Effective Solutions to Reduce Energy Consumption in the Turbo-Blowers of a Sewage Treatment Plant

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Abstract: *Since the energy consumption of the turbo blowers represents 68% of the energy consumption of the station, it was sought to reduce this consumption by installing oxygen sensors in the bioreactors; these sensors detect the reaching of the optimal (maximum) oxygen threshold of 2.0% and at this moment they partially close the butterfly valves from the discharge of the turbo blowers, which leads to the reduction of the flow rate and implicitly the energy consumption of the turbo blowers. Through the SEAU's SCADA system for the oxygen volume, the necessary data were obtained to calculate the percentage opening of the butterfly valves from the discharge of the turbo blowers in order to monitor the efficiency of the regulation system, and implicitly, the reduction of energy consumption. The following were calculated: the initial annual consumption established by design, the three-day consumption, the value of the optimized energy, the value of the energy saved, obtaining the economic efficiency of the proposed solution. The regulation system tests the oxygen concentration in the aerobic bioreactor and maintains its value at around 1.5%. The rapid control valve system is set to operate in the 15%-65% opening range. When the oxygen detector detects reaching the 1.5% threshold, the valves open and the air flow increases; at the same time, the power consumed by the turbo blower obviously increases. The diagram of the variation of the oxygen regime and the response of the opening of the turbocharger discharge valve are represented in parallel.*

Keywords: *Energy, consumption, sewage, plant, solution, optimization*

1. Introduction

In the operational flow of a sewage treatment plant, under anoxic conditions, the denitrification process takes place, and under aerobic conditions, the nitrification process takes place in the four lines of the bioreactors. Therefore, four blowers are installed in operating mode, assistance 1 and 2 and stand-by to cover the oxygen requirement in the bioreactors. The electricity consumption of the turbo blowers has an important share in the general energy consumption of the station. Thus, each of the four THOLANDER turbochargers has a nominal power of 355 [kW], while the FLYGT C 3400 intake pumps have a nominal power of 125 [kW] each (five pumps) and the FLOTTWEG centrifuges have a nominal power of 55 [kW] each (4 centrifuges) [1]. The energy share of turbo blowers is over 68% in the general annual consumption [2, 3].
Control of ventilation systems mainly comprises a concentration of two separate control cycles:
- the air regulating valves controlled by the concentration of dissolved oxygen which influences the pressure in the air line and

- air blowers that are controlled by the pressure inside the air pipe; in this way, the blowers operate in a variable speed regime and implicitly in electricity consumption.
The ventilation system has the following characteristics (Figure 1) [4]:

• Typical conditions for oxygen demand: 85639 [kg O_2/day]

• Maximum oxygen absorption per hour: 3586 [kg O_2/h] at 27[°C]

• Air requirement: 37,820 [m3/h]

The turbo blowers work in 3+1 stand-by mode with a suction flow of 13,000 [Nm^3/h], total 39,000 [Nm^3/h].

Fig. 1. Air flow through a screw blower [4]

Where 1- the admitted air is trapped; 2- the volume is reduced; 3- exhaust under pressure; 4- room completely evacuated.

2. Materials and methods

2.1 Materials

Under these conditions, the Constanta North Wastewater Treatment Plant, where oxygen detectors were placed on the bioreactors, was chosen as the study location. The biological needs of aerobic bacteria were taken into account. Diaphragm diffusers with small bubbles absorb air under pressure. The air supply lines to the bioreactors are equipped with air control valves, with each tank having an air control valve. Two oxygen flowmeters (a main probe and a reference probe) will be installed at each bioreactor to regulate the air intake volume in the bioreactor in question. Air flow to each bioreactor line separately is measured and recorded by flowmeters.[5]
At the Constanta-North treatment plant, chambers five and six are non-variable aerobic zones, where nitrification takes place. These furnaces are equipped with aeration systems to provide the necessary dissolved oxygen (included in the pressurized air).

2.2 Methods and researches

Next, the efficiency of the regulation system is calculated from the point of view of energy consumption, given that the turbo blowers have a significant weight in the station's consumption (over 68%).

