REDUCING THE COST OF ELECTRIC ENERGY IN WASTEWATER TREATMENT

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Abstract

Energy consumption in wastewater treatment plants has been well documented. However, the cost of energy is not determined solely by consumption. The various billing methods used by utilities are discussed, emphasizing time of day and demand usage. Methods to reduce cost by taking advantage of rate structures are addressed. Various types of automatic controls for reducing both cost and consumption are explained. Methods for determining cost effectiveness are given.

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Introduction

Since the OPEC induced energy crisis of the '70s, energy conservation has been an increasing concern for the American public in general and environmentalists in particular. In addition to the initial considerations of finite resources, apprehensions about greenhouse gas emissions, global warming, acid rain, and environmental degradation make reducing energy use even further a national priority.

Wastewater Treatment Plant (WWTP) operators are usually more aware and knowledgeable about energy usage than the general public. Plant upgrades and process modifications almost always include energy efficiency in the analysis of alternatives.

Pressure to reduce operating budgets has forced most facilities to implement conservation techniques. The increasing acceptance of automatic controls and computers in Publicly Owned Treatment Works (POTWs) have made analysis and optimization of energy use more effective.

STATE	Rank	$/kwh	STATE	Rank	$/kwh	STATE	Rank	$/kwh
Hawaii	1	$0.11	South Carolina	18	$0.06	North Dakota	35	$0.05
Rhode Island	2	$0.09	Delaware	19	$0.06	South Dakota	36	$0.05
New York	3	$0.09	Vermont	20	$0.06	Alabama	37	$0.05
California	4	$0.08	Florida	21	$0.06	Arkansas	38	$0.05
New Jersey	5	$0.08	Alaska	22	$0.06	Virginia	39	$0.05
Connecticut	6	$0.08	Missouri	23	$0.06	Montana	40	$0.05
New Hampshire	7	$0.08	Mississippi	24	$0.06	Minnesota	41	$0.05
Massachusetts	8	$0.08	Kansas	25	$0.05	Wisconsin	42	$0.05
Arizona	9	$0.07	Louisiana	26	$0.05	Oklahoma	43	$0.04
Dist. Columbia	10	$0.07	Michigan	27	$0.05	Wyoming	44	$0.04
New Mexico	11	$0.07	Indiana	28	$0.05	West Virginia	45	$0.04
Illinois	12	$0.07	North Carolina	29	$0.05	Idaho	46	$0.04
Pennsylvania	13	$0.07	Texas	30	$0.05	Utah	47	$0.04
Maryland	14	$0.06	Nebraska	31	$0.05	Tennessee	48	$0.04
Maine	15	$0.06	Nevada	32	$0.05	Kentucky	49	$0.04
Ohio	16	$0.06	Colorado	33	$0.05	Oregon	50	$0.04
Georgia	17	$0.06	Iowa	34	$0.05	Washington	51	$0.04

1990 Composite Average Electrical Energy Costs. Includes On & Off-Peak and Demand Charges for 1,000 kw Peak Demand and 400 MW-hr daily consumption (approx. 600 hp Average Motor Load)

Despite the progress, however, most POTWs still provide opportunities for further reduction in both energy use and energy costs. The same budget restrictions that encourage cost reduction also make it difficult to obtain the new equipment that is often required to improve efficiency. Wastewater treatment processes and equipment are also more complex than most energy consumption systems, and special considerations are required. Concerns over the impact of energy reductions on process performance make many operators reluctant to change operating procedures. Because of confusing rate structures it is sometimes difficult to accurately assess the financial impact of energy optimization programs.

These barriers can be overcome by increased understanding of the way energy bills are developed. Better awareness of simple cost reduction techniques, both manual and automatic, will allow operators to develop programs for their facilities. Some simple techniques can then be used to determine the cost effectiveness of the program, and to establish the order of implementation.

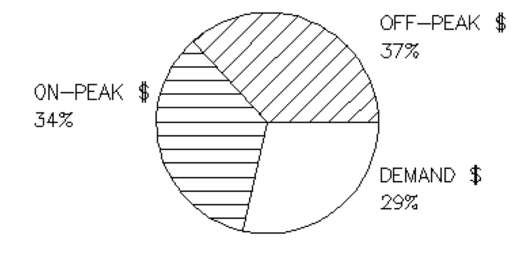
Energy consumption and energy cost are obviously related, but they are not always proportional. Natural gas and electricity are the primary sources of purchased energy in WWTPs, and for natural gas the utility charges are generally a function of consumed energy and a fixed cost per unit. Consumption of electricity is usually much higher than for other forms of energy in most POTWs, and so the reduction of electrical energy charges is usually the first objective.

Rate Structures

Electric bills are more complex because of the nature of generation and distribution. It is often possible to reduce the cost of electric power without changing the amount of energy used by taking advantage of the rate structure. Electricity is often billed based on time of day, energy used, distribution efficiency, and rate of use. Utilities structure rates to encourage usage patterns that minimize their costs.

The various terms used on electric bills are often confusing. A kilowatt-hour (kwh) is a measure of energy or work -- it takes a fixed amount of energy to raise 10 gallons of water one foot (ignoring pump efficiency). However, the faster you raise the water, the higher the rate of energy use becomes. Consequently, more power (horsepower or kw) is required to raise 10 gallons one foot in 10 seconds than is required to raise it in 10 minutes.

