White Paper

Cost Savings with Variable Frequency Drives

Think smart. Save with variable frequency drives.

Facilities with one or more of the following criteria are prime targets for energy-efficient VFD installations:

- **Run machinery on moderate to high horsepower**
- **Rely on load adjustment via throttling**
- **Long operating hours**
- **Any friction systems (no static head)**
- **Control valve that is constantly modulated**
- **Pumps in parallel or series operation**
- **Pumping system with multiple design points**
- **Modulating bypass valve**
- **Cooling towers that start and stop frequently**

"If it isn't broke, don't fix it." Organizations sticking by this old idiom will be left behind in an increasingly more competitive marketplace. Meanwhile, the new model, "Update to take advantage of practical cost savings," is taken seriously by successful, progressive companies, especially those in U.S. regions with high utility rates.

Over half of all electricity consumed in the U.S. is used to power electric motors. Variable frequency drives (VFDs) is one proven method to better control the amount of energy electric motors use. More and more facilities are paying for the minimum power needed and no more. When management applies this *minimum requirements* principle to flow control, energy consumption is drastically reduced. Decreased power use, reduced stress on machinery, and better flow control for liquids and gases, such as water and air, are just a few reasons VFDs are growing in popularity.

This white paper covers the disadvantages of typical flow control methods and what characteristics qualify a company to switch over to VFDs. It shows how VFDs work and cut energy costs in centrifugal systems, as well as provides financial analysis for energy reduction, cost savings, and payback.

Common flow control methods and why they don't work

Pump and fan motors without VFDs employ throttling control to adjust flow with mechanical dampers and valves. These solutions restrict output to reduce flow volume. This approach comes with its share of problems. Closing a valve to decrease flow to 60% still requires the motor to run at 100%, with no energy reduction. Controlling the flow in this way compares to reducing the speed of a car by pressing the break pedal while still pushing on the gas pedal. Using inlet vanes to restrict airflow into a fan poses this same inefficiency.

Facilities often use eddy current couplings to control the torque between fans and motors. However, they are less efficient than other drives and can cause system components to overheat, resulting in premature system failure. Pitch adjustment with axial fans can also cause high temperatures. Finally, on/off control is often used in lieu of VFDs and unfortunately causes mechanical stress and pressure peaks.

Replacing these outdated solutions with VFDs and EE motors is quickly gaining popularity among industrial-scale facilities. A stainless steel tubing supplier that services the automotive, food, pharmaceutical, and petrochemical industries replaced its magnetic starter and eddy current clutch with a VFD vector drive and line reactor.[1] The company also substituted its standard-efficiency 150 HP, 1800-rpm motor with a high-efficiency 200 HP, 1200-rpm motor.

As a result, the facility benefits from greater horsepower and more torque output, which cuts the number of draws required for its tubing. Analysts calculate the company reduced its operating time by 623 hours and decreased its energy consumption by 34%. These reductions translate into annual savings of $20,812 in energy, $23,473 in labor, and $41,322 in stainless steel.

Who benefits from variable frequency drives

Approximately 40% of all electricity used in industry is consumed by pump and fan systems.[2] Therefore, commercial and municipal facilities running pumps, fans, and blowers can gain 30% to 35% cost reductions with VFDs. Prime targets for energy-efficient VFD installations are facilities that run machinery on moderate to high horsepower or rely on load adjustment via throttling. Also, long operating hours is one more measure that qualifies an organization for VFDs.

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In addition to the previous criteria, if your operation employs any of the following, it will benefit from incorporating VFDs into the system:

- Any friction systems (no static head)
- Control valve that is constantly modulated
- Pumps in parallel or series operation
- Pumping system with multiple design points
- Modulating bypass valve
- Cooling towers that start and stop frequently

TXI Operations LP, a leading supplier of cement and aggregate, realized quickly that its operation would save significant costs with VFDs. TXI experienced significant energy cost savings after installing five VFDs drives to control flow of fresh water of up to 15,000 gallons per minute. Four more VFDs were deployed to leverage flow back to the water supply.[3]

Board chair of the Professional Pool Operators of America estimates that slowing down a 25 HP pump by 150 gallons per minute can save facilities $2.50 an hour.

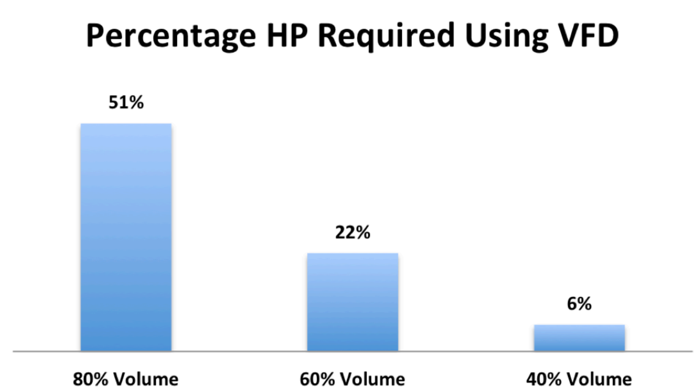
Why variable frequency drives lower energy costs

Manufacturers design pumps and fans to handle peak demand. Although these *oversized* systems are efficient when running at 100%, they are too large for their primary operating function, which is to run at 60% for 80% of the time. As pointed out previously, these systems run at 100% power despite the decreased flow.

