

Variable Frequency Drives

Introduction

A Variable Frequency Drive (VFD) is a device that strategically reduces the power supplied to mechanical equipment when the demand for power is reduced. Some examples of mechanical equipment that incorporate VFD technology are pumps, fans, compressors, and conveyors. The European Commission attributes 22% of the world's energy demand to pumping systems^[1]. Pump manufactures are integrating VFD technology into new pump designs. However, there are many pumps currently in service that need to be retrofitted. For instance, irrigation, vacuum extraction, waste water treatment, and heating ventilating and air conditioning (HVAC) have the potential to benefit from VFDs. To illustrate this point, a case study of pumps designed for vacuum extraction is presented. The case study is based on farm audits performed in New York^[2]. This document includes the maximum and minimum savings obtained from the audits. The results are concluded in the economic summary.

Background

There have been substantial technological advancements in the field of variable frequency drives within the past decade. During this time frame, the market was constantly driven by the desire to reduce the amount of power squandered by centrifugal pumps and fans. In 1995, there was approximately \$600 million invested in AC drives in North America, 36% of which were pump and fan applications^[3]. None of these AC drives were equipped with variable frequency capabilities, since VFDs were large, loud, expensive, and unreliable in 1995.

VFDs were transformed into an affordable and dependable technology after the integration of micro-processing and Insulated Gate Bi Polar Transistors (IGBTs)^[4]. IGBTs are invertors that oscillate the frequency of a waveform between on and off so quickly that a change is hardly noticed. Pre-existing silicon controlled rectifiers had previously performed this function, but at a much slower rate. IGBTs also have the ability to manipulate the output voltage by configuring on and off intervals, unlike its predecessor. The inverted waveform has a better resolution as engineers refine and increase the IGBT's on and off switching functions.

Heat generation and signal interference are reoccurring obstacles that design engineers grapple with. Increased switch frequencies produce energy that is dissipated in the form of heat^[5-6]. This poses a potential hazard because the circuit can overheat and malfunction. The study of heat transfer and material science has improved wire insulation and, in turn, diminished the consequences of heat production. Another side effect from operating at high frequencies is line disturbance. There are companies that specialize in designing protective equipment that limit noise interference and heat generation.

The ability to manipulate the output voltage permits VFDs to control the speed and therefore the power consumption of a pump or fan. This was an amazing breakthrough in energy savings because average pumps and fans are designed to operate continually at 120% of their maximum load. During times of low load, the VFD can reduce the speed of the pump.

Current Applications

Pumps and fans constitute a significant amount of the electricity consumed by mechanical equipment^[1]. Figure 1 illustrates the breakdown of electricity consumed by mechanical equipment in 2004.

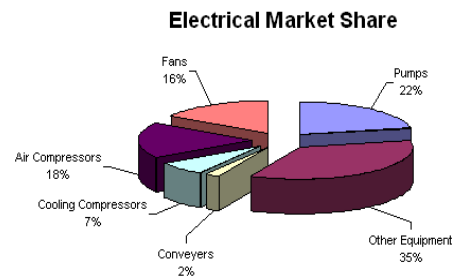


Figure 1: Based on Mechanical Equipment ^[1]

Pumping applications are notorious for being inefficient. Most pumps have efficiency of less than 75%. Therefore, pumps are typically over-designed to operate at 15-20% more than the actual load^[2]. Pump manufactures incorporate VFD technology into pump designs because they want the ability to operate at the maximum load, but they do not want to exhaust the equipment by operating continually at maximum capacity.

VFDs reduce life cycle costs associated with pumping equipment. VFDs control the amount of power supplied to the pumping equipment, which in turn adjusts the fluid's flow rate. The pressure and frictional forces exerted on valves, couplings, and machinery is decreased when fluid flow is limited. These reductions extend the longevity of the pump, saving money on repair fees.