Time of day is important because most energy consumption follows a daily pattern similar to diurnal variations in plant influent flow. During high usage periods utilities use less efficient peaking generators. During the day "on-peak" rates are charged for each kwh. These are higher than the "off-peak" nighttime and weekend rates because the cost to the utility are higher. Summer rates are sometimes higher than winter rates for the same reason.



Typical Distribution of Electric Power Costs for a Municipal WWTP

To further limit peak usage many utilities use a "kw demand" charge for the highest rate of energy usage during a month or year. This is usually based on the highest usage for any fifteen minute period. A 40 hp filter backwash pump can cost as much in demand charges by running for 1/2 hour as a 10 hp clarified effluent pump running continuously for a month.

Voltage is the measurement of driving force behind the flow of electricity, in the same way pressure is a measurement of driving force behind fluid flow. Current (amps) is a measure of how much electricity is flowing, just as gpm is a measure of how much fluid is moving. Resistance (ohms) is a measurement of the restriction to current flow, similar to pipe friction in fluid flow. Power is a function of voltage and amperage, but distribution losses (sometimes called I^2R losses) are a function of current and resistance only.

In order to minimize wire size electric utilities distribute power at very high voltages (up to 500,000 volts) and use transformers to reduce voltage for customer use. It is less expensive for the power company to distribute power at high voltage and low amperage, and many utilities charge less per kwh if the customer accepts power at higher than 460 Volts.

The relationship between voltage, current, and distribution losses is also the basis for "power factor". Inductive loads (coils) like transformers and motors cause alternating current to get out of synchronization with the voltage. This forces the power company to send more current for the same amount of power, which means their distribution losses increase. Power factor is a measurement of how much the current and voltage are out of synch. To encourage customers to minimize the distribution losses utilities often charge penalties for low power factor.

Not all utility customers have the same rate and billing structures. In general large users have the lowest charge per kwh, but are more likely to be penalized for poor power factor, high demand, etc. Lift stations which are metered separately are generally billed on consumption only, and small ones will probably not even have time of day rates.

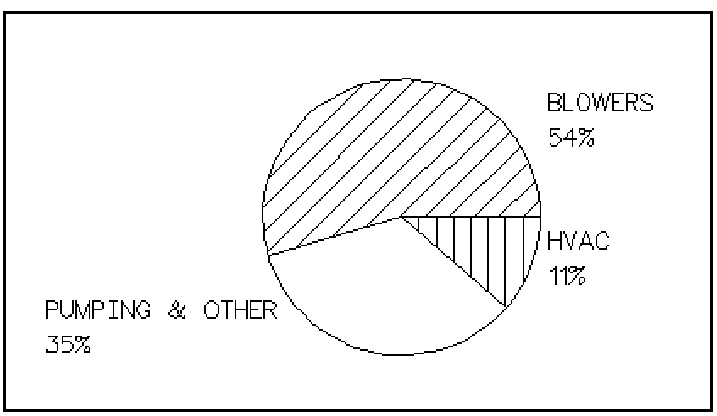
In addition to being aware of the electric utility charges for energy, the plant operator should become familiar with the incentives for conservation provided by many utilities. These incentives include rebates or low interest loans that cover a significant portion of equipment costs.

The incentives are usually available for both new and retrofit equipment. High efficiency motors, improved Heating, Ventilating, and Air Conditioning (HVAC) equipment, and Variable Frequency Drives (VFDs) usually have fixed rebates based on equipment size. Special process modifications like high efficiency diffusers or automatic controls also qualify for most incentive programs, with the rebate or loan amount determined by the utility on a case by case basis. Reduced demand, lower consumption, or improved power factor are considered by the utility in their calculations.

General Guidelines

Taking advantage of the rate structure allows WWTPs to reduce energy cost without reducing consumption. A plant can improve power factor or transfer some operations to off-peak periods and reduce the electric bill for the same total energy consumption. Reducing consumption is obviously important, but it may not always be the most cost-effective approach to reducing operating costs.

Before beginning an energy management program specific objectives should be identified. The most common objective is reducing consumption, but reduced demand or improved power factor may be better objectives. Besides the impact on operating budgets, improvements in these areas can reduce equipment problems or extend the life of marginal distribution systems.



Typical Distribution of Electric Energy Used in a Diffused Aeration Activated Sludge Facility

The most <u>cost-effective</u> steps should be implemented first. These are not necessarily the ones that produce the biggest change in bills, or the ones that are least costly to implement. In other words, the operator should try to get the most "bang for the buck".

Return on Investment (ROI), present worth analysis (PWA), and simple payback period are ways of determining the best energy management measures. For most operators payback period is the easiest to calculate and provides an adequate basis for decisions.

One of the first steps at any facility should be to contact your local utility field engineer. They are very interested in helping customers reduce energy use and cost, and although they are not able to analyze process factors they can usually identify opportunities for reducing charges. The utility representatives will assist the operators in evaluating bills, and can go over the specific billing methods at the facility. Utilities will generally provide records of usage, including monthly demand graphs. Analyzing these can identify recurring high demand charges or other patterns of usage.

Good record keeping is absolutely essential in a successful program. Not only do records provide insight into energy use, but unless changes are accurately tracked the success of each strategy cannot be determined. This may result in duplication of a marginal strategy instead of a more cost effective one.

Initial Conservation Measures

Manual conservation measures are typically common sense things like night set-back thermostats, tightening belts, cleaning filters, etc. HVAC is usually 10% to 20% of the total energy used at a POTW, but does not get the same attention as process equipment. Because the investment is very low, payback for this type of maintenance is very good.

