

### VFDs can Help Reduce Aeration Basin Energy Costs By Grant Van Hemert and Ivan Spronk

The cost of aeration accounts for approximately 50-60% of the fixed energy expenditures in a wastewater plant. Controlling this cost can result in significant energy and monetary savings. A properly balanced aeration basin control scheme using variable frequency drives (VFDs) to control the blowers, instead of the typical fixed speed inlet throttling valve scenario, can help achieve considerable energy savings.

The source for all the air in a diffused aeration system is the blower. This is where the energy and efficiency of the system is measured. Therefore, it's imperative to examine blower control when implementing a properly balanced aeration control scheme.

For large, multiple-basin systems, the most common type of blower is a centrifugal blower. Compared to a positive displacement blower, centrifugal blowers offer the greatest cost savings. These machines are incredibly robust as long as they are operated above their surge point. If the blower is operated below this point, it cannot maintain its rated pressure and a severe vibration problem will result. If this remains unchecked the blower's impeller and other components can be damaged.

In a typical inlet throttling valve set up, a centrifugal blower is operated at a fixed speed and the amount of air entering the blower is physically modified. A normal fixed speed configuration includes some form of starter, such as a reduced voltage soft start (RVSS), which starts the blower and slowly increases the speed to full. A RVSS

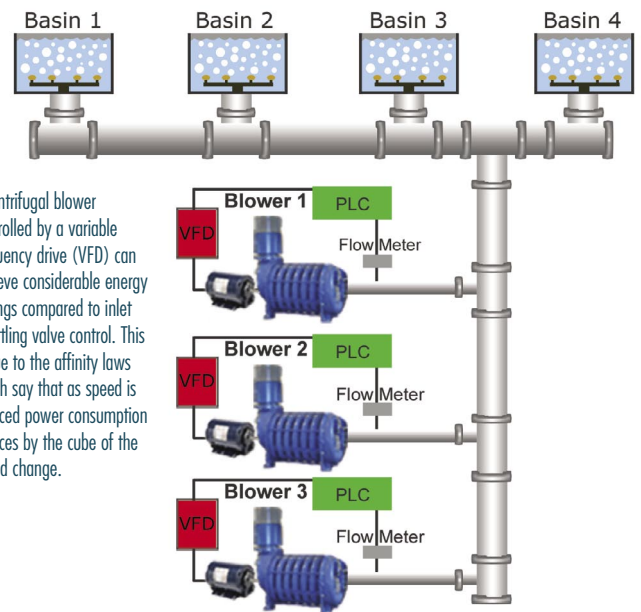
produces maximum heat for a sustained period. A bypass contactor will minimize heat production and result in a smaller enclosure.

In addition to the starter or RVSS, other equipment is necessary to detect the surge point and motor overload point of the blower. Information from these devices is used with the control system to ensure that the blower operates in its valid range. Finally, air control is accomplished via a valve that is placed in the blower inlet pipe.

An inlet throttling valve system has several limitations to efficient control. When a blower runs at a constant speed, the surge point is at a fixed airflow and amperage at that speed. Thus, control must occur between that point and the maximum amperage of the blower.

Mechanical butterfly valves often are used in inlet throttling valve systems. These valves are cost effective but don't have a linear modulation response. Complicating matters is that valve positioning equipment is a hybrid of mechanical and electric devices. These devices often are not capable of providing tight control. To compensate, the control program in the PLC has to be very loose to ensure stable control, but loose control inherently wastes energy. Therefore, this combination of valve, positioning equipment and loose control program can prevent tight control near the blower's surge point. Operating a blower in the region just above the surge point results in significant energy savings.

Unlike an inlet throttling valve system where the blower operates at a fixed speed, VFDs regulate the speed of the centrifugal blower which modifies the amount of incoming air. Therefore, a VFD control scenario does not require valves or guide vanes for air modulation. Also, due to the electrical nature of VFDs, they can provide extremely tight control over the speed of a blower, and thus airflow. This



A centrifugal blower controlled by a variable frequency drive (VFD) can achieve considerable energy savings compared to inlet throttling valve control. This is due to the affinity laws which say that as speed is reduced power consumption reduces by the cube of the speed change.

means a tighter control program can be created, enhancing energy savings.

