On-Site Measurement Analysis, "Customer" WWTP

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Introduction

The objective of this analysis is to study the potential energy savings by replacing the existing aeration system at “CUSTOMER” WWTP (Waste Water Treatment Plant), with an energy efficient solution from Siemens. Siemens is one of the exhibitors at IFAT India 2013.

The analysis is based on measurements acquired at “CUSTOMER” WWTP. These measurements are utilized to determine the actual performance and operational area of the existing aeration system. An estimate of the potential energy savings is obtained by a comparison of a Siemens turbo-blower solution designed for “CUSTOMER” WWTP and the measured performance of the existing system.

The aeration system at “CUSTOMER” WWTP consists of three PD (Positive Displacement) blowers from 1989 with the following specifications:

2 units of Aerzener compact blower type GMa 12.6

- Inlet flow 22.4 nm^3/min (for each)
- Motor performance 37.0 kW

1 unit of Aerzener compact blower type GMa 11.4

- Inlet flow 12.6 nm^3/min
- Motor performance 19.5 kW

These specifications correspond to a total air flow of 3444 nm^3/h

In this analysis the total performance of the aeration system is evaluated, not the performance of each individual PD blower. It is assumed that all the PD blowers will be replaced or utilized as a backup solution.

Measurement Philosophy

The following parameters must be known in order to obtain the performance and operational range of the existing aeration system.

Notation	*Description*
v	The total volume flow m^3/h
P_2	Discharge pressure bar
ρ_1	Air density (surrounding air outside) kg/m^3
P	The total power consumption W

Table 1: Performance measurement parameters

The operation range can be described as (v, P_2), specified for a given ρ_1.

Data should be collected over a large time interval to represent all process dynamics that occur at the WWTP. This analysis contains data acquired over 44 hours, which gives a realistic picture of the process at “CUSTOMER” WWTP.

Data Acquisition

The data acquisition was conducted the 12 March at approximately 11PM to 14 March.

Figure 1 shows the current consumption of each PD blower as well as a black dashed line which illustrates all the three blowers running. The zoom plot displays the start/stop sequence of each blower. The smallest blower starts first (Comp 3) and cannot deliver enough air. Therefore the next blower (Comp 2) starts, and subsequently the last blower starts (Comp 1) so all three blowers are finally running to produce the required air flow.

From the information found in Figure 1, it can be determined that 74% of the time at least one blower is running. This time can be considered as the aeration time. Furthermore it is determined that all three blowers are running during 75% of the aeration time or 55% of the total time data was collected.

It was also observed that during the end of the aeration period, the valves close gradually. This is related directly to the increase of current consumption shown in Figure 1.