If power factor charges are high you can install power factor correction capacitors. The utility engineer can provide assistance in determining if this is worthwhile. Only higher horsepower loads are usually considered, particularly if they are lightly loaded or low speed (1200 or 900 rpm). Capacitors can be installed at individual motors, but it is often more efficient to install them at incoming transformers or in distribution equipment. Power factor penalties are usually eliminated above a target value (85% for many utilities), so avoid installing more correction than is necessary.

By scheduling grit pumping, digester supernating, or similar discretionary loads on off-peak times, both demand and consumption charges can be reduced. In some cases simple timer controls can be used to automate these processes.

New technology and process modifications are constantly becoming available. Keep energy requirements in mind when evaluating equipment replacement or plant upgrades. Energy savings alone may not be enough to justify new equipment, but should certainly be a factor in selecting and specifying systems for upgrade.

Automatic Controls

Few facilities have the staff to monitor and regulate process equipment as often as desired. The process efficiency, energy efficiency, and operator convenience available with state of the art automatic systems cannot be obtained with manual controls. Technological advances are making automatic control systems cost effective for smaller plants. This is partially a result of reduced hardware cost. In addition, simpler operation has made it unnecessary to have computer or instrumentation specialists available to use the systems.

Process Efficiency

- Stable Biology
- Improved Sludge Settling
- Uniform Performance
- Resistance to Upsets & Slug Loads

Energy Efficiency

- 15% to 20% Typical Savings
- 1 to 5 year payback
- Energy Use Proportional to Loading

Operator Convenience

- Reduced Equipment Failures
- Automatic Recovery from Failures
- Simple Tuning and Adjustments

Advantages of Automatic Controls Over Manual Process Control

The savings from improved convenience and data logging with automatic controls are difficult to quantify but very real. In a large facility the ability to log data and print reports automatically can be a significant time savings. Graphs of real time performance parameters are extremely useful in optimization. By monitoring equipment performance and operating trends equipment wear can be detected before catastrophic failure occurs. When problems result in shut downs during un-staffed periods, a control system can provide recovery without special staff call-outs.

A basic knowledge of control system terms is essential to evaluating the benefits of automatic controls. The control logic is handled by the central processing unit (CPU) or central control unit (CCU). Input signals from field devices and the control commands output to them are referred to as I/O. Discrete (or digital) I/O are on/off signals like switches or pilot lights. Analog I/O signals, such as a 4-20 mA pressure transmitter signal, are proportional to the measured variable.

Programmable logic controllers (PLCs) were originally developed as relay replacements, but have evolved to include analog I/O, PID control algorithms, math functions, and high level language blocks. PLCs are generally programmed in a relay ladder logic (RLL) language proprietary to each PLC manufacturer. They are the best choice when the control requires high speed, timing and logic functions, and predominantly discrete I/O.

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Sample of PLC Ladder Logic Programming

Process control computers developed from the digital computers used for management information systems. Industrial single board computers are now available to emulate a personal computer. They often include MS-DOS® operating systems, printer port, and communication ports on one device. Solid state data storage is frequently used instead of disk drives. Programming is usually in higher level languages such as C, Pascal, or BASIC. Many types are available with built-in monitors and keyboards hardened for industrial environments. Compatible I/O systems are available from many sources and are not usually proprietary.

Specialized controls for energy management have become commonplace in commercial and industrial environments. These are typically geared towards HVAC loads. They will be beneficial in controlling energy costs, but cannot affect a significant portion of a WWTP's total energy bills.

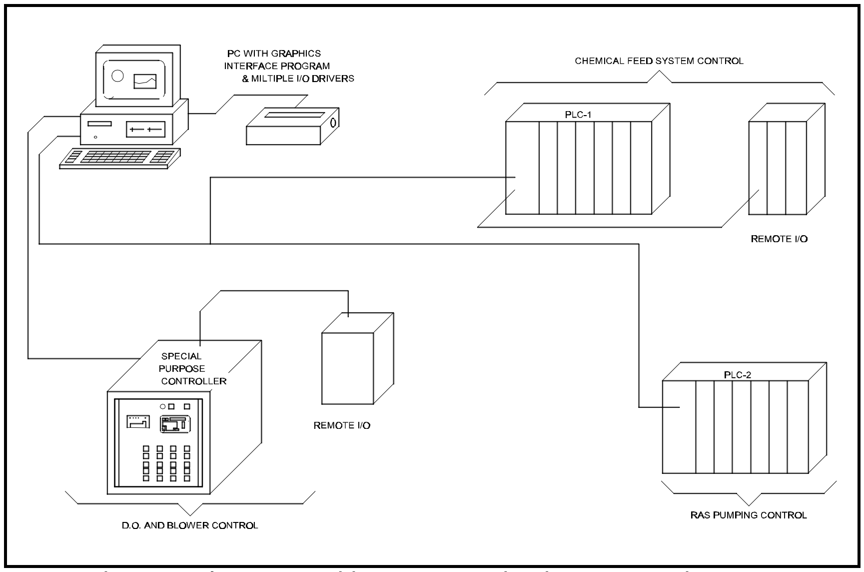
Process controllers originally developed from pneumatic and electronic proportional-integral-derivative (PID) controllers. They were originally single loop dedicated devices with one analog input and one analog output per unit. Many now have multiple loop capability, discrete alarm outputs, programming capability, and data communications.

Communications networks for PLCs, I/O, computers, and process controllers vary widely. Many systems employ proprietary hardware and software protocols, but the trend is towards more "open" systems and networks. Some open data and I/O communications are based on formal industry standards (for example the IEEE-488 GPIB standard), others are based on "de facto standards" (such as Optomux® serial communications).