The estimated consumption value by design is taken as the basis of calculation, i.e.:

$$E = 9125.68 \text{ [MWh/an]}. \tag{1}$$

This value is obtained from the sum of the electricity consumption of the turbo blowers, intake pumps and centrifuges. These consumptions are specific to the sewage treatment plant depending on the flows, so on the number of equivalent inhabitants.
The regulation system tests the oxygen concentration in the aerobic bioreactor and maintains its value at around 1.5%.
The rapid control valve system is set to operate in the 15%-65% opening range. When the oxygen detector detects reaching the 1.5% threshold, the valves open and the air flow increases; at the same time, the power consumed by the turbo blower obviously increases.
Next, the consumption and concentration of oxygen in the bioreactor is taken from the station's SCADA system. The data from the period: 01-31 July 2022, 01-31 October 2022, 01-15 November 2022 were available. The diagram of the variation of the oxygen regime and the response of the opening of the turbocharger discharge valve are represented in parallel (e.g. Fig. 2, Fig. 3) [1].

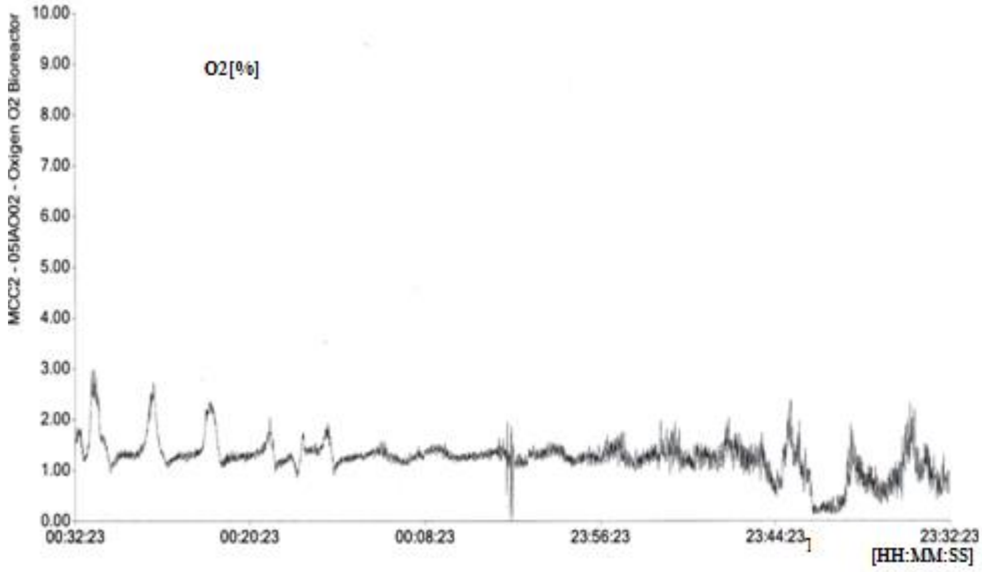

Fig. 2. Variation of oxygen during July 1-15, 2022

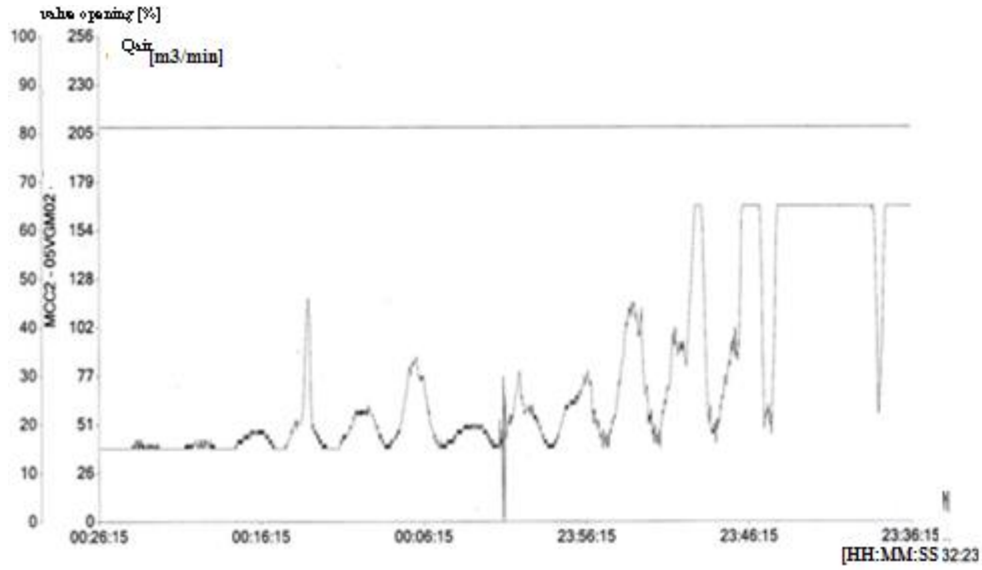

Fig. 3. The variation of the opening of the air butterfly valve between July 1-15, 2022

The same is done for all periods.

3. Results and interpretations

In the period 16.07-31.07 2022 it is observed that the variation of the oxygen concentration required in the bioreactor varies between the limits of 0-10 [%].In the period 1.10-15.11.2022 It is observed that the variation of the concentration of oxygen required in the bioreactor varies between the limits of 0-10 [%] (Fig. 4).

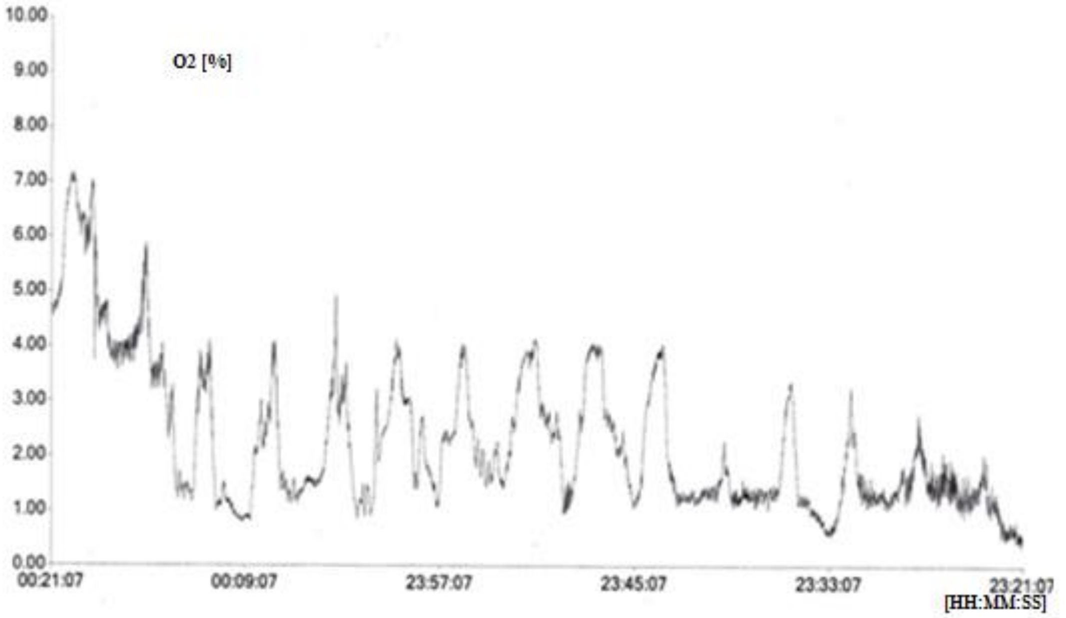

Fig. 4. Oxygen variation in the period October 1-November 15, 2022

The variation of the opening of the air butterfly valve during the period October 1-November 15, 2022 is presented in Fig. 5.

