ADAPTIVE CONTROL FOR LOW PRESSURE WASTEWATER TREATMENT AIR SYSTEMS

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In recent years, there have been many changes in wastewater treatment. Most modern processes control three cycles: DO, NH4, and NO3, and all of the processes require high volumes of air. Undeniably, the low pressure air system uses more electrical power than the rest of the wastewater treatment plant combined. The blower packages in these systems can be equipped with low noise enclosures, fixed speed or variable speed drives, and can include all the instrumentation needed for self-protection. The latest designs are classified as end-products which are "plug-and-play." In addition, manual process control is being replaced by automated process control. These sophisticated system controllers match the blower capacity to the process demand by delivering the required flow in real-time for optimized, efficient operation. This is accomplished by measuring data from the process as well as data from the machines connected to the process. New blower technologies also include gearless, high speed turbines and oil-free, rotary screw blowers. All of these advancements can help to improve low pressure air system efficiency when controlled efficiently.

When modern wastewater treatment facilities are designed and built, they are dedicated to serve a defined region and are many times substantially oversized to handle the future growth of the community they serve. This growth however, depending on the local economy, could take years to reach maximum capacity. The specified "worst case" site conditions may only occur a few days a year, but the plant must pay the higher electrical cost every other day.

It is common for new system designs to include variable frequency drives on all of the blowers. While variable frequency drives (VFDs) offer great flexibility, they have a high investment cost and their own efficiency drawbacks. The most efficient low pressure air systems are a combination of fixed speed units and VFD controlled units that work in conjunction with the wastewater treatment process controls. VFDs are perfectly suited for applications where the air flow is variable. However, in applications where there is a broad range of airflows, a method of system splitting can be applied. In system splitting, the low pressure air system can be controlled more efficiently by cycling fixed speed machines to cover the large portion of the demand and using VFD machines to provide the trim load. This is a result of the losses in the VFDs, the blowers, and the drop off in motor efficiencies at partial loading / speeds which are not found in fixed speed machines.

The second part of the system is an intelligent controller which can analyze the system / process requirements in real-time. A controller that combines the requirements of the process with available capacity in the most efficient way is known as *adaptive system control.* The wastewater treatment process controller communicates the process requirement to the adaptive low pressure air system controller which provides the air that is needed by selecting the most efficient combination of units to match the current demand. When the input power of this selected combination

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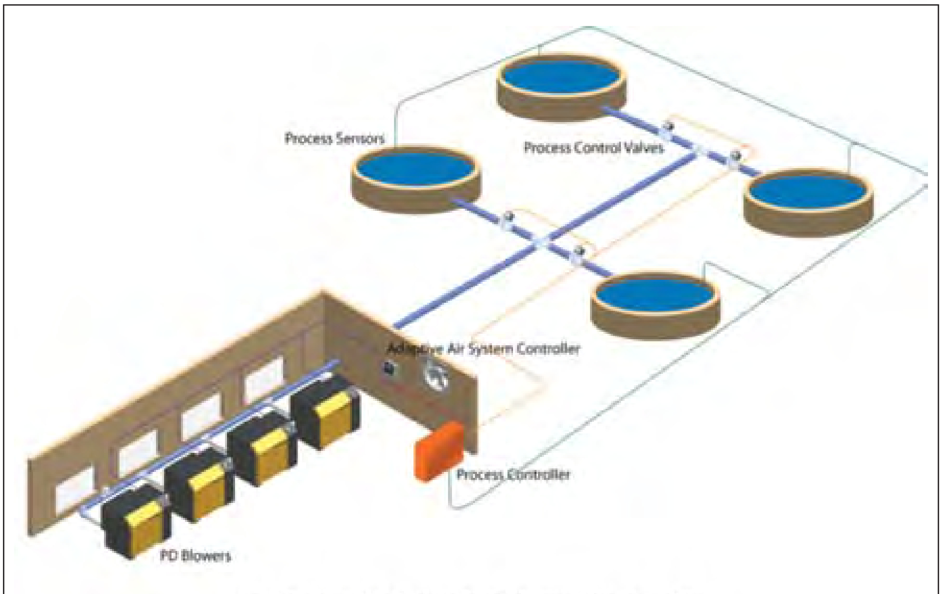
of units is compared to the input power of the multiple VFD solution, the efficiency gains can be seen. Adaptive control combined with system splitting is an attractive alternative because it offers reduced initial investment cost, lower cost of redundancy, improved system reliability, and optimized system performance.