Operator interface - access to the system for status and process information and for tuning - varies from simple switches and pilot lights to sophisticated computer software. New systems generally utilize some type of personal computer (PC) software that displays trends, annunciates alarms, and transfers setpoints and tuning parameters to the control hardware. Several I/O "drivers" should be available simultaneously to allow mixing hardware from different vendors on one PC screen.

Graphics software uses a schematic or physical representation of the process to display status and performance, making most of the pertinent information available at a glance. Most graphics interface programs can duplicate PID controller face plates and digital displays as well as annunciators and pilot lights. Trend displays show "real time" and historical data from disk files in a bar chart or an X-Y plot format. This facilitates process monitoring and optimization. Logged data can be printed in a variety of formats.

A distinction should be made between control systems which modify process operations automatically and monitoring systems which input data and present it to the operator. Monitoring systems only change operations based on specific actions by plant staff. Supervisory control and data acquisition (SCADA) systems generally fall into the monitoring category, but software vendors are adding control features.



Automatic Control System with a Communications Network

Process control for WWTPs requires special expertise. Systems should be designed, programmed, and installed by firms familiar with wastewater treatment, not generalized systems houses. Control systems and their related sensors should, whenever possible, be installed by instrumentation sub-contractors. Electrical or mechanical contractors are usually unable to perform the specialized testing and calibration required.

Control equipment and software trends are leading to both distributed control and increased consolidation. Although this may seem contradictory, it is a result of low cost electronics and data communications systems being applied to both the field devices (pumps, valves, sensors, etc.) and to the operator interfaces.

Related control logic for separate pieces of equipment can be programmed into one unit instead of having separate controllers for each device or unit process. For example, a single PLC or process controller may be tied to several chemical feed pumps, a pH sensor, influent flow sensors, and mechanical mixers in order to control nutrients. This PLC may be connected to a PC with a graphics interface program. This represents consolidation.

The I/O may be separated into several remote I/O units mounted close to the mechanical equipment and connected to the controller CPU by a communications network. This reduces wiring and maintenance problems. The PC's graphic interface program may be connected to several independent controllers or PLCs, each responsible for a separate process. This distributed control reduces the impact of the failure of one controller on an entire facility.

All automatically controlled equipment should be provided with manual over-rides. They are not only required in case of controller failure or system servicing, but are also useful for testing and troubleshooting. Note that the "Manual" setting on some controllers may not bypass the processor. It may be necessary to supply additional devices to permit operation in cases of severe controller problems.

Motor Replacement

In older facilities it may be cost effective to replace standard efficiency motors with new "high efficiency" types, particularly if utility rebates are available. Replacing motors which are running only partially loaded is particularly beneficial, because older motors generally had bad efficiency and power factor at less than 3/4 load.

Be sure that the new efficiency is actually high enough to justify the change. Definitions of high efficiency vary from manufacturer to manufacturer. Old U-frame motors may be actually higher in efficiency than new motors. Calculate the energy savings on actual loads, not name plate horsepower.

Replacing a motor with a new one of the same horsepower may not be the best choice. Most process equipment is designed for 20 year projected loads, and the loads may not reach design level for years. By testing for actual motor power input both reduced initial cost and improved efficiency can be achieved by using smaller replacement motors. (Note: amperage readings alone are not an accurate indication of power consumption for lightly loaded motors.)

Motor hp	Standard Efficiency	High Efficiency
5	84%	88%
25	90%	93%
50	91%	94%
75	92%	94%
100	93%	95%

kw = hp x 0.746

Typical Full Load Motor Efficiency, 1800 rpm

Sometimes reduced energy consumption can be achieved by replacing an existing motor with a larger one. Pumps and blowers often have capacity to generate flow and pressure beyond the nameplate rating of the motor. By installing a larger motor it may be possible to operate with one unit close to maximum capacity instead of two units at partial output. Be sure to coordinate changes in motor size with equipment manufacturers to make sure that drive and coupling ratings, shaft capacity, etc. are not exceeded. Also make sure that overload protection at starters and drives, shear pins, etc. are properly sized to match the new motors.

Try to make sure that the loadings will not increase before the new motors pay for themselves, and that adequate capacity is available for short term peaks. Sometimes modifying only one or two units can insure capacity for peak loads.

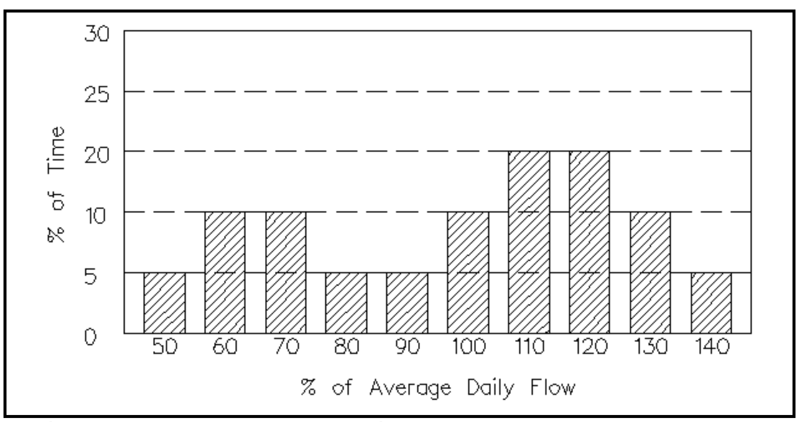
Pumping

In most facilities pumping is a major electrical load, and in some processes it may even be the largest. Careful monitoring of pump performance is essential to achieving significant reductions in energy cost.