VFDs eliminate energy waste created by oversized systems. A VFD decreases flow in conjunction with decreasing energy consumption. Any process that runs variable loads should be examined as a candidate for a VFD, since this small robust device optimizes a motor's speed to correspond with load requirements.

Affinity laws help analysts calculate the scale of savings VFDs provide. Affinity laws show mathematical relationships between pressure, volume, speed, and pump/fan power. As defined by these laws, power is proportional to the cube of shaft speed. To better understand this proportion, consider walking slowly through water versus running through water. In the end, both the walker and the runner get through the water; however, the runner is exhausted. With the affinity laws being true, minimal speed reductions yield a considerable decrease in power consumption.

Robert Kappel, executive board chair of the Professional Pool Operators of America, recently began applying affinity laws to aquatics facility management. He estimates that slowing down a 25 HP pump by 150 gallons per minute can save facilities $2.50 an hour.[4] He recommends installing VFDs to control pump speed. Kappel gauges that many pools can run their pumps on 75% less electricity and still meet high pool standards.



60% of electrical energy consumed in the U.S. runs motors. 75% of these motors are variable torque fan, pump, and compressor loads.[5] This is significant because minimal speed corrections made on centrifugal pumps and fans have a substantial impact on loads. For example, differences as slight as 5 rpm greatly affect loads. Therefore, with the help of affinity laws, centrifugal systems with variable torque offer

the greatest energy savings with VFDs, as compared to most other systems (unless 100% flow or pressure is required consistently).

Running a pump at 60% of its operating volume with a VFD requires only 22% input HP, as opposed to 100% HP input without a VFD.

How variable frequency drives work

The terms VFDs, inverters, variable-speed drives (VSDs), frequency converters, and AC drives can be used interchangeably in most cases. These electronic devices provide gradual speed control to electric AC motors. A VFD functions by converting the fixed supply frequency (60 Hz) to a variable-frequency and variable-voltage output.

A VFD has an embedded microprocessor and operator interface, with which users start, stop, and adjust motor speed. Depending on requirements, users can also reverse rotation and switch between manual and automatic speed control. Many VFDs allow users to configure, adjust, monitor, and control operations from a computer.

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What's more, some VFDs manage the return of energy to the power grid through regenerative capability. In *cyclical* applications, mechanisms coast to a certain speed or return to a set state. During this process, much inertial energy generated by the machine is wasted. However, regenerative VFDs recover this energy and return it to the facility's power grid.

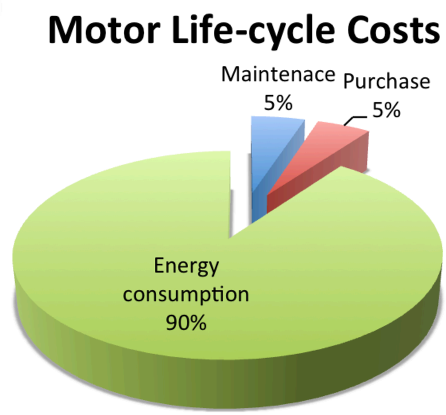
In *breaking* applications, the load is either slowed or stopped entirely. During this process, energy dissipates as it converts to heat inside the electric motor or within the bank of resistors on the drive. However, regenerative VFDs pass this energy into a resistor, convert it into electricity, and then return the energy to the facility's grid.

Economics that work

Experts agree that 90% of motor life-cycle costs for fans and pumps are spent on energy. With this high percentage, companies miss bottom line opportunities if they do not periodically analyze energy consumption and generate forecasting based on VFDs and EE motors.

Although initial purchase price is one of the first bills to hit the books, this expenditure is minute compared to the complete life-cycle cost of the unit. Maintenance is another cost; however, it is much less than energy costs and often lower for motors with VFDs than for motors without VFDs.

Central Metal Finishing, a precision finisher providing electroplating, anodizing, and coating services for aircraft, automotive, and defense manufacturers, did the math. Afterward, the company applied VFDs to seven motors powering its ventilation



system. With these drives in place, the company saves $27,830 in annual electricity costs and benefits from a $14,800 utility incentive. In the end, Central Metal Finishing is recouping $226,520 in lifetime energy costs and enjoying an ROI of 72%.

Moreover, upgrading existing VFDs makes economic sense. A U.K. water pumping station, owned by United Utilities, distributes water between its Prescot and Aspel reservoirs. The utility company replaced three older VFDs with new 400 kW industrial drives, saving the organization USD$30,000 per year in energy costs.[6]

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Calculating your potential

To calculate the total cost savings recovered with VFDs, gather the following information:

- Number of hours the motor runs per year
- Percentage of time the motor runs at 10%, 20%, 30%, and so on, up to 100%
- Motor horsepower (HP x .746 = kilowatts)
- Utility rate
- Other information that applies, such as degree of efficiency (high or standard) or type of fan control
- VFD price
- Costs of installation and downtime
- Availability of utility rebates

Many VFD manufactures have cost savings calculators available online. The next section shows an example of calculating cost savings and payback rates.

