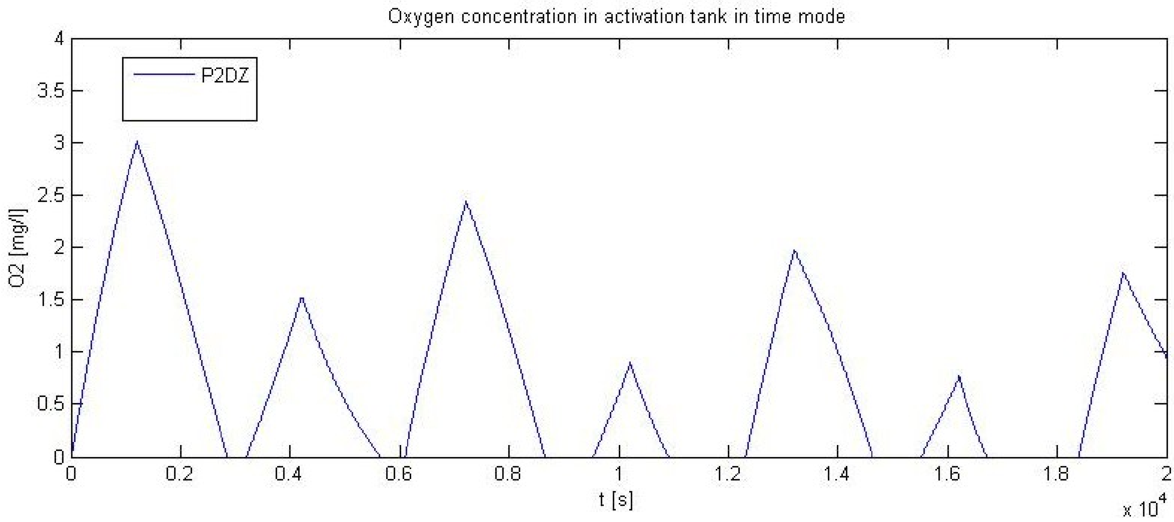

Figure 4: Oxygen concentration in activation tank in time mode.

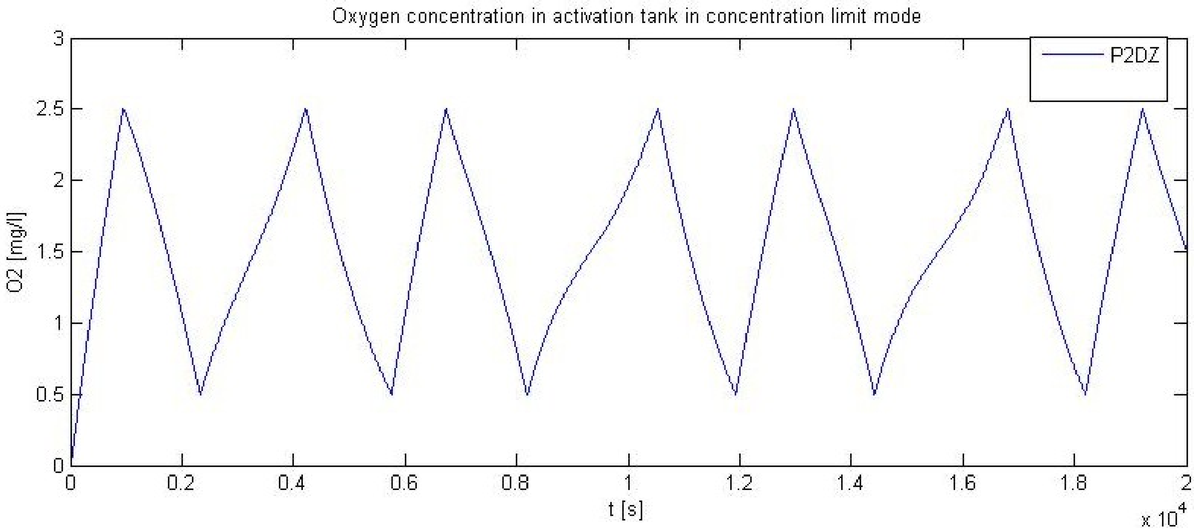

Figure 5: Oxygen concentration in activation tank in concentration limit mode.

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