Compare actual pump loadings and performance with specified and nameplate values. Impeller wear, clogged piping, or poorly sized valves can decrease efficiency. Periodic checking of flow, pressure, and power draw should be part of your energy conservation and preventive maintenance programs.

For some wet well pumping applications where short term surges are experienced, it may be possible to reduce the number of pumps running by changing float switch levels. This would allow one pump to operate longer and reduce cycling.

If pumps are running on short cycles or lightly loaded it may be cost effective to modify them for reduced capacity and power requirement (or increased capacity if multiple units run lightly loaded). The two principal techniques for accomplishing this are impeller trimming and changing speed.



Typical WWTP Pump Rate Profile

Impeller trimming involves the expense and labor of rebuilding the pump. If the original impellers are not at the maximum diameter for the pump case, increased capacity can be obtained by installing a larger diameter impeller. For belt driven pumps a simple sheave change may be all that is required. These techniques are most practical in applications where the design capacity of the pumps exceed the maximum requirement of the process and operation is fairly uniform.

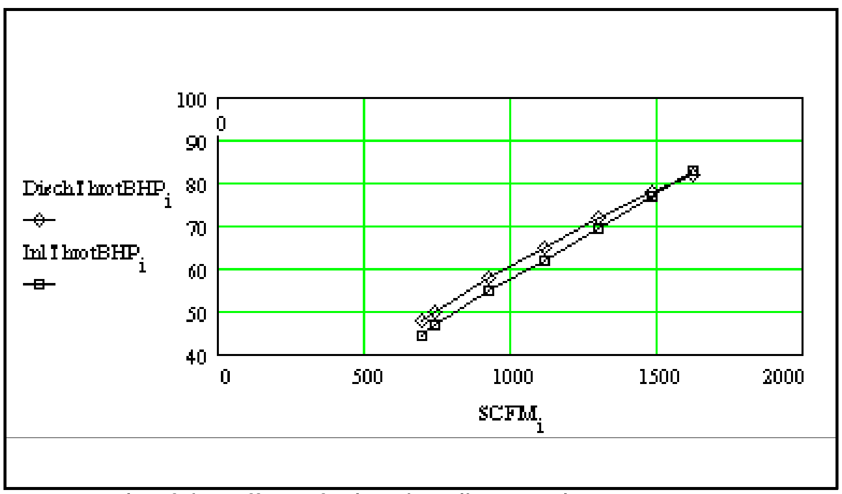
In applications where flow is constantly varying, such as return activated sludge (RAS) or raw wastewater pumping, variable frequency drives (VFDs) are very cost effective. This is especially true where the head is predominantly due to friction losses in piping. In general, the higher the percentage of static head, the lower the achievable savings.

If speed is reduced too much the pump may not produce enough pressure to create flow, particularly in high static lift applications. In some cases a minimum flow is needed to prevent overheating. Consult with the pump supplier before making changes, and make sure the minimum speed is limited to a safe level.

Aeration

In activated sludge, activated biofilter (ABF), or sequencing batch reactor (SBR) processes the biggest use of energy in a facility - 50% to 90% of total energy - is in providing oxygen to the aeration basins. This is clearly an area that justifies investigation in any energy conservation program.

In diffused aeration systems the replacement of coarse bubble diffusers with higher efficiency fine bubble types is usually a cost effective measure. Efficiency improvement varies with the type of diffusers being replaced, tank geometry, piping constraints, etc. Reductions of 50% in energy cost are possible. Some increased maintenance may offset the energy savings and should be considered in selection of diffuser type and in cost effectiveness evaluations.



An Example of the Effect of Inlet Throttling on Blower Power

Pressure requirements are often higher for fine bubble diffusers, and blower performance should be checked as part of the evaluation. However, static head resulting from diffuser submergence is usually more significant than diffuser or piping losses, and most blower systems have enough reserve pressure capacity to handle the modifications.

For mechanical aerators the energy reduction options are usually limited without major system modifications. However, varying the speed of aerators, changes in submergence, and controlling the number of operating units are all feasible.

With any suspended growth system proper mixing to prevent solids deposition is an important concern. Careful consideration of mixing requirements is necessary in any control scheme. In many systems, particularly in new facilities, aeration energy is limited by mixing constraints and not by oxygen transfer. Both energy and process evaluations should carefully review this factor. In some applications installing supplemental mixers may be cost effective.

Blowers

The blowers used in most municipal treatment facilities are usually either multi-stage centrifugal or positive displacement (PD) lobe type units. It is usually easier to vary the flow in centrifugal blowers, but both types can be controlled to optimize performance. In both cases it should be remembered that discharge pressure is a result of combined static head and friction losses. Pressure is the end result of flow and if enough pressure capacity is available to overcome submergence, the header pressure will automatically rise to match system requirements at a given flow rate. Power reduction is usually directly proportional to decreases in flow rate.

