IMPLEMENTATION AND EVALUATION OF ENERGY SAVINGS FOCUSED AERATION DESIGN AND CONTROL OF SEQUENCING BATCH REACTORS IN WASHINGTON

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ABSTRACT

The design and operation of activated sludge process aeration systems has become a major focal point of study in regards to improving plant robustness, treatment capacity, and energy efficiency. This paper demonstrates the importance of selecting proper blower technology, size, and control ideology to best optimize operational returns on Cap-Ex, especially when given funding opportunities where specific energy savings milestones must be achieved.

This case study of the Quincy, Washington WWTP involves replacing (1) defunct 447 kW (600 HP) multi-stage blower with two smaller 242 kW (325 HP) screw type positive displacement blowers equipped with VFDs, and implementing a bioprocess aeration control system focused on maintaining plant defined DO setpoints in two separate lagoon style sequencing batch reactors. By designing the system to provide the appropriate amount of blower turndown to match typical loading conditions and implementing proper controls techniques which minimize over aeration, the facility has demonstrated 57% aeration energy savings compared to the 2013 baseline, despite unusually high loading conditions during the monitoring and verification period. The upgrade, designed to qualify the facility for an energy savings rebate, exceeded performance expectations by approximately 330,000 kWh during the four month monitoring and verification period (62% greater than the original estimate) and qualified the facility for the maximum rebate value amounting to approximately 40% of the total cost of the project.

Despite the North-West's characteristically low energy rates, the remaining 60% capital cost of the project has a projected payback period of 3 years 8 Months assuming 2,344,000 kWh/year savings at $0.0413 per kW, a rate 58% of the national average.

KEYWORDS: Energy Savings, Aeration Control, Aeration Design, SBR Optimization

INTRODUCTION

Quincy WWTP, located in the state of Washington, treats on average 11,772 m^3/day (3.11 MGD) of industrial wastewater by utilizing two alternating duty sequencing batch reactors. The facility, originally equipped with (3) 447 kW (600 HP) centrifugal blowers experienced unit failure on one of their blower cores in 2014 prompting EMC, the plant's contractor operator, to begin evaluating funding opportunities and process improvements. An energy rebate opportunity offered by Grant County Public Utility District was identified as a potential funding source and PACE Engineering, BioChem Technology, and Atlas Copco were contracted to put together an aeration package which would meet the plant's demands, while simultaneously qualifying the plant for the energy rebate.

METHODOLOGY

The installation of the blower and control package occurred in two stages. The facility, originally equipped with 4 blower pads and three blowers, first required that the old non-functional blower be removed to provide enough space for the two new blowers. The Atlas Copco sound dampening blower enclosures also contained the VFD and local electronics required to monitor and operate the blower locally. The aeration control cabinet was hung in an adjacent control room and RS-485 cables were run between the new blowers and the control cabinet to provide a medium through which Modbus RTU communication could be established between the controllers.

The second stage of the install involved systems integration efforts between the main control panel, provided by BioChem Technology, the blower local control panels, provided by Atlas Copco, and the rest of the facility. In order to accommodate the existing Data Highway+ legacy communication network in use at the facility, data highway+ to Ethernet IP gateway modules were utilized to send signals to the plant's main operations building and Ethernet IP to Modbus RTU communication gateway units were utilized to communicate directly with Atlas Copco's blower LCPs.

The main control panel was configured to continuously monitor the influent splitter box valve configuration, which periodically shunts influent from one SBR to the next. Additionally, the main control panel monitors the air supply valves to each SBR. By monitoring which SBR is receiving influent and airflow, the main control panel can be certain to use the correct set of control data with which to make process adjustments. The splitter box and aeration valves are controlled remotely by plant operators and primarily function on timers. Should the plant close both airflow valves, the control system would go into a controlled shutdown.

The aeration control panel allows each sequencing batch reactor to have a customized airflow 'floor' to promote a constant and vigorous mixing pattern in each uniquely shaped basin. During normal operation, the system allows for the airflow to vary according to the aeration demand in the tank to maintain a DO setpoint, however occasionally, during low loading periods, this minimum airflow floor will prevent the system from turning down further in the interest of favoring proper mixing over accurate DO control. While DO control is slightly compromised during these low loading periods, this configuration offers a more energy efficient method of mixing the tanks verses utilizing the tank's mechanical mixers. This configuration also gives the operators flexibility. The reactor basins have sloped sides, so water level has a direct effect on the surface area of the SBRs. Because the minimum airflow required for mixing is directly proportional to the surface area of the vessel, adjusting this water level allows the plant to modify not just the total treatment volume, but also the minimum airflow required to maintain mixing. The blower package has no difficulty adapting to the change in pressure, as the screw type blowers are positive displacement in nature. As would be expected, beyond the monitoring and verification period, plant operators have plans to reduce reactor surface area/depth to allow the system to turn down further.