Furthermore, when using a VFD the surge point of the centrifugal blower is not fixed. This means that additional energy savings can be garnered. When a blower's speed is decreased, the blower curve shifts. The net result is that the surge point decreases as the blower speed decreases. Therefore, a blower controlled by a VFD has a greater operating range than an equivalent constant-speed blower. This enhanced turn down is on the low end of the operating range where there are greater efficiencies. The closer you can run the blower to its surge point the more efficient it will be because the surge point is where the amperage is lowest. The tighter control of a VFD allows stable operation closer to the blower's surge point. A lower motor speed means less energy consumption.

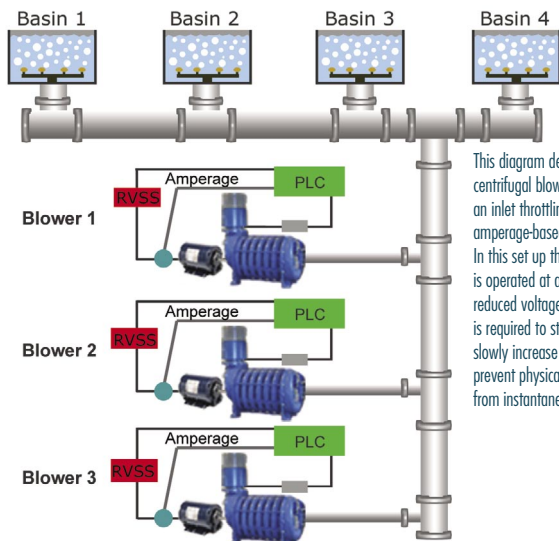
#### How Much Energy Can Be Saved?

A general rule of thumb to follow is that a centrifugal blower delivering 80 percent of its rated speed only requires 50 percent of the rated power. The affinity laws state that there's a cubed relationship between speed and power. Figure 1 demonstrates the relationship between flow and power requirements of a centrifugal blower.

Consider the following examples:

#### Example 1 Criteria:

- An inlet throttling valve aeration system with four (4) 400 hp 480 vAC multistage centrifugal blowers.
- On average, two blowers are operating 24 hours a day year round.
- The blowers operate at 98 percent capacity



This diagram depicts a typical centrifugal blower controlled by an inlet throttling valve with amperage-based surge protection. In this set up the centrifugal blower is operated at a fixed speed and a reduced voltage soft start (RVSS) is required to start the blower and slowly increase it to full speed to prevent physical and electrical stress from instantaneous starting.

is necessary because the mass of a centrifugal impeller can cause extreme physical and electrical stress if instantaneous starting is attempted. Furthermore, an RVSS can diminish demand charges by minimizing the inrush during a motor start. However, when a RVSS is at full speed, it

for about 10 percent of the time, 87 percent for about 20 percent of the time, 74 percent for about 65 percent of the time, and 60 percent for about 5 percent of the time.

The following formula can be used to calculate the yearly energy cost for a given capacity:

Voltage x Amperage x % of full capacity x Power Factor x 1.732 / 1000 Watts x \$KW/Hr x 365 Days x 24 Hours/Day x % of time at capacity x # of blowers.

The total cost for each capacity point is shown below.

$460V \times 440A \times 98\% \times 0.89 \times 1.732/1000W \times \$0.08KW/Hr \times 365Days \times 24Hours/Day \times 10\% \times 2 = \$42,854.71$

$460V \times 440A \times 87\% \times 0.89 \times 1.732/1000W \times \$0.08KW/Hr \times 365Days \times 24Hours/Day \times 20\% \times 2 = \$76,088.97$

$460V \times 440A \times 74\% \times 0.89 \times 1.732/1000W \times \$0.08KW/Hr \times 365Days \times 24Hours/Day \times 65\% \times 2 = \$210,337.90$

$460V \times 440A \times 60\% \times 0.89 \times 1.732/1000W \times \$0.08KW/Hr \times 365Days \times 24Hours/Day \times 5\% \times 2 = \$13,118.79$

This results in a total annual energy cost of **\$342,400.37**

**Example 2 Criteria:**

- The same blowers and criteria as in the above configuration, except that they are modulated by VFDs instead of throttling valves.

To make a proper analysis, the power consumptions in the previous example are correlated to power consumptions in the VFD scenario. To accomplish this, the inlet throttling valve power was converted to airflow for each capacity. This airflow was then converted via the affinity laws to the equivalent VFD power for each flow range (For complete calculation information, contact the author).

The following formulas can be used to calculate the costs of the system:

$KW \times KW/Hr \times 365Days \times 24Hours/Day \times \% \text{ of time at capacity} \times \# \text{ of Blowers}$

The total cost for each capacity point is shown below.