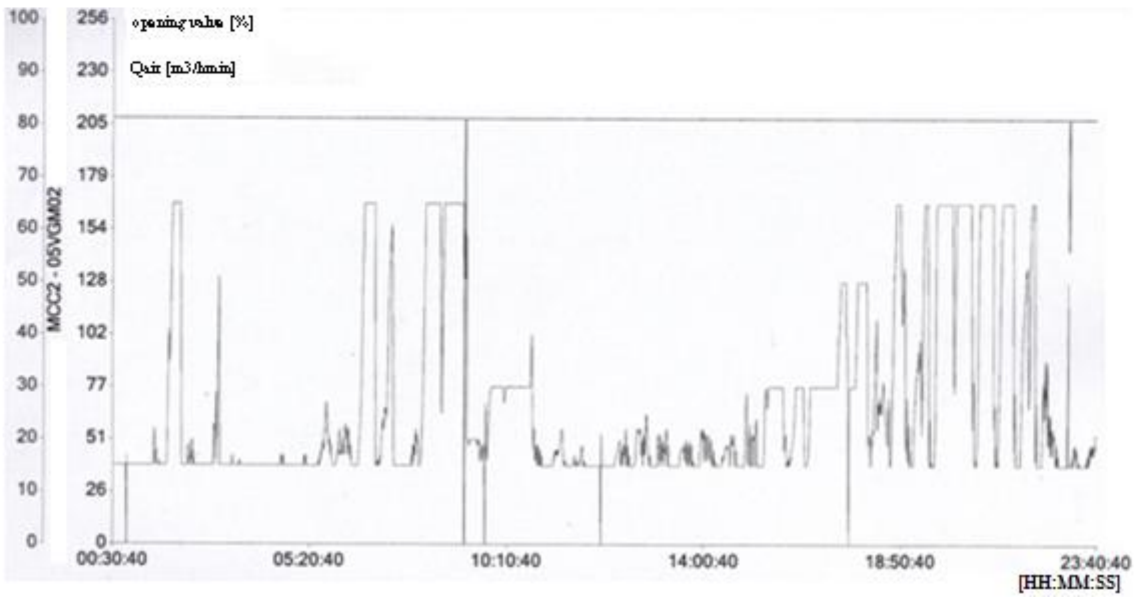

Fig. 5. The variation of the opening of the air butterfly valve

In the period 16.10-31.10.2022 for MCC2 group it is observed that the variation of the valve opening varies between the limits of 15-65 [%], frequently 15 [%], but there are also jumps (42%). The air flow variation is between 40 [m3/min] and 170 [m3/min] (Fig. 6).

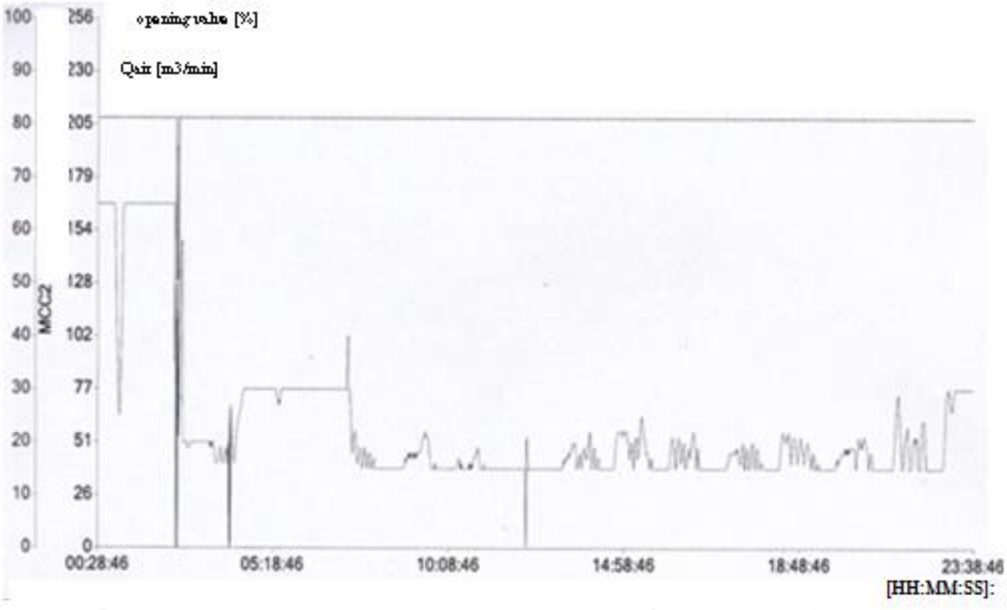

Fig. 6. The variation of the opening of the air butterfly valve between October 16-31, 2022