A typical "conventional" system will include two or more identically sized units with identical variable frequency drives. In this arrangement, several units are running in parallel with another unit for redundancy. The simplest control systems are often setup to share the demand and the blowers operate at the same speed resulting in an accumulation of inefficiencies at lower demands. In comparison, a split system is setup with three or more units. One or two units will include variable frequency drive and the balance of the air blowers are fixed speed machines with reduced current starting and auto-dual control. The initial investment cost is reduced by limiting the number of variable frequency drives needed.

In system splitting, auto-dual control on fixed speed positive displacement blowers allows the unit to be placed into an idle condition where ambient air is passed through the blower at no pressure (which requires very little power). The unit can remain in this idle condition for a defined period of time before shutting down, allowing the adaptive controller to observe the system's response and reload if needed. This ability to load and unload as well as start and stop the motors offers quick response times while consuming minimal energy (especially when compared to blowing off air at pressure). The variable speed machine(s) are configured with Proportional Integral Derivative (PID) loops which enable the units to hunt for a speed that matches the systems demand in real-time. The VFD machine should be no larger than required to reduce investment cost while covering the gaps in supply that will occur when fixed speed machines are placed into idle. It is more efficient to turn blowers off than to turn blowers down.

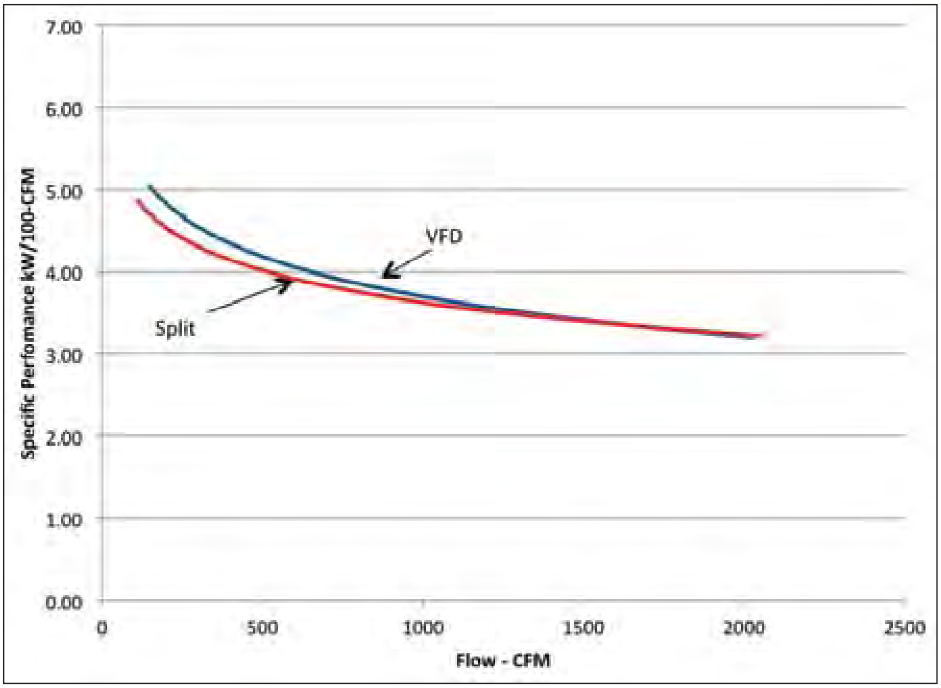
The performance advantages depend on the size of units selected and effectiveness of the



Low Pressure Air System for Watertreatment Facility control scheme. The goal when sizing units is to utilize the minimum number of fixed speed machines to provide the base load while staying within the turndown range of the VFD unit to trim the transient system variations. The fixed speed units, setup to operate at their best efficiency point, provide the best wire-to-air efficiency when considering all of the losses in power transmission. The VFD unit can be set to follow the variations in demand to optimize system performance, by matching system demand.