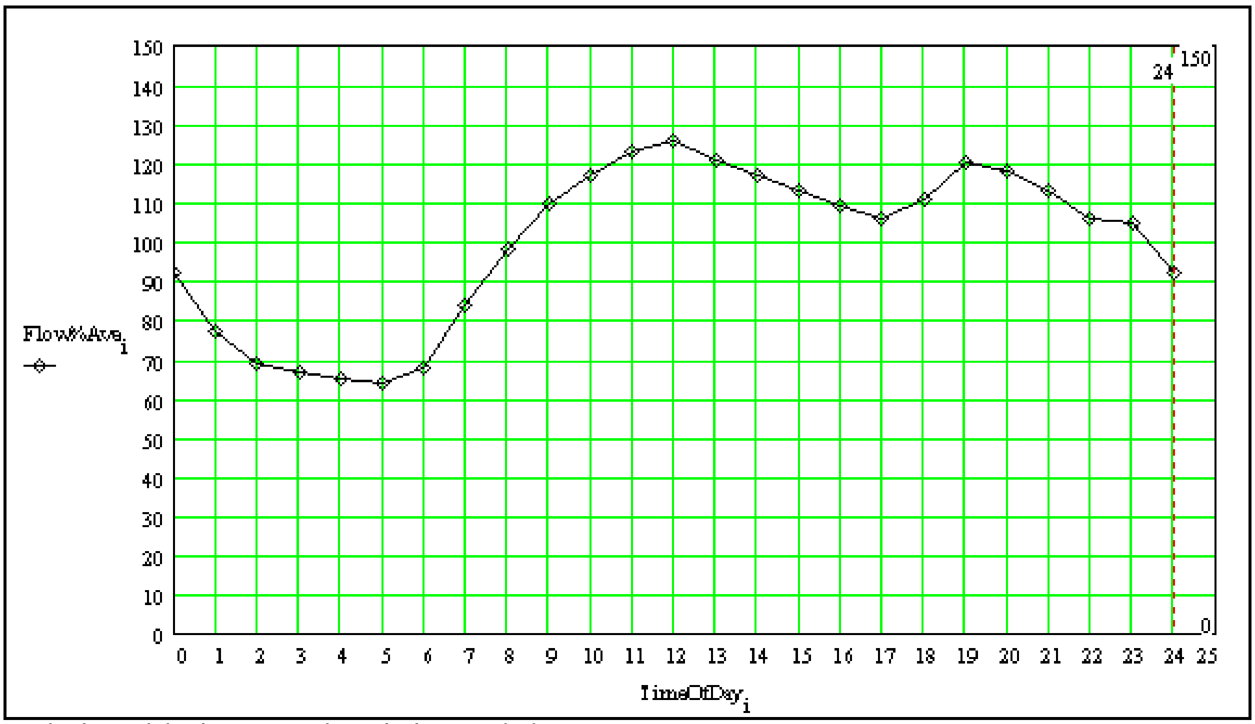
Centrifugal blowers can be throttled by a simple butterfly valve to modulate the discharge flow rate. As much throttling as possible should be performed at the blower inlet, since this reduces air density as well as producing pressure drop. Consequently flow control by inlet throttling is more efficient than by discharge throttling.

When throttling centrifugal blowers to low flows a pulsating pressure phenomenon known as "surge" can result. If this condition persists for more than a few seconds it will cause damage to the blowers. The blower manufacturer's recommendations should be strictly adhered to for minimum flow, and precautions taken to prevent any operation in a surge condition.

Positive displacement blowers require a variation in speed to change flow rate. PD blowers must never be throttled. Smaller blowers often employ sheave changes to modify blower speed and change air flow. In multiple blower systems it may be effective to have different speeds for each blower and select the operating unit based on oxygen demand. However, the most flexible operation is achieved by using variable speed drives, usually VFDs.

Two cautions should be observed in applying variable speed drives to PD blowers. One is that constant motor torque is required regardless of blower flow rate. This usually means a higher capacity VFD is required than for the same horsepower pump or centrifugal blower. The VFD supplier should be made aware of the load type during equipment selection.

The second factor is heating problems in both the blower and the motor that can result from low speed. Blower heating is a result of "friction power" or slip, which remains nearly constant at any speed. The motor heating is caused by reduced cooling at the lower rpm. Both types of heating can be limited by restricting the minimum speed to a safe level. Motor heating problems can also be minimized by using a totally enclosed non-ventilated (TENV) motor or an oversized frame.