During the period 01.11-15.11.2022 it is observed that the variation of the oxygen concentration required in the bioreactor varies between the limits of 0-10 [%] (Fig. 7).

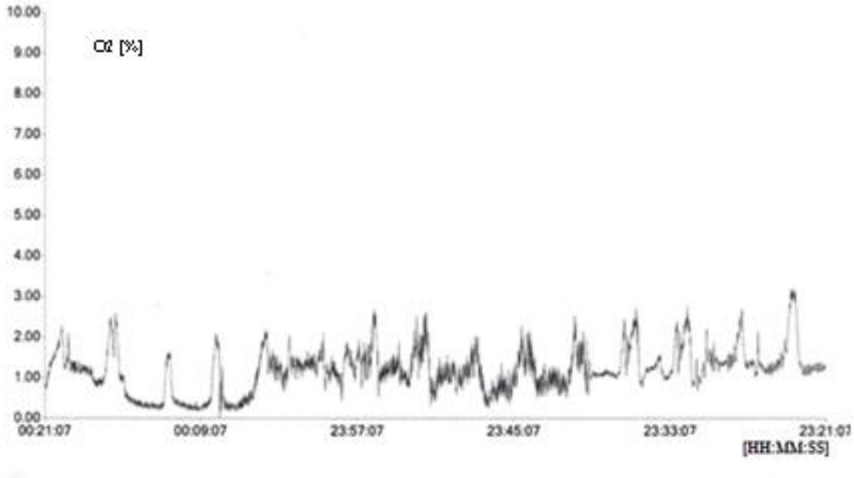

Fig. 7. The variation of the oxygen concentration in the bioreactor

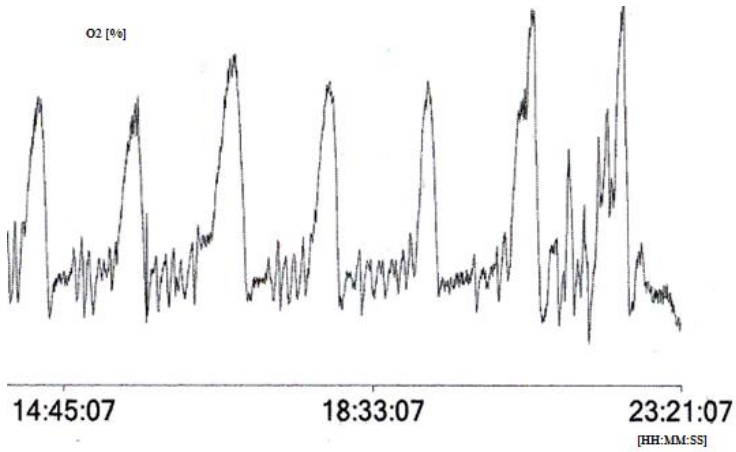

Fig. 8. Oxygen variation - period 26 October H14:45:07 - 31 October H32:21:07

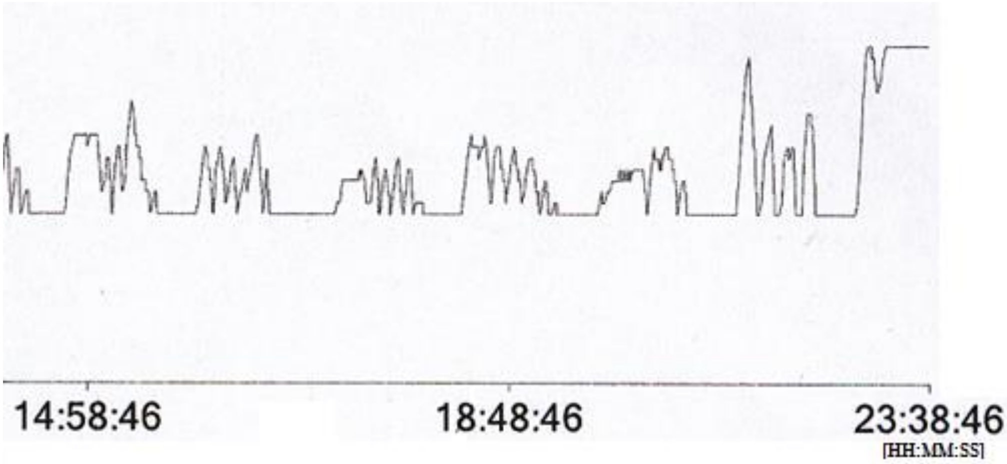

Fig. 9. The variation of the opening of the air butterfly valve - the period October 26 H14:45:07 - October 31 H32:21:07

It is observed that the variation of the valve opening varies between the limits of 15[%] and 65 [%], and the air flow varies between the limits of 30-170 [m^3/min] (Fig. 8, Fig. 9).