$289.19KW \times 0.08KW/Hr \times 365days \times 24H/Day \times 10\% \times 2 = \$40,532.87$

$202.64KW \times 0.08KW/Hr \times 365days \times 24H/Day \times 20\% \times 2 = \$56,804.04$

$122.88KW \times 0.08KW/Hr \times 365days \times 24H/Day \times 65\% \times 2 = \$111,948.59$

$67.39KW \times 0.08KW/Hr \times 365days \times 24H/Day \times 5\% \times 2 = \$4,722.69$

This results in a total annual energy cost of **\$214,008.19**

Potential Annual Savings: **\$342,400.37 - \$214,008.19 = \$128,392.18**

In this hypothetical scenario, a municipality could potentially save \$128,392.18 annually with a centrifugal blower controlled by a variable frequency drive instead of one controlled by an inlet throttling valve.

**Surge Point**

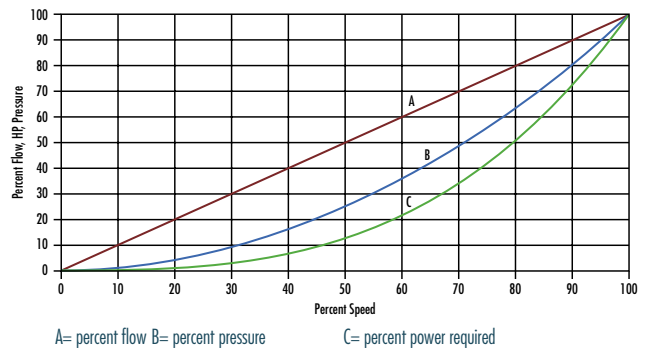
The surge point is the trick to controlling a centrifugal blower. In a fixed-speed system, the point is constant, thus surge control can be as simple as an ammeter. In VFD control, the surge point must be recalculated for every speed change. The affinity laws will help dictate these limits. Once the surge airflow has been calculated at a given speed, it can be compared against the actual airflow being produced to determine if a surge exists. To further protect the blowers, flow meters that determine airflow direction should be used. These flow meters, typically thermal mass flow meters, will be able to detect an airflow reversal that is characteristic of an occurring surge. Finally, vibration sensors should be placed on the blowers to determine vibration. Not only will this detect an occurring surge, they also can help to determine things like bearing wear.

In a theoretical VFD scenario, the blower speed can be reduced much more dramatically than what is possible in a real application. This is because other factors will dictate the lowest speed of the motor before it gets to the surge point. For example, as the blower speed is decreased, the motor driving the blower, and the blower itself will start to lose its ability to dissipate internal heat. For the motor, this usually is caused by a decrease in the speed of the fan attached to the motor shaft. For a blower, the airflow though the blower is not sufficient to carry the heat of compression out of the blower. Thus, these points must be calculated to determine the absolute minimum speed at which

the blower can operate. After all, lack of heat dissipation can damage the blower, motor or diffusers the same as a surge can.

**More than Just Energy Savings**

The advantages of having an increased ability to turn down the capacity or speed of the blower before hitting the surge point can be beneficial, especially to older systems. Using VFDs to achieve greater turndown can eliminate the need to replace older blowers for ones with greater operating range. Also, a VFD is about the same size as a RVSS and with its associated initiating and bypass contactors such as the panel, floor or MCC, space usage is about the same. The equivalence in space can come into play in older systems when the controller of the existing blower system may not have the speed or performance required for the complex calculations needed to run a VFD solution. Fortunately advanced drives exist that can address this scenario. These VFDs can have an integrated controller card which has the flex-



ibility of a PLC. However since they are inside the VFD, they can reduce panel real estate requirements, wiring costs and component costs compared to an external PLC solution. In addition, it is not uncommon for the cost of today's advanced VFDs to be equivalent to or less expensive than a RVSS-throttling valve scenario. **WW**

**About the Authors**

Grant Van Hemert is an automation and control applications engineer for the Schneider Electric Water Wastewater Competency Center. Van Hemert has over 11 years of water and wastewater experience. Previously he was a design and implementation engineer where he designed and commissioned automation and instrumentation systems dealing with aeration, screening, and clarification. He can be reached at [Grant.VanHemert@us.schneider-electric.com](mailto:Grant.VanHemert@us.schneider-electric.com). Ivan Spronk is the product line manager for AC drives and softstarters for Schneider Electric. He has 15 years of experience in motor control and has held a variety of development engineering, application engineering and product marketing positions within Schneider's motor control business.