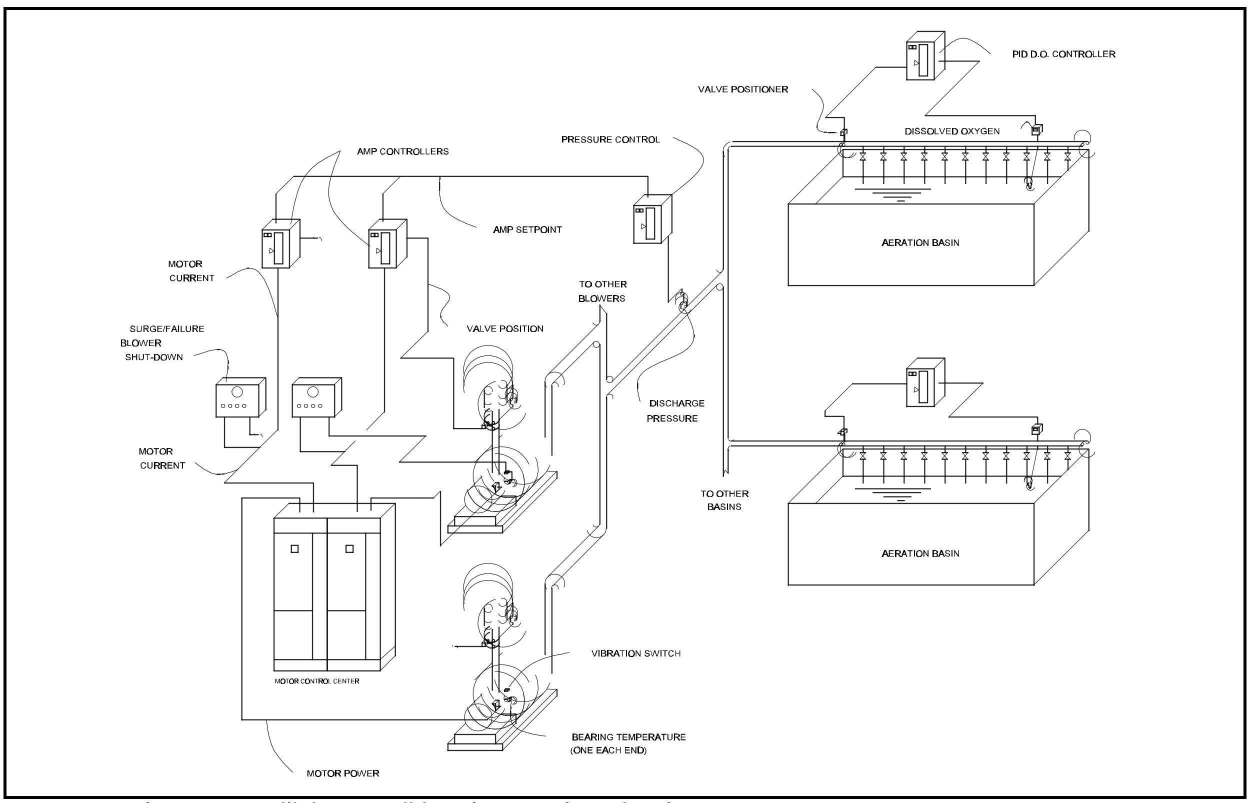
Typical Municipal WWTP Diurnal Flow Variation

D.O. Control

Because of the fluctuations in diurnal loading, the oxygen demand in most aeration systems is constantly changing. In order to meet process requirements aeration systems are usually set to meet the maximum demand for any given period. In most plants with manual controls the equipment can only be adjusted on an occasional basis - daily at best, but more commonly once a week.

The resulting over-aeration is not only wasteful from an energy standpoint, but may also impede process performance. This is particularly true where precise control is required for nutrient removal, but even in conventional treatment excess aeration can result in poor floc formation, undesirable micro organisms, and foaming. Without D.O. control slug loads can result in upsets, and the biology may take days to re-stabilize.

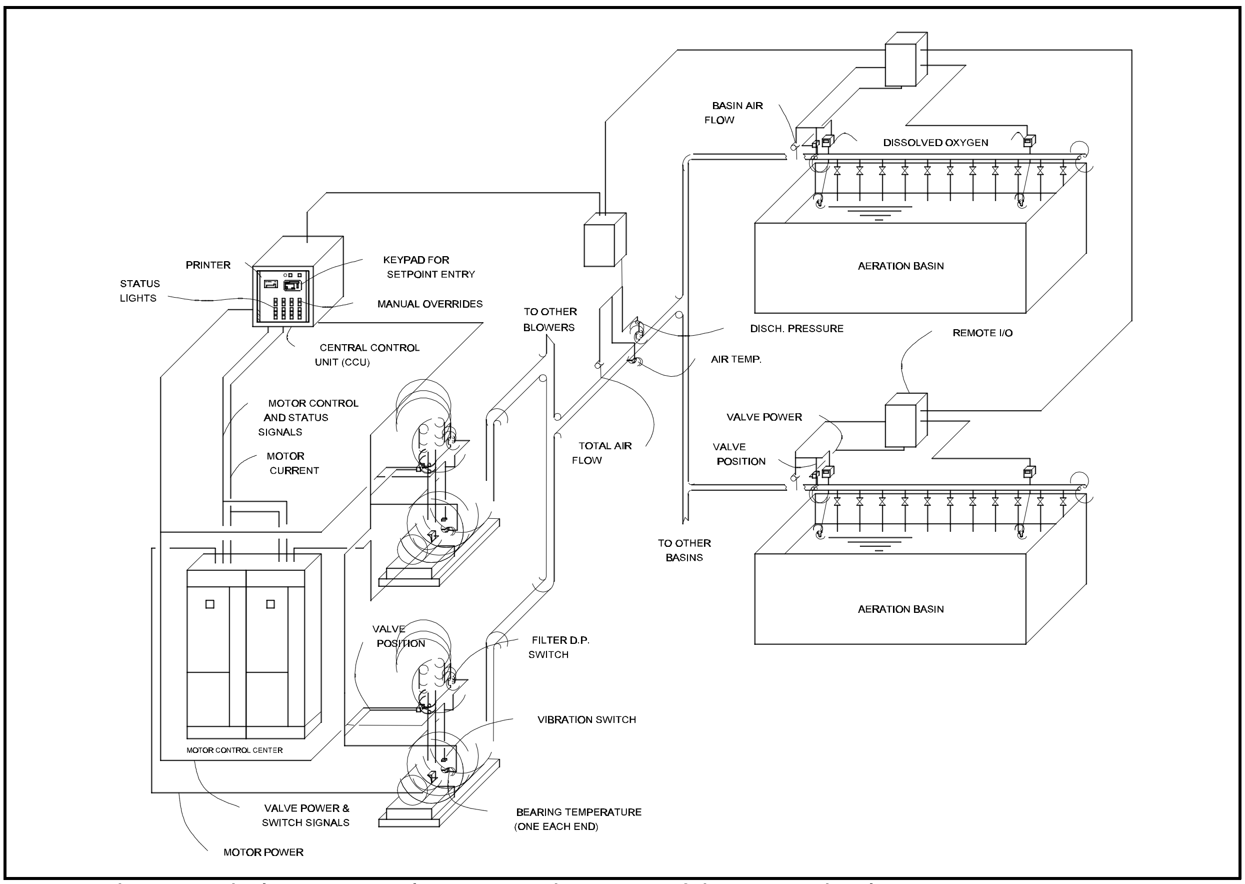
In cases where D.O. levels are too low the resulting problems far outweigh the energy savings. Insufficient BOD removal, development of filamentous growths, and poor sludge settling are common effects.