Following the superimposition of the two graphs, proceed by drawing the vertical line for the moment of starting the opening of the air butterfly valve (with a black line) marked A, respectively the moment of finishing the opening of the air butterfly valve and returning to the minimum opening value of 15 % (with green line) marked B (Fig. 10).

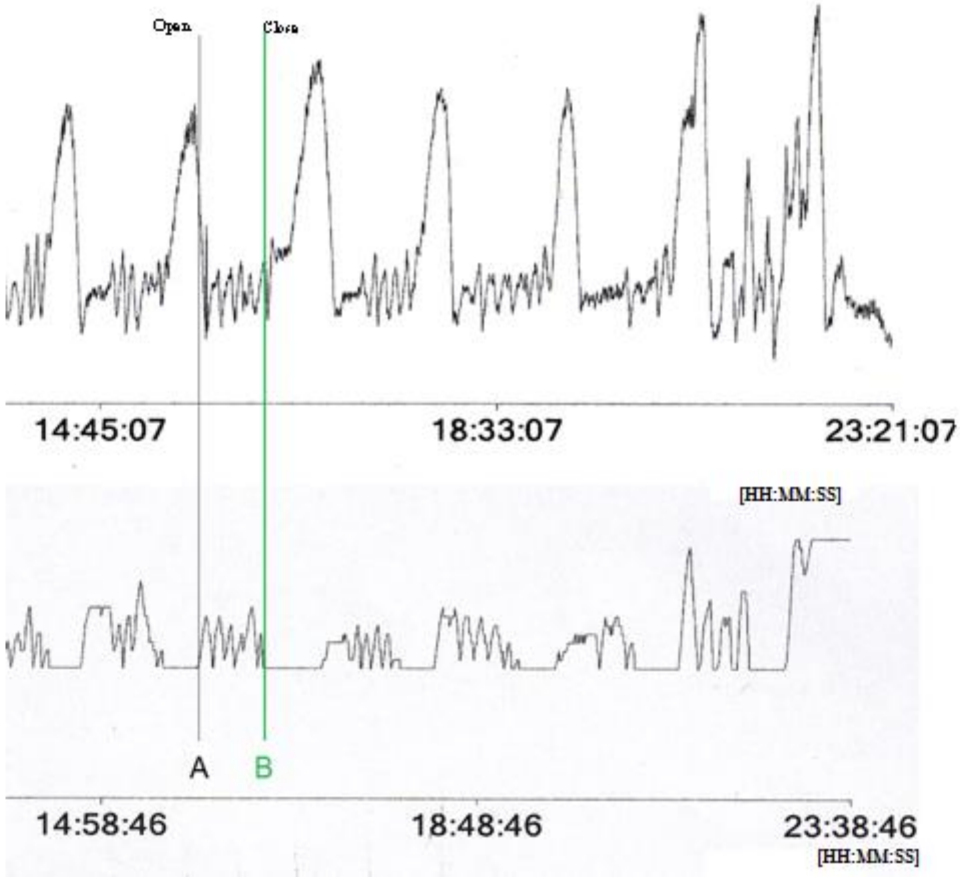

Fig. 10. Overlap of the variation of oxygen and the opening of the air butterfly valve - period 26 October H14:45:07 - 31 October H32:21:07

The variation of the consumed power is calculated depending on the opening of the valve on discharge (Fig. 11).