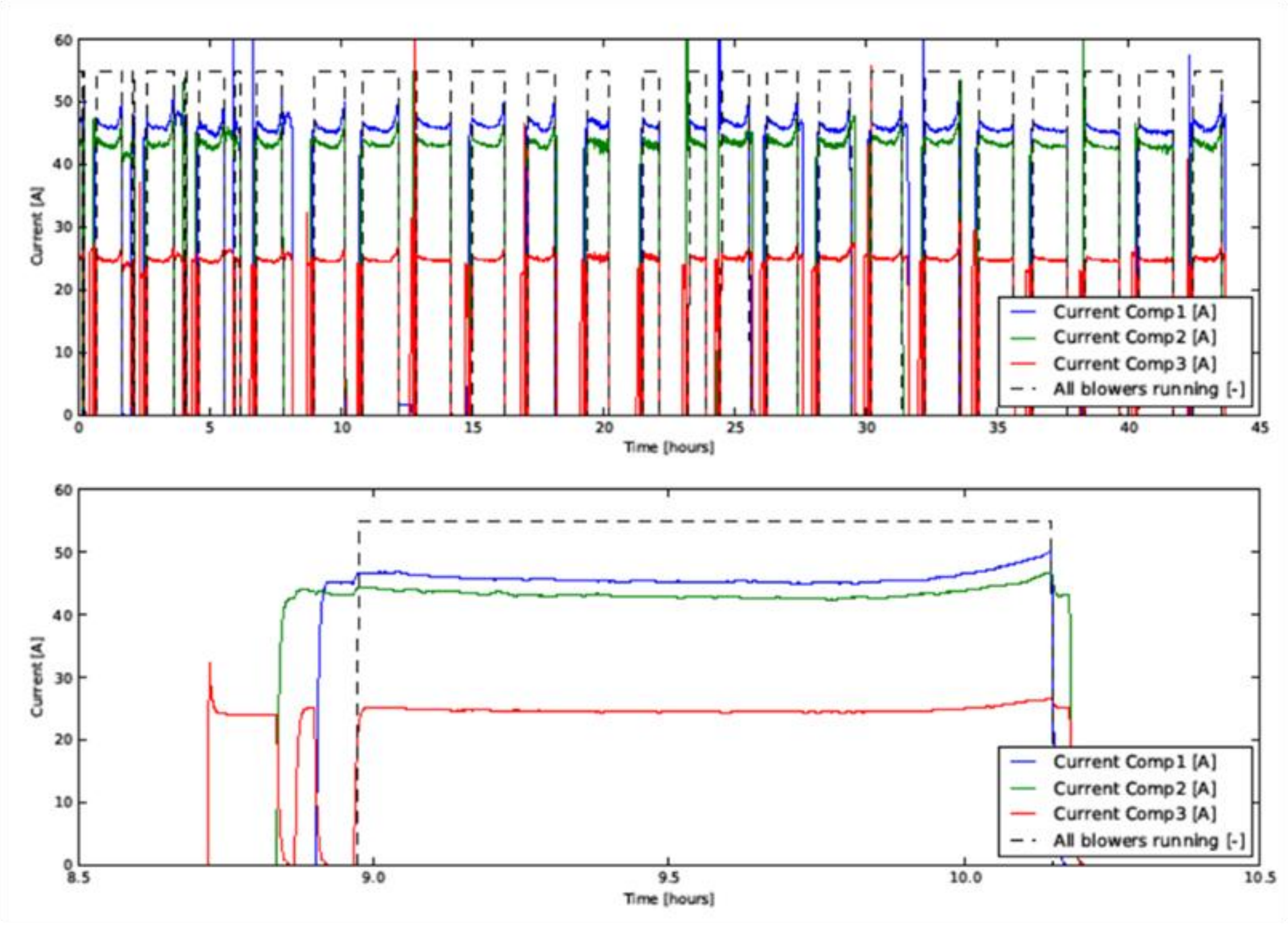

Figure 1: Current consumption for each PD blower
At the top the current consumption is shown over 44 hours while it is shown as a zoom over two hours at the bottom.

The volume flow, discharge pressure and the density for the surrounding air outside is shown in Figure 2. These three factors can be used to describe the operational range of the aeration system.

Figure 2 shows the air flow is approximately 2200 m^3/h with a discharge pressure of approximately 0.5 bar when the blowers are operating. The discharge pressure gradually increases at the end of each aeration period when the oxygen-valves closes, shown in Figure 2. Again, it was observed that the current consumption increases gradually.