Case Study

Farming has seen a dramatic benefit from the incorporation of VFDs into daily processes. For example, VFDs have been amalgamated into the vacuum pump systems used to milk cows on dairy farms. The benefits from this technological merger are astounding. These savings are exemplified in a report submitted to the New York State Energy Research and Development Authority^[2]. Figure 2 illustrates the available power savings from installing VFDs.

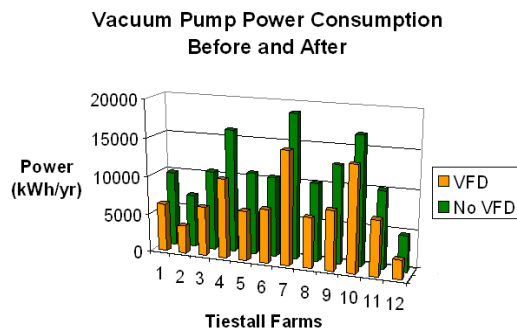


Figure 2: Vacuum Pump Power Savings of 12 Farms

In the study ^[7], twelve tie stall dairy farms were audited and recommended to implement VFDs on their vacuum pump systems. The size of the farms ranged from 42-140 milking cows. The average pump reportedly saved 35% on energy demand upon retrofitting their vacuum system. This translated to an average reduction of 11% in yearly energy bills. The statistical mean payback period was 4.97 years, based on an initial investment of \$3,400. After this time frame, farms began saving \$760 per year in energy consumption.

The best and worst case scenarios have been selected to gauge the impact of farm size on savings. Significant savings were observed on larger farms, where the operation time is considerably greater. This is anticipated because there is more potential to reduce the pumping requirements for the extended time the equipment is in service. For example, Farm 7 from Figure 2 had 80 cows and an

ideal return on their investment. Their original vacuum pump energy consumption was 18,779 kWh/year. After installing a VFD, their energy consumption was reduced to 14,729 kWh/yr. These savings resulted in the initial investment being paid off in 2.1 years. The lower savings quartile is represented by Farm 12. Prior to installing a VFD, Farm 12 spent 4,622 kWh/yr milking 43 cows. This annual figure was reduced to 2,475 kWh, but their payback was 5 times longer than Farm 7.

Economic Summary

The price of an electric motor is only a fraction of the cost required to operate the device. Initial or retrofit investment in VFDs is recouped by annual savings. The effectiveness of this was demonstrated during the tiestall dairy farm study ^[2]. Some significant results of the case study are shown in Table 1.

Table 1: Economic Summary of Average Benefits from Retrofitting Vacuum Pumps with VFDs

	Power Demand (kWh/yr)	Annual Savings	Installation Cost	Payback (Years)
No VFD	11,457	-	-	-
VFD	7,715	\$764	\$3,182	4.97

References

End Notes

- [1] Variable Speed Pumping, a Guide to Successful Applications. Oxford, UK: Elsevier Advanced Technology, 2004.
- [2] D. Ludington, E.L. Johnson, "Dairy Farm Energy Audit Summary" [Online Document] 2003 Jun [cited 2006 Nov 17]. Available HTTP: <http://www.nyserda.org/publications/dairyfarmenergysummary.pdf>
- [3] M. O'Kane, "Control Technique Drives" [Online Document]. 2000 [cited 2006 Nov 17]. Available HTTP: <http://www.maintenanceresources.com/ReferenceLibrary/ACDrives/VFD.htm>
- [4] "Insulated Gate Bipolar Transistors." [Online document]. 2006 June 26. [cited 2006 Nov 17]. Available HTTP: http://www.joliettech.com/igbt-insulated_gate_bipolar_transistors.htm
- [5] C.A. Phipps, Variable Speed Drive Fundamentals, 3rd ed., Lilburn, Georgia: The Fairmont Press Inc., 1999.
- [6] W.L. Stebbins, How to Select and Apply ASD Systems Selected Readings. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers Inc., 2000.
- [7] R. Darby, Chemical Engineering Fluid Mechanics, 2nd ed., New York: Marcel Dekker, 2001.