In addition to acting as the blower MCP, the aeration control system utilizes process design based equations to indirectly track each SBR's internally calculated oxygen uptake rate factor. Tying this additional information into the controller allows for the system to calculate the specific airflow requirements for the reaction vessel in order to maintain its user defined DO setpoint and subsequent reaction rate. From this airflow setpoint, blowers are modulated utilizing a simple feedback control which considers the blower stage RPM and calculates the estimated SCFM output using performance data supplied by the blower manufacturer.

Verification and monitoring of the energy savings at the facility was conducted during a four month period starting in June and ending in September 2015. Influent pretreatment and process configuration with the exception to the amendments to the aeration system mentioned above were held constant in order to provide a consistent comparison to 2013 operation. After the power consumption data was collected, it was found that loading into the facility in 2015 was also very similar to loads treated in 2013 as depicted below in Tables 1 & 2.

RESULTS

During the monitoring and verification period, the facility has demonstrated 57% aeration energy savings despite higher loading conditions compared to the 2013 baseline all while maintaining comparable treatment levels, see Tables 1 and 2 below.

Table 1. Ratio of 2015 to 2013 influent loads.

	2015/2013	
	BOD Influent Load	TSS Influent Load
Jan	1.0	1.1
Feb	1.5	1.3
Mar	0.8	1.0
Apr	1.0	0.5
May	0.8	1.1
Jun	0.9	1.0
Jul	1.2	0.7
Aug	1.1	1.1

Table 2. Comparison of the BOD and TSS loads to the IWWTP and percent removal in 2013 and 2015. The highlighted months are those used for the M&V period.

2013	BOD			TSS		
	Influent kg	Effluent kg	Removal %	Influent kg	Effluent kg	Removal %
1/1/2013	15,518.29	108	99.3%	13,361.91	171	98.7%
2/1/2013	8,829.17	61	99.3%	9,621.59	83	99.1%
3/1/2013	19,356.13	68	99.6%	12,676.08	85	99.3%
4/1/2013	13,882.18	41	99.7%	15,298.75	124	99.2%
5/1/2013	15,063.34	54	99.6%	11,122.08	84	99.2%
6/1/2013	21,980.61	57	99.7%	16,155.13	132	99.2%
7/1/2013	21,724.79	45	99.8%	15,979.59	155	99.0%
8/1/2013	25,545.39	39	99.8%	18,286.11	129	99.3%
Average	**17,737.49**	**59**	**99.7%**	**14,062.66**	**121**	**99.1%**

2015	BOD			TSS		
	Influent kg	Effluent kg	Removal %	Influent kg	Effluent kg	Removal %
1/1/2013	15,214.38	83	99.5%	14,105.80	81	99.4%
2/1/2013	13,540.17	46	99.7%	12,560.42	80	99.4%
3/1/2013	15,452.97	88	99.4%	13,195.44	219	98.3%
4/1/2013	14,564.39	70	99.5%	8,300.28	292	96.5%
5/1/2013	11,476.33	52	99.5%	12,303.68	158	98.7%
6/1/2013	19,515.34	172	99.1%	16,295.29	368	97.7%
7/1/2013	26,744.24	103	99.6%	10,529.23	202	98.1%
8/1/2013	27,721.28	137	99.5%	20,250.61	334	98.3%
Average	**18,028.64**	**94**	**99.5%**	**13,442.60**	**217**	**98.4%**

The upgrade, designed to qualify the facility for an energy savings rebate, exceeded performance expectations by approximately 330,000 kWh during the four month monitoring and verification period (62% greater than the original estimate) and qualified the facility for the maximum rebate value amounting to approx 40% of the total cost of the project, Table 3 and Figure 1. Note that while the system was active in May, May's data was disqualified from the V&M period due to blower malfunctions interfering with the test.

Table 3. Comparison of energy usage between the 2013 baseline and the 2015 upgrade during 4 month monitoring and verification period.