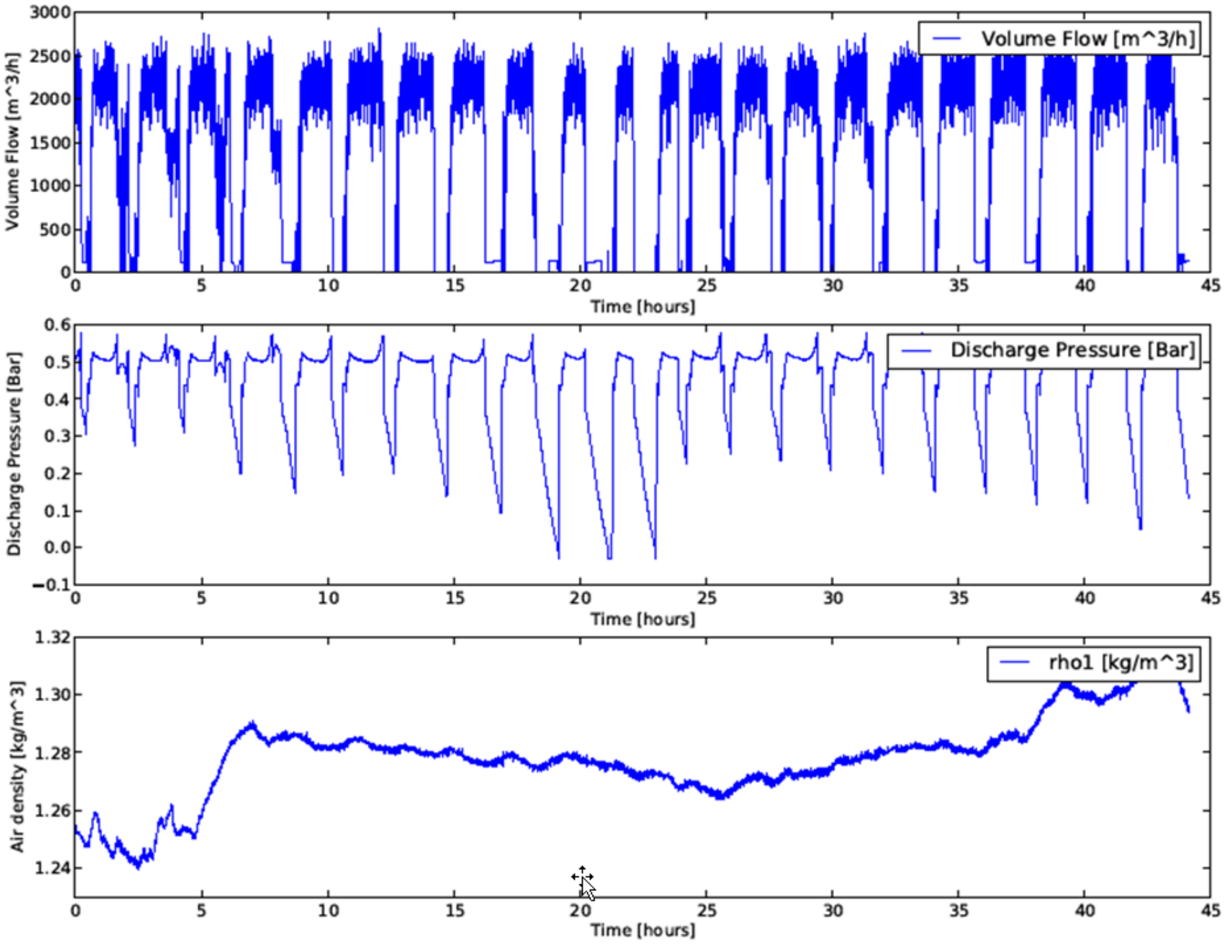

Figure 2: Volume flow, discharge pressure and the density for the surrounding air outside

Calculations and Potential Savings

Since all three blowers operate 75% of the time during the aeration period, all analysis and calculations are based on all three blowers operating. Table 2 displays the average measurements for periods which all three PD blowers are running.

Note: It is the total power consumption and flow for all three PD blowers that are shown in the table.

Name	Value
Mass flow	3636 kg/h
Volume flow	2167 m^3/h
Normal volume flow	2814 Nm^3/h
Power consumption	64.8 kW
Air density (surrounding air outside)	1.28 kg/m^3
Relative humidity	43 %
Barometric pressure	100019 Pa
Air temperature (surrounding air outside)	-0.9 ℃
Discharge pressure (Gauge)	0.511 bar

Table 2: Average measurements for all three PD blowers

The operating point collected from the supplier indicates the blowers should deliver approximately 3444 Nm^3/h of air flow, when first installed. However, the data shows the actual air flow to be approximately 2814 Nm^3/h.

A Siemens turbo blower with IGV (Inlet Guide Vane) technology can be designed to operate at the same operational point as the average measurements. The Siemens blower will have a guaranteed shaft power of 38.4kW (See “Suggested Solution” section).

In order to compare the shaft power of the turbo blower with the power consumption measured directly on the motors of the PD blowers, it is necessary to include the efficiency of the motor. It is assumed that the new motor which comes with the turbo blower possess an efficiency of 94%[1].

Thus the total power consumption of the turbo blower including motor efficiency is:

$$P_{\mathrm{Turbo}} = \frac{38.4\ \mathrm{kW}}{0.94} = 40.9\ \mathrm{kW}$$

It can be concluded, that the turbo blower in this operating point, obtains a saving of:

[1] 1LE1501-2DA23-4AA4 (Siemens Low-Voltage Motors) - https://eb.automation.siemens.com/mall/en/uk/catalog/products/10028832?tree=CatalogTree&activeTab=order

$$P_{saving} = 64.8\ kW - 40.9\ kW\ =\ 23.9\ kW$$

Therefore the turbo blower consumes 36.9**%** less power than the existing PD blowers. Assuming that all three PD blowers are running 55% of the time over a year, yields:

$$T_{aeration}\ =\ 365\ days * 24\ hours * 0.55\ =\ 4818\ hours$$

This results in a yearly energy saving of:

$$E_{saving} = T_{aeration}\ *\ P_{saving} =\ 115150\ kWh$$

Not included in this calculation, is the power consumption during the time outside the black dashed line (Figure 1). The power consumption outside the black dashed line represents the time which only some of the blowers are running. This is 25% of the aeration time and will add a significant saving to the calculation.