The efficiency gains can be seen by examining each unit's specific power and the combination of these units over the entire operating range of the system. Specific power is a ratio of total input power (kW at the input to the unit's control system) over the produced flow rate (cfm). In low pressure air systems this can be given as kW/100 cfm. It is very important to consider the input kW to the control panel to include all losses and power consumers to run the equipment, not just the estimated power at the motor at a given design point or the efficiency of the airend. On VFD driven machines, input kW will vary over the entire operating range of the machine. At constant pressure, the efficiencies will drop at the lower end of the operating range; not only because of the lower airend efficiencies, but because of the losses in the motor and drives.

As an example let's review a 2,000 cfm system at 7.0 psig (assuming standard conditions). A typical specification may require three like-sized VFD positive displacement blower packages. For the conventional (VFD) setup, the units are to be sized for at least 667 cfm at 7.0 psig which results in a 30 hp positive displacement blower. The combined average specific power of three units in operation will be 4.26 kW/100 cfm over the entire operating



Graph 1.

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range of the system. Average specific power is identified by looking at the specific power of the system at data points across the entire operating range of the system.

The split system concept would utilize one 30 hp VFD driven positive displacement blower package, two 20 hp positive displacement mid-load fixed speed machines, and one 40 hp positive displacement base-load fixed speed machine. The average specific performance of this system over the entire operating range is 3.68 kW/100 cfm.

Graph 1 shows a comparison of the specific power of the two systems with the constant pressure and variable flow. At full flow performance, the VFD solution is marginally better. However, at lower flows the adaptive control system shows greater efficiency. If the entire performance envelope is examined and averaged, the adaptive control system is 13% better than the VFD-only solution. Over a 10-year period, this equates to $95,000 in savings (assuming $0.09/kW-hr & inflation).

While this example is somewhat elementary when compared to actual site conditions, the potential for savings is clear. Furthermore, many plants are sized with provision for community growth and for "worst case" conditions. The specified low pressure air system capacity may be much more than what is actually required. With this consideration, the plant may not see full flow conditions for many years to come which will only further increase the operational savings provided by a high efficiency low pressure air system. By substituting fixed speed machines for the base load and trimming with one VFD unit, the overall system reliability is improved. By limiting the accumulative effect of running larger blowers at lower speeds where losses are greatest, system efficiency is improved.

Modern wastewater treatment technology has become very advanced. Most control three cycles — DO, NH4, NO3 — in each basin. Aeration represents the majority of the energy consumption. It is reasonable to investigate the most efficient means to produce and deliver the air. Adaptive controllers and system splitting offer both an advanced option for air delivery and selection method for the equipment that produces this air. While multiplex VFD controlled units offer inherent redundancy and flexibility, it comes at cost when evaluating the system specific power consumption. Even the most efficient blowers may not result in the lowest power if the control system is not efficiently controlled. Combined with lower initial cost, lower cost for redundancy, and greater reliability, an adaptive control scheme is very appropriate for wastewater treatment plants with sophisticated automation.

When evaluating existing blower systems, it is a good idea to contact your blower specialist. Working closely with your blower specialist can determine which control strategy is best for your specific process, and if a system audit is needed. System audits can uncover energy savings opportunities within the system and can pay big dividends.

The Compressed Air Challenge is a voluntary collaboration of industrial users; manufacturers, distributors and their associations; consultants; state research and development agencies; energy efficiency organizations; and utilities. This group has one purpose in mind — helping you enjoy the benefits of improved performance of your compressed air system. The mission of the CAC is to be the leading source of product-neutral compressed air system information and education, enabling end users to take a systems approach leading to improved efficiency and production and increased net profits. For more information, please visit www.compressedairchallenge.org. BP

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