	2013 power use, kwh	2015 power use (actual), kwh	Power reduction: 2015 from 2013, kwh	Projected Power reduction , kwh	% Power reduction from 2015 to 2013	Projected % Power reduction	2013 Annual Power cost	Cost savings in 2015
JAN	298,800		298,800	-				
FEB	343,800		343,800	-				
MAR	367,200		367,200	-				
APR	327,600		327,600	-				
MAY	350,400	205,200	145,200	237,354	0.41	0.68	$11,211	$4,646
JUN	424,200	171,000	253,200	156,135	0.60	0.37	$11,670	$6,966
JUL	401,400	177,600	223,800	225,856	0.56	0.56	$11,170	$6,228
AUG	321,600	148,800	172,800	136,703	0.54	0.43	$9,554	$5,133
SEP	347,400	138,000	209,400	121,599	0.60	0.35	$8,995	$5,422
OCT	442,800					0.53		
NOV	358,200					0.54		
DEC	411,600					0.68		
Total (June to September)	**1,494,600**	**635,400**	**859,200**	**640,293**	**0.57**	**0.43**	**41,389**	**23,749**
Annual projection	**4,395,000**		**2,329,350**			**0.53**		
Projected annual savings				**2,526,552**				

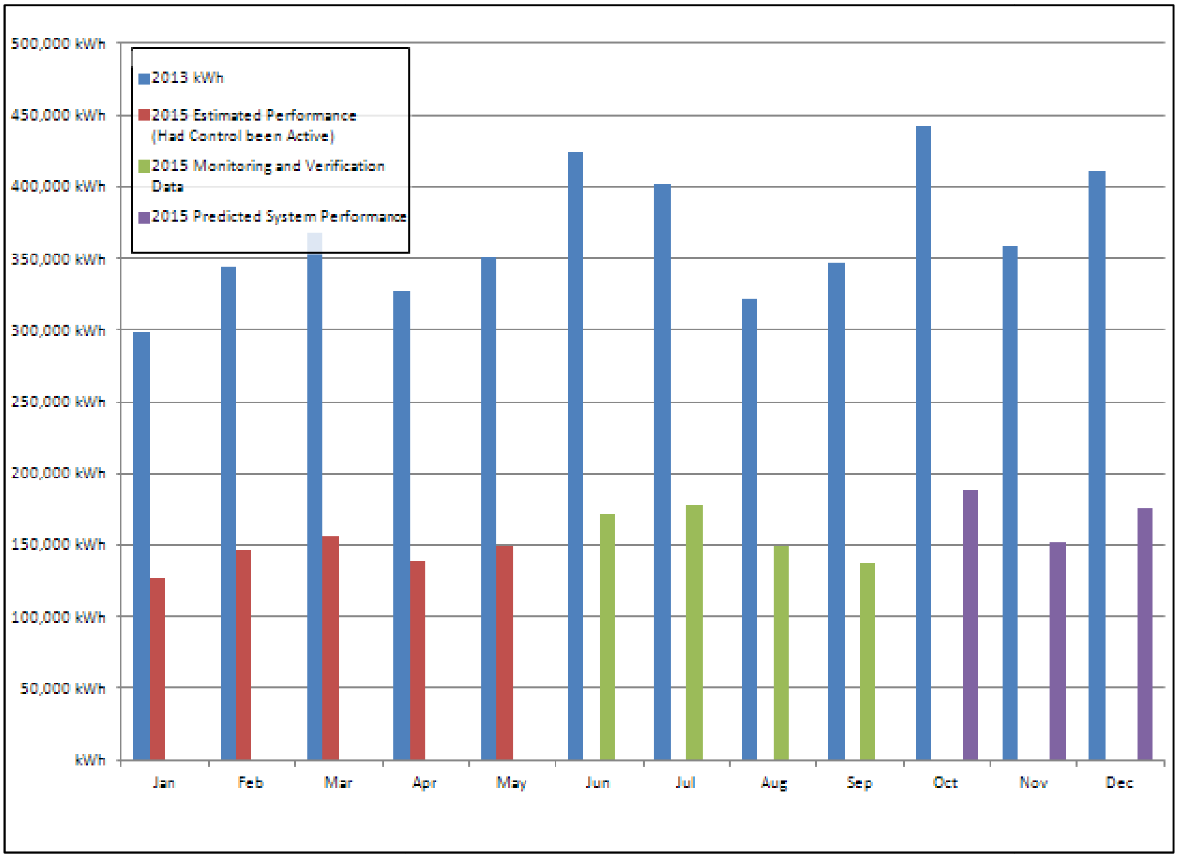

Figure 1. Power usage for 2013 compared to 2015 measured and expected potential power usage

Figure 2, below illustrates the dissolved oxygen setpoint tracking performance of the aeration controller. Please note that during this two day commissioning period the active SBR was swapped approximately every 4 hours. The dissolved oxygen setpoint for each vessel during was set to a static value of 1.5 mg/L. The aeration control system managed to maintain DO levels in the active basin to within .5 mg/L of the setpoint during 75% of all measured control periods despite transient loading conditions and the swapping of active basins.

