National Regulatory Research Institute

Assessment of Variable Frequency Drives for Increased Energy Efficiency at Drinking Water Utilities Supplied by Groundwater

Gregory A. Payne

Dr. Gregory W. Harrington

Department of Civil and Environmental Engineering

University of Wisconsin—Madison

January 2009

09-01

Preface

The University of Wisconsin—Madison, Department of Civil and Environmental Engineering published a paper in July 2003 for Focus on Energy and the Energy Center for Wisconsin entitled, *Energy Use at Wisconsin's Drinking Water Facilities*. It found that installing variable frequency drives (VFDs) on pumps results in more energy-efficient operation than throttling valves with fixed speed drives. NRRI published a paper in June 2008 entitled, *Reducing Electricity Used for Water Production: Questions State Commissions Should Ask Regulated Utilities*. The paper recommended installing VFDs on pumps as a potential way for water utilities to reduce electricity use. It also recommended that state commissions induce electric utilities to offer, and water utilities to participate in, energy efficiency programs, such as those that promote VFDs.

NRRI and UW Department of Civil and Environmental Engineering partnered in the Fall of 2008 for a study to determine and quantify the effectiveness of VFDs in reducing power consumption at water utilities that have installed them. The project is part of an undergraduate independent study program at the school. Herein is an interim report, following the first semester's work on the project. NRRI and the Department hope to continue their partnership to complete additional research on this and other topics to help state commissions meet regulatory challenges.

This report is available electronically at http://nrri.org/pubs/water/NRRI_var_freq_dr_assess_jan09-01.pdf.

David Denig-Chakroff
Principal
National Regulatory Research Institute

ASSESSMENT OF VARIABLE FREQUENCY DRIVES FOR INCREASED ENERGY EFFICIENCY AT DRINKING WATER UTILITIES SUPPLIED BY GROUNDWATER

Interim Report
December 2008

Prepared by:
Gregory A. Payne and Gregory W. Harrington
Department of Civil and Environmental Engineering
University of Wisconsin – Madison
1415 Engineering Drive
Madison, Wisconsin 53706

Submitted to:
David Denig-Chakroff
National Regulatory Research Institute
8730 Georgia Ave. #201
Silver Spring, Maryland 20910

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Roughly four percent of all electricity generated in the United States is used for pumping and treatment in wastewater and drinking water systems. Pumping accounts for at least 85% of that electrical use by drinking water utilities. In the coming years, federal and state regulations may request more energy-demanding treatment processes such as ozonation, membrane filtration, and ultraviolet irradiation. Therefore utilities are interested in reducing their electrical consumption as much as possible. Some studies suggest using variable frequency pump drives, instead of constant speed pump drives, to increase energy efficiency (Elliott *et al.* 2003, Denig-Chakroff 2008). In response to such studies, Wisconsin Focus on Energy has issued grants to water utilities to help implement variable frequency drives.

The variable frequency drive system works by controlling the amount of electricity delivered to the electric motor by altering the frequency of the current. Variable frequency drives are used throughout business and industry on a wide range of applications from pumps to fans. Ideally, variable frequency drives offer greater control over the speed of the electric motor and can shift electricity costs from on-peak to off-peak costs, thus saving money. While reducing the costs of electrical use is an important objective for any utility, reducing the amount of electricity used is also important. Focus on Energy suggests that variable frequency drives also save electricity, but there are few studies that demonstrate how much electricity is actually saved when using variable frequency drives.

There are some fundamental reasons why variable frequency drives are expected to use less electricity per gallon of water pumped. For example, groundwater utilities operating at lower speeds create less groundwater drawdown in their wells (see the Background Section). In doing this, the water does not need to be lifted as high, suggesting that less power is needed per gallon of water pumped. Some utilities with constant speed pumps use isolation valves to throttle down the amount of water delivered by a pumping system and reduce the frequency at which their constant-speed pump is turned on and off. In doing this, these utilities increase the amount of electricity needed per gallon of water pumped. Replacing the constant speed drive with a variable frequency drive can allow these utilities to fully open their valves and reduce the amount of electricity used per gallon of water pumped.