D.O. Control System Utilizing Traditional Control Technology

Automatic control of D.O. can reduce energy consumption by 20% in most municipal applications, and in cases with extreme flow variations or slug loadings greater savings are achievable. When combined with the process benefits, automatic D.O. controls are usually very cost effective, and typically have two or three year payback periods. Smaller facilities (less than 100 hp blowers) will have longer payback, and process improvements may be needed to justify the capital expenditure.

In the past, D.O. controls have not been utilized in most suspended growth systems because of a variety of factors. Older designs of D.O. probes required frequent maintenance. Traditional PID controls were very difficult to tune, and were often unable to achieve both stability and effective control of demand variations. Because of the interrelationships of process and equipment, and the operating constraints of the equipment, controls based on



Integrated D.O. and Blower Control System Using State of the Art Technology conventional technology were either inadequate for fully automatic operation or else very complex and difficult to tune and maintain.

New technology has overcome these restrictions. New D.O. probe designs are very robust, and can withstand all but the most severe wastewater applications. Calibration and maintenance, when required, are fast and easy. More sophisticated control strategies have been developed. The advent of low cost and reliable microprocessor based controls has made it possible to accommodate the complex relationships between process equipment. Simplified operator adjustment is now available, and fine tuning performance is practical.

In older types of D.O. controls it is common to maintain a constant discharge pressure in the air header and vary flow to individual basins based on D.O. This is done to prevent changes in one basin valve from affecting flow to the other basins. In systems of this type blower control is principally less efficient discharge throttling. Care should be taken to set the discharge pressure as low as practical in order to minimize this effect.

In selecting D.O. controls a number of factors should be considered. The equipment should be microprocessor based, since conventional controls are not as reliable. Process and equipment constraints should be fully addressed. Simplicity of tuning and operator adjustment are important factors. Finally, as with any automatic control system, manual operation should be available for emergency and maintenance situations.

Variable Frequency Drives

Variable frequency drives are a very cost effective approach to both energy and process optimization for many kinds of equipment. They should always be considered for new pumping applications, and may be very cost effective in retrofit situations for pumps and blowers as well. Many utilities offer rebates for installing VFDs.

Older wound rotor motors or eddy current drive systems are not very efficient. At reduced speeds efficiency is often as low as 50%. Power factor is also poor for many of these older drives. There are many types of VFDs available, but most new designs are of the pulse width modulated (PWM) type. They usually have a high (>90%) efficiency and power factor throughout their operating range. Current source or variable voltage designs are more efficient than eddy current or wound rotor motor controls, but are not generally as cost effective as PWM drives.

When evaluating replacement drives, the weighted average of daily power consumption should be included. In other words, if the pump operates at 50% capacity for 6 hours each day, at 75% capacity for 12 hours, and at 100% capacity for 6 hours, the energy usage and efficiency should be prorated accordingly. The diurnal variations in flow and the pump curves can be used to evaluate the loading.

Be careful to include demand, on-peak, and off-peak charges in the evaluation. In lift stations with separate power metering, for example, charges are often based on straight consumption. In these cases it may not be cost effective to install VFDs, since total daily energy consumption is not changed. Simple float controls and full capacity pumping is most cost effective. On the other hand, if demand charges are a factor, VFDs and level control can be cost effective by providing continuous operation at a lower flow rate and reduced peak power.

Payback Calculations

Simple payback is usually adequate for evaluating the cost effectiveness of various energy cost

old power - new power = power savings

power savings x 60 hours per week x on-peak billing rate x 52 = annual on-peak savings

power savings x 108 hours per week x off-peak billing rate x 52 = annual off-peak savings

power savings x demand charge x 12 = annual demand savings

(old power factor - new power factor) x power savings = power factor savings

power factor savings x power factor penalty x 12 = annual power factor savings

on-peak + off-peak + demand + power factor savings = total annual savings

equipment cost + installation cost = total cost

total cost ÷ total annual saving = payback period, years

Calculations for Determining Simple Payback Period for Energy Conservation Projects

reduction measures. The procedure consists of calculating the annual energy savings, determining the capital costs of equipment and installation, and dividing the savings by the cost. The result is how long it will take for the equipment to pay for itself. For electrical power on-peak, off-peak, power factor, and demand billing should all be considered.

Many municipalities have guidelines for the maximum payback period for capital expenditures. Projects with longer payback are not considered good investments, even if they will ultimately pay for themselves. Payback limits are based on the amount of cash or borrowing capacity available, interest rates, etc. Many municipalities look for investment returns of three years or less, but limits vary from two to five years or more.

Conclusion

Evaluating and reducing energy costs may at first seem intimidating. By taking a logical approach and breaking down the techniques into individual steps a manageable and effective program may be developed. The guidelines and suggestions presented here will provide a good basis for determining the most cost effective approach and avoiding common problems.

In any treatment plant energy costs are a significant factor in operating budgets. Conscientious efforts to reduce these charges can result in both reduced costs and improved process performance.