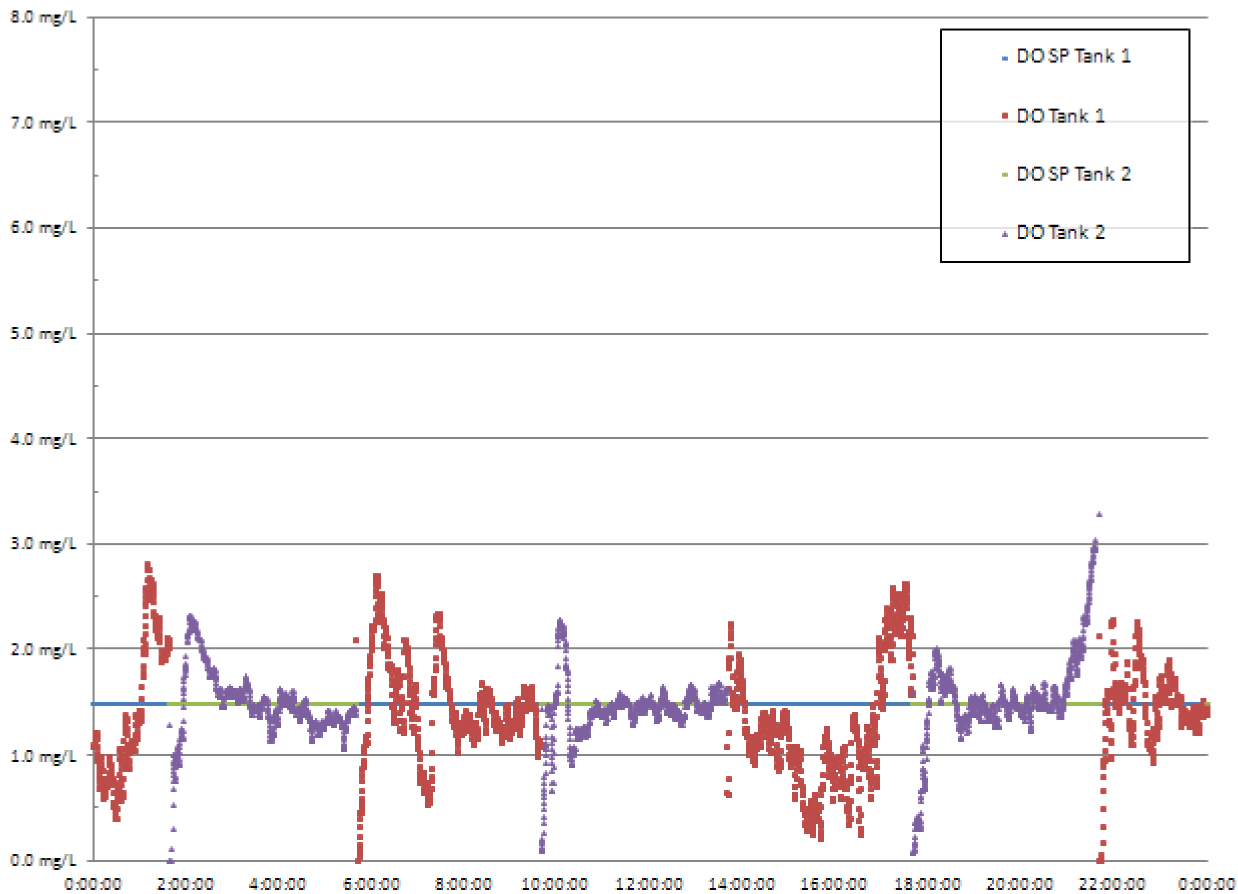

Figure 2. DO performance data for both SBR1 and SBR 2 during two day system commissioning

DISCUSSION & CONCLUSIONS

Proper aeration engineering design and controls techniques yield significant energy and operational savings, especially when upgrading legacy systems lacking variable output blowers and subsequent controls systems. Operational expense focused improvements like this, in conjunction with capital expense funding incentives like energy rebates provide unique avenues with which to fund projects which improve and replace aging infrastructure, reduce long term costs, and minimize the environmental impact of these 24/7 facilities all while treating effluent to the same quality.

It should be noted that frequently, towards the end of an SBR reaction cycle, DO residual is noted to rise above the setpoint, or 'break through' the loading demand, due to the system's inability to turn down further for mechanical and mixing reasons. Physically, this corresponds to the oxygen supply surpassing the loading and/or biological treatment capacity of the vessel, and may provide a valuable indicator for assessing the vessel's resident waste strength or biological health. Should this DO 'break through' point correspond with an SBR's reaction completeness, quantifying this point could help operators or control system designers to determine the completion time of any given reaction cycle without prior knowledge to the strength of the influent. This, perhaps expected, phenomenon lends itself to further study in an effort to continually improve SBR operational efficiency via automation.