Measurement Uncertainties

The measurements are conducted with the following uncertainties (defined by 95% confidence interval):

Uncertainty type	Name	Value
Instrument uncertainty*	Mass flow	± 168 kg/h
Instrument and measurement uncertainty	Power consumption	± 2.8 kW
Instrument and measurement uncertainty	Discharge pressure	± 0.035 bar
Instrument and measurement uncertainty	Air density	± 0.04 kg/m^3

Table 3: Uncertainties on measurements
* *See section "Assumptions for Measurement Uncertainties of Mass Flow"*

Assumptions for Measurement Uncertainties of Mass Flow

FCI (Fluid Components International) recommends their flow meters to be placed in a straight run of pipe, with a minimum of 20 inner pipe diameters upstream and a minimum of 10 inner pipe diameters downstream of the flow meter. This is to avoid pipe turns or other disturbances that affects the measurement uncertainty significantly[2].

At "CUSTOMER" WWTP there are approximately 30m of straight run pipe without disturbances (on the bridge over the basins) with an outer diameter of 250 mm and an assumed pipe thickness of 3mm. This corresponds to a straight run of 223 inner pipe diameters, which by far meets FCI's requirement. Hence it can be assumed that the *flow profile* is fully developed at the flow measurement point.

Short explanation of *flow profile:*
The flow velocity is measured with a Pitot-tube in the center of the cross section of the pipe. Due to friction near the edge of the pipe, a higher flow velocity will occurs at the center of the cross section. Because there is a velocity difference from the cross sectional center to the edge, a flow profile is formed.

Since the Pitot-tube is mounted in the center of the cross section (indicating maximum velocity), a correction factor must be applied, which is defined as:

$$\epsilon = \frac{u_{avg}}{u_{max}}$$

Where u_{avg} is the average flow velocity and u_{max} is the maximum flow velocity, measured at the center of the cross section.

During the data acquisition period, the Reynolds number is > 200000 which indicates that the flow is turbulent. This indicates the flow profile is relatively flat, which corresponds to a relatively high correction factor ϵ. It is assumed that ϵ = 0.95, which is a fairly high assumption (ϵ ~ 0.82-0.87 for Reynolds number at ~ 200000[3]). This will most likely mean a higher flow was estimated for the PD blowers, compared to the actual flow. This suggests the actual flow is less than specified in the "Calculations and Potential Savings" section, which means the turbo blower will consume less energy because less flow is required, thereby making the energy saving increase.

[2] http://www.fluidcomponents.com/Industrial/Library/manuals/Flowmeters/ST50,%20ST51,%20ST75%20Guides%20&%20Manuals/ST51%20Guide%20(06EN003389-).pdf
[3] http://www.vortab.com/pdfs/Vortab-Transitional-Flow-0809.pdf

The Operator Requests

The “PLANT OPERATOR” in charge of the daily operations of the plant expresses that they are satisfied with their present aeration strategy. However, there sometimes is a need for a higher air flow capacity than the present PD blowers can supply. It is not planned to replace the diffusers in the basin or main header that goes from blowers to basin.

Suggested Solution

The Siemens blower solution is designed to perform in the same operational range as the present aeration system.

Based on the need to deliver slightly more air, this solution is designed to deliver 20% more air flow than shown in Table 1.
Since the basin diffusers and the main header remain unchanged, the same discharge pressure will be needed. However increasing the flow by e.g. 20% will induce more pressure loss in the pipes, which will require a slightly larger discharge pressure.

The design and calculations utilized in this analysis is a Siemens blower solution is designed with the following requirements.

- Can deliver a maximum flow of 3377 Nm^3/h
- Can regulate the volume-flow between 45 – 100% of maximum flow
- Can handle a maximum discharge pressure of up to 0.6 bar
- Can handle a maximum inlet temperature of 30 ℃

These aeration requirements can be fulfilled with a single turbo blower. This blower can regulate the volumetric air flow between 45-100% of maximum flow by changing the blower’s variable diffuser position. The blower is available with different control technologies for energy optimization. These include IGV (Inlet Guide Vanes) that can regulate the inlet air amount or a VFD (Variable Frequency Drive) which controls the speed of the motor. The addition of energy optimization technology will thus reduce the operational costs but require a larger investment.

A Siemens blower with IGV technology was applied in this analysis, for maximum energy savings.

Backup Solution

Although the aeration requirements can be fulfilled by a single turbo blower it is recommended to have a backup solution. One possibility would be to buy one turbo blower for primary use and keep the two biggest PD blowers as backup. Another possibility would be to buy two equal turbo blowers but with only one blower operating at a time and the other one in standby.