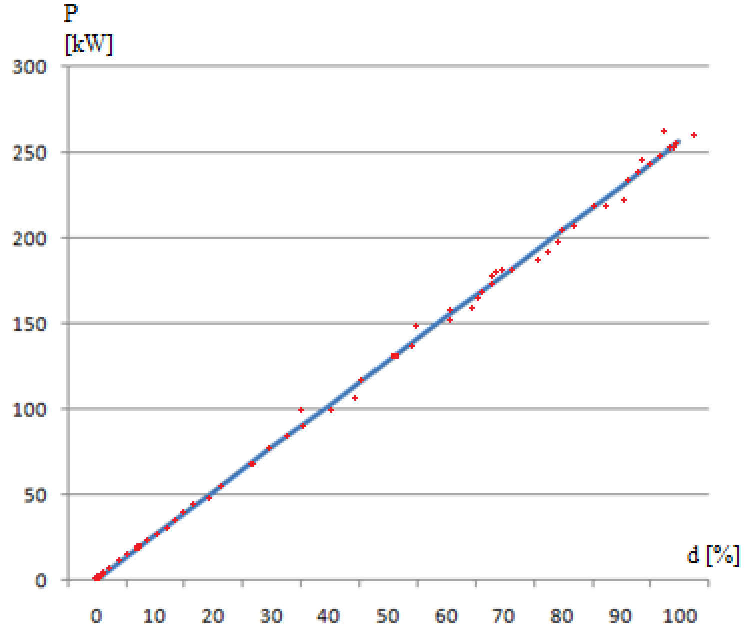

Fig. 11. The variation of the power of the turbo blower depending on the opening of the butterfly valve on discharge

The actual energy consumed after the introduction of the regulation system is E_{real}=51354 [kWh] (for 3 days) and was obtained from the station's SCADA system [2, 5, 6, 7, 8].

4. Conclusions

Since the energy consumption of the turbo blowers represents 68% of the energy consumption of the station, it was sought to reduce this consumption by installing oxygen sensors in the bioreactors [9]; these sensors detect the reaching of the optimal (maximum) oxygen threshold of 2.0% and at this moment they partially close the butterfly valves from the discharge of the turbo blowers, which leads to the reduction of the flow rate and implicitly the energy consumption of the turbo blowers. The initial annual consumption established by design is:

$$E = 9125.68 \text{ [MWh/an]}. \quad (2)$$

So the consumption for three days is:

$$E_{initial} = E/365 * 3 = 75005.5 \text{ \{kWh]} \quad (3)$$

The value of the optimized energy was obtained from the data acquisition system of the station and is:

$$E_{optimized} = 51354 \text{ [kWh]}. \quad (4)$$

In order to quantify the energy savings obtained, $E_{economised}$ was calculated by the difference between the energy consumed when operating with nominal flow of the turbo blower (during 3 days) $E_{initial}$, and the optimized $E_{optimized}$:

$$E_{economised} = E_{initial} - E_{optimized} \quad (5)$$

So $E_{economised}$ = 23.651 [kWh].

Considering the unit price of energy P_e=350 [lei/MWh], the economic efficiency of the solution was obtained:

$$C = P_e * E_{economised} * 1/3 \quad (6)$$

So: C= 2759 [lei/day].

In conclusion, through the wastewater treatment plant SCADA system for the volume of oxygen, the necessary data were obtained to calculate the percentage opening of the butterfly valves from the discharge of the turbo blowers in order to monitor the efficiency of the regulation system, and implicitly, the reduction of energy consumption.

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