While there are energy-saving opportunities when using variable frequency drives, there are also fundamental reasons why variable frequency drives are expected to use more electricity per gallon of water pumped. For example, operation of pumps at lower speeds suggests that the pump is not being operated at its optimal wire-to-water efficiency point, increasing the energy required per gallon of water pumped. Also, surface water utilities do not have source water drawdown, so variable frequency drives are not expected to reduce the electricity used per gallon of water pumped for these utilities.

To summarize, variable frequency drives may improve financial aspects of electricity use by shifting some electrical use from peak electricity demand periods to non-peak electricity demand periods. However, it is unclear whether variable frequency drives offer sustainable energy use over the long term because they have the potential to either decrease or increase the amount of electricity used per gallon of water pumped. Research is needed to define those conditions that lead to reduced energy use per gallon of water pumped. Thus, the purposes of this study are to:

1. quantify the changes in energy use that can be attributed to the installation of variable frequency drives at municipal water utilities
2. determine which scenarios yield the highest energy savings, if any
3. give businesses and utilities statistical evidence that will either support their decision to purchase a variable frequency drive or oppose it
4. give state regulatory commissions statistical evidence that will either support or oppose policies that encourage use of variable frequency drives

This report is only an interim report. A follow-up report is expected in late May 2009.

BACKGROUND

The utilities chosen for this study were those supplied by groundwater. A groundwater unit well typically has one vertical turbine primary pump that moves the water from the aquifer to the earth's surface. This primary pump is often called a deep-well pump. In some cases, the deep well pump sends water directly to the distribution system, which typically contains a water tower having the maximum elevation of water in the system. A simplified schematic of such a system is shown in Figure 1a and is commonly used in smaller communities. In other cases, the primary pump delivers water to an intermediate, ground-level reservoir as shown in Figure 1b. In this type of system, which is common for larger communities, a booster pump is used to pump the water from the ground-level reservoir to the distribution system. In most cases, the booster pump is a horizontal split-case centrifugal pump, but the pump could be a vertical turbine pump. Like those systems represented by Figure 1a, these distribution systems typically contain a water tower having the maximum elevation of water in the system.

In both types of systems, a significant amount of the overall electrical use is determined by the change in elevation from the pumping water level in the aquifer to the water level in the water tower. The primary difference is that two pumps are used to lift the water in one type of utility while only one pump is used in the other type of utility.

The pumping water level, or drawdown, shown in Figures 1a and 1b is determined by a number of factors. For example, the depth of the pumping water level decreases as the permeability of the geologic formation increases. Thus, because the water is lifted over a smaller elevation change, the electricity used per gallon of water pumped can be expected to decrease with increasing permeability of the geologic formation. The depth of the pumping water level

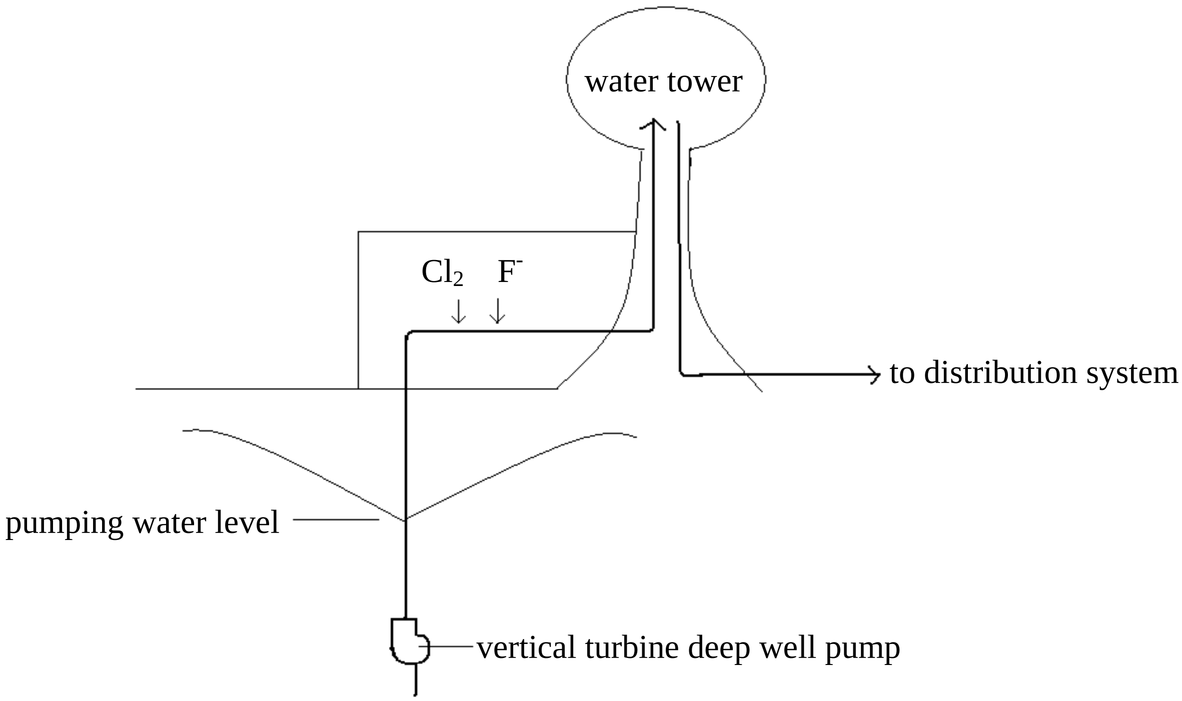


Figure 1a. Unit well with a single primary pump.

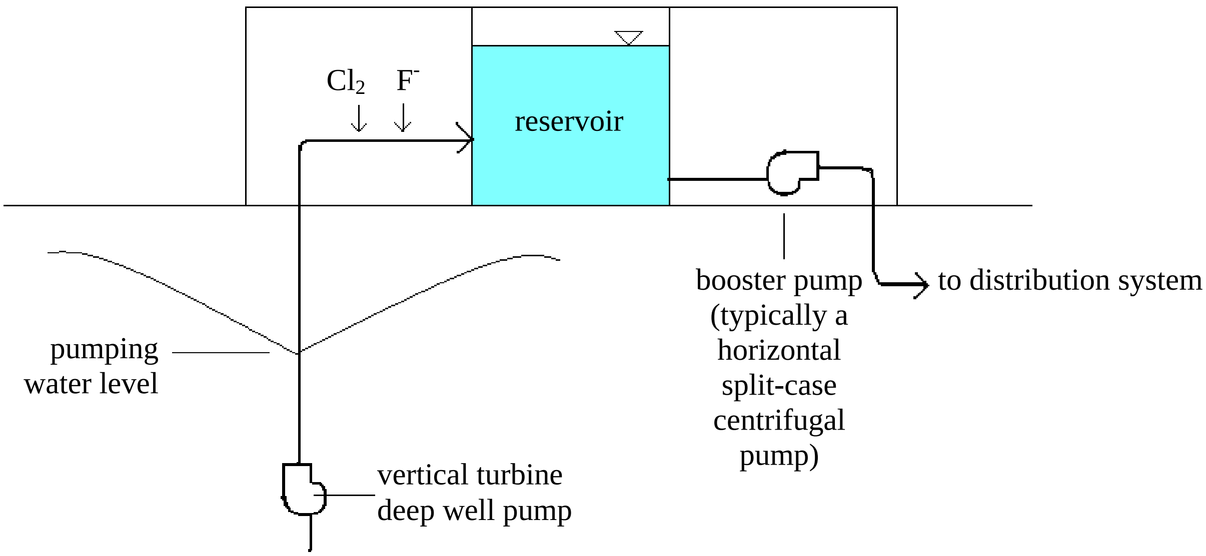


Figure 1b. Unit well with a primary pump and a booster pump.

also decreases as the flow rate of water pumped is decreased. Thus, installation of variable frequency drives to reduce flow rate can potentially lead to decreased amounts of electricity used per gallon of water pumped. Because there is no drawdown in the ground-level reservoir, a variable frequency drive on the booster pump would not be expected to produce a significant decrease in the amount of energy used per gallon of water pumped.

STUDY METHODS

General Approach

The intended approach for this project is to determine which utilities in Wisconsin have installed variable frequency drives and interview them for data collection purposes. As noted in the next section, there were some unanticipated hurdles to this approach and this interim report was based on an alternative approach. In this alternative, general data were collected for 49 utilities from publically-available databases and analyzed as described in the next section. In addition to this, interviews were conducted with the Madison Water Utility to develop some more specific data on variable frequency drive implementation.

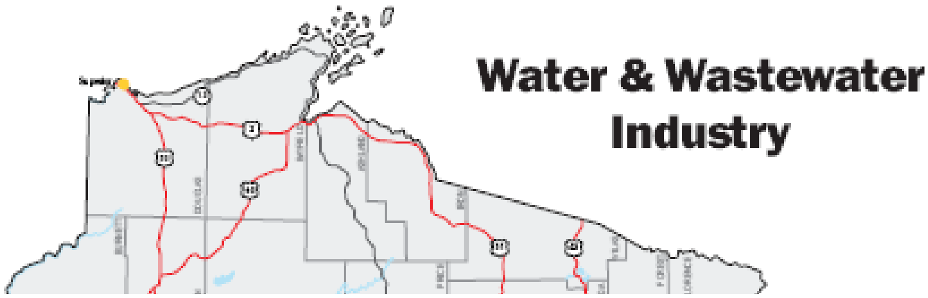
49 Utility Database

The intended approach was to determine which utilities had received a Focus on Energy grant and contact these utilities for electrical use data prior to and following variable frequency drive implementation. After contacting Focus on Energy, it was learned that grant listings were considered confidential. To obtain the necessary information, an open records request was filed with Chuck Sasso at the Wisconsin Energy Conservation Corporation and with Preston Schutt at the Wisconsin Public Service Commission. Some records were received by the end of the 2008 fall semester, but these were inadequate to do a thorough study. To properly continue the study in the 2009 spring semester, enhanced cooperation with these individuals and agencies will be critical.

While waiting for the release of grant information, the study was approached in a different manner. Focus on Energy promotes its program by releasing maps that pinpoint locations that have received grants. The map for water or wastewater grants is shown in Figure 2, and yellow circles on this map indicate the locations of water and wastewater utilities that received Focus on Energy grants. Appendix A shows a list of several locations that received grants. However, the map does not indicate what the grants were for or when they were provided. For example, the grants could have been for variable frequency drives, higher efficiency motors, or for the reduction of energy use in wastewater systems. Future cooperation from Focus on Energy is needed to receive this information.

The list generated from this map contains utilities from across the state, excluding the southeastern portion of Wisconsin. Points in the southeastern section were too close to each other to determine which utility they were. Areas of high population density were also difficult because of the large amount of surrounding utilities.

The next step was to determine which utilities to use and to collect data from them to see whether they improved in energy efficiency over time. Wisconsin water utilities must submit annual reports regarding finances and water operation to the Public Service Commission. The reports are then posted on an internet web site for public viewing. The web site contains annual reports from 1997 to the present for each water utility. These reports contain information on the total number of gallons pumped for the year, the total amount of electricity used by the utility in kilowatt-hours (kWh) for that year, number of wells in the community, and number and type of pumps used in the community. The average efficiency of energy use at each utility was obtained by dividing the number of kWh by the number of gallons. Because the data only account for electricity use and water production on a system-wide basis, the impacts of a variable frequency drive or any other upgrade on a single well cannot be tracked over time. However, such an upgrade should have a noticeable impact on system-wide use for those utilities having only a few



unit wells. Thus, for this interim study, the annual reports and Figure 2 were used to choose grant-receiving utilities that had two to six unit wells.

Data were also collected for groundwater utilities around Wisconsin that were not represented on the Water and Wastewater Industry map. These utilities serve as controls, allow for the estimation of a typical standard deviation in energy use for a utility, and allow for a comparison of energy use with grant-receiving utilities. The control utilities can also indicate if the grant-receiving utilities are doing any better than utilities that have not received grant money.

For the selected utilities, the progress of energy used per gallon of water delivered over an 11-year span from 1997 through 2007 was evaluated to note any changes at each of the chosen utilities. Upgrades such as new pumps and new motors are listed in the annual reports and this information was included in the data tables. The standard deviation of annual energy use over the 11-year period was determined for each utility for the purpose of verifying whether the electrical use in any given year was significantly different from prior years. With improved cooperation from Focus on Energy and grant recipients, more specific data can be used to improve the database and allow for more definitive interpretations.

When a well is constructed in Wisconsin, a well construction report and a high capacity well report must be filed with the Department of Natural Resources (DNR). The DNR then posts this information publically on the internet. From these reports, the chief aquifer and the main type of rock present in the geologic formation were obtained and recorded. The reports also list the pumping water level for the well when tested at a specific flow rate for a given amount of time. This level was also entered into the database.

As noted in the Background Section, the pumping water level is important because this is the elevation that the water is lifted to the ground surface when the pump is running. A larger pumping water level would suggest more energy is needed per gallon to move the water to the distribution system. Similarly, the level of water in the water tower and/or the ground-level reservoir impacts the energy needed to pump a given amount of water. These elevations are not reported in publically available databases on the internet and further work on this project will need to collect this information.

Case Studies at Madison Water Utility

In addition to the above items, a series of phone interviews was conducted with Alan Larson, the principal engineer of the Madison Water Utility. This utility has taken several steps to reduce electrical costs and electrical use. The results of these efforts are described in the Results Section.

RESULTS

By the end of the study, a total of 49 groundwater utilities from across Wisconsin were evaluated. The 49 utilities fall into two classes: utilities that received grants from Focus on Energy for water or wastewater treatment, and control utilities that did not receive grants. This section summarizes key results obtained from the 49 utility data set and includes a case study involving the Madison Water Utility.

Utilities Using Deep Well and Booster Pumps versus Utilities Using only Deep Well Pumps.

The Wisconsin DNR database contained pumping water level data for 42 of the 49 utilities and Figure 3 shows how energy use depends on the pumping water level for these 42 utilities. As expected, the graph suggests that energy use is proportional to pumping water level. Scatter of data about the trend line is likely due to a number of factors, including water elevations in the distribution system, head loss due to flow through valves, head loss due to flow through pipes, type of pump drive, and efficiency of pumps and pump motors. For example, data points above the trend line may represent utilities with higher water tower elevations while data points below the trend line may represent utilities with lower water tower elevations.

The red squares in Figure 3 represent the 7 utilities that use booster pumps and 6 out of the 7 points fall below the best fit line. Thus, utilities that split the load between two motors and two pumps had lower energy use per gallon than the average utility. This is not necessarily consistent with expectation and more data will be needed to definitively reach a conclusion on whether this makes sense. For the rest of this report, the 7 utilities with booster pumps were removed from the graphs to eliminate the possible skew they may cause on data interpretation.

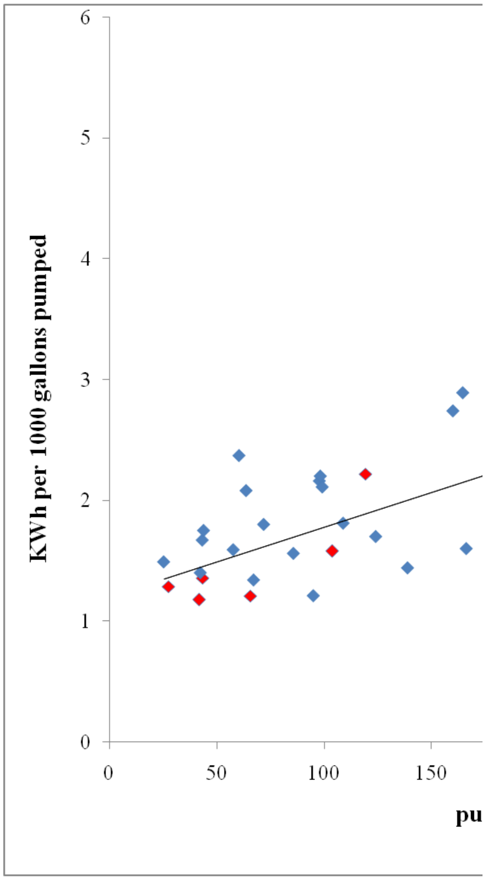


Figure 3. Dependence of energy use on pumping water level for groundwater utilities in Wisconsin.

Influence of Aquifer Type on Energy Use.

The influence of aquifer type on energy use is illustrated in Figure 4. As noted in the Background Section, utilities using less permeable aquifers will have deeper pumping water levels and higher energy use per gallon. This plot suggests that energy efficiency depends mainly on pumping water level, but also aquifer type. For example, the average energy use for utilities with sand and gravel aquifers is less than that of the utilities with other aquifers. Also, the utilities with a sandstone aquifer average less energy use per gallon than utilities with either a limestone aquifer or a granite aquifer. It is apparent that the influence of aquifer type is not limited to the influence of aquifer type on pumping water level. Additional study is needed to