Typical payback rates

Energy efficiency investment yields more dividends in a shorter amount of time than many other investment opportunities. Typical VFD applications pay for themselves in less than two years. And in regions with higher energy rates, such as Massachusetts and Rhode Island, drives and their installations often pay for themselves in less than six months.

Consider this typical example of a 100 HP motor with a VFD operating a pump at 60% speed. This is how cost savings are calculated:

Fixed-Speed Motor running at 100% flow volume manipulated with a valve

100 HP **X** 100/95 efficiency **X** .746 (HP conversion to kW) **X** .16 $/kWh **X** 12 hours/day **X** 360 days/year = **$54,280** per year in energy costs.

VFD-Controlled Motor

100 HP **X** $.6^3$ (break HP) **X** 100/95 efficiency **X** .746 (HP conversion to kW) **X** .16 $/kWh **X** 12 hours/day **X** 360 days/year = **$11,720** in energy costs.

This typical 100 HP VFD installation example yields $42,560 a year in energy savings. The cost of both the drive and the installation ($19,000 total) is absorbed in less than six months, due to an average of $3,540 in cost savings per month.

Additionally, the stainless steel tubing supplier, mentioned earlier, calculated a $77,266 annual cost savings. Since the project totaled $34,000, their VFD and EE motor paid for themselves in only six months.

Lower energy consumption often qualifies organizations for tax incentives, utility rebates, and select finance programs.

Additional advantages of variable frequency drives

VFDs offer advantages stretching beyond economic gain. These include decreased mechanical stress, more accurate products, rebate qualifications, and lower carbon emissions. Due to speed and torque control, motors endure less wear and tear, which leads to lower maintenance costs and downtime. For instance, VFDs provide soft-start capabilities, which decrease electrical stresses and line voltage sags associated with full voltage motor startups, especially when driving high-inertia loads.

Tax deductions, rebates, and other incentives for reducing energy exist because energy conservation measures provide mutual benefits. Swansea Water District in southern Massachusetts is enjoying over $14,000 in cost savings per year with the help of a motor replacement and updated motor controls. Additionally, the district qualified for $21,000 in utility rebates. This was a combined rebate for retrofit of an existing motor with an EE motor and VFD.

Moreover, lower energy consumption often qualifies organizations for tax incentives, utility rebates, and select finance programs, which quicken return on investment. Also, with a marketplace falling more into the hands of environmentally conscious consumers, your company can boast its energy reduction and market itself as an organization with environmental stewardship. For example, Central Metal Finishing,

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as discussed earlier, reduced over 187,000 kWh annually from its electricity consumption, reducing its greenhouse gas emissions by 183,000 pounds of carbon per year by installing seven VFDs.

Substantiated savings with variable frequency drives

Facilities can uncover much energy and cost savings with VFDs. Experts predict that VFD technology will play a major role in facilities meeting growing energy reduction demands. Using VFDs to control flow speed in pumps and fans is not a new innovation; however, new technology has made VFDs more effective and more affordable. With these changes, VFDs are even more of a sound economic investment than before.

Success stories substantiating VFDs are well documented. In addition, government incentives, utility rebates, and savings-based financing provide low upfront investment and ROI in as few as three to six months. Please consult a Munro Distributing Mechanical Energy Department Sales Executive for proper feasibility, analysis, and product requirements before purchasing and installing a variable frequency drive.

End Notes

[1] "A Case Study: Replacement of Eddy-Current Drive with a VFD," *Natural Resources Canada*, oee.nrcan.gc.ca, retrieved 8/7/12

[2] Kerns, Ken. "VFDs Drive Energy Efficiency in Motors: How to Save Energy, Cut Costs Using Variable-Frequency Drives," *Green Manufacturer*, 1/1/11, retrieved 8/7/12

[3] Hart, Tom. "Case Study: Variable Frequency Drives Cut Energy Costs," Design News, 4/3/12, retrieved 8/7/12

[4] Attwood, Emily. "Variable Frequency Drives Help Pools Maximize Energy Efficiency," *Athletic Business*, 5/2/12, retrieved 8/7/12

[5] Bose, Bimal K. "The Past, Present, and Future of Power Electronics," *Industrial Electronics Magazine, IEEE*, 6/09

[6] "ABB Drives Save £19,000 on Pumping Energy Costs for United Utilities," abb.com, 7/16/12, retrieved 8/7/12

About Munro Distributing

Munro Distributing Company is a forward-thinking purveyor of electrical, conservation, and renewable energy solutions. Its Mechanical Energy Division personnel are experts in needs analysis and implementation of motors, motor starters and controls, variable frequency drives, power factor correction equipment, energy-efficient transformers, backup generators, and energy-efficient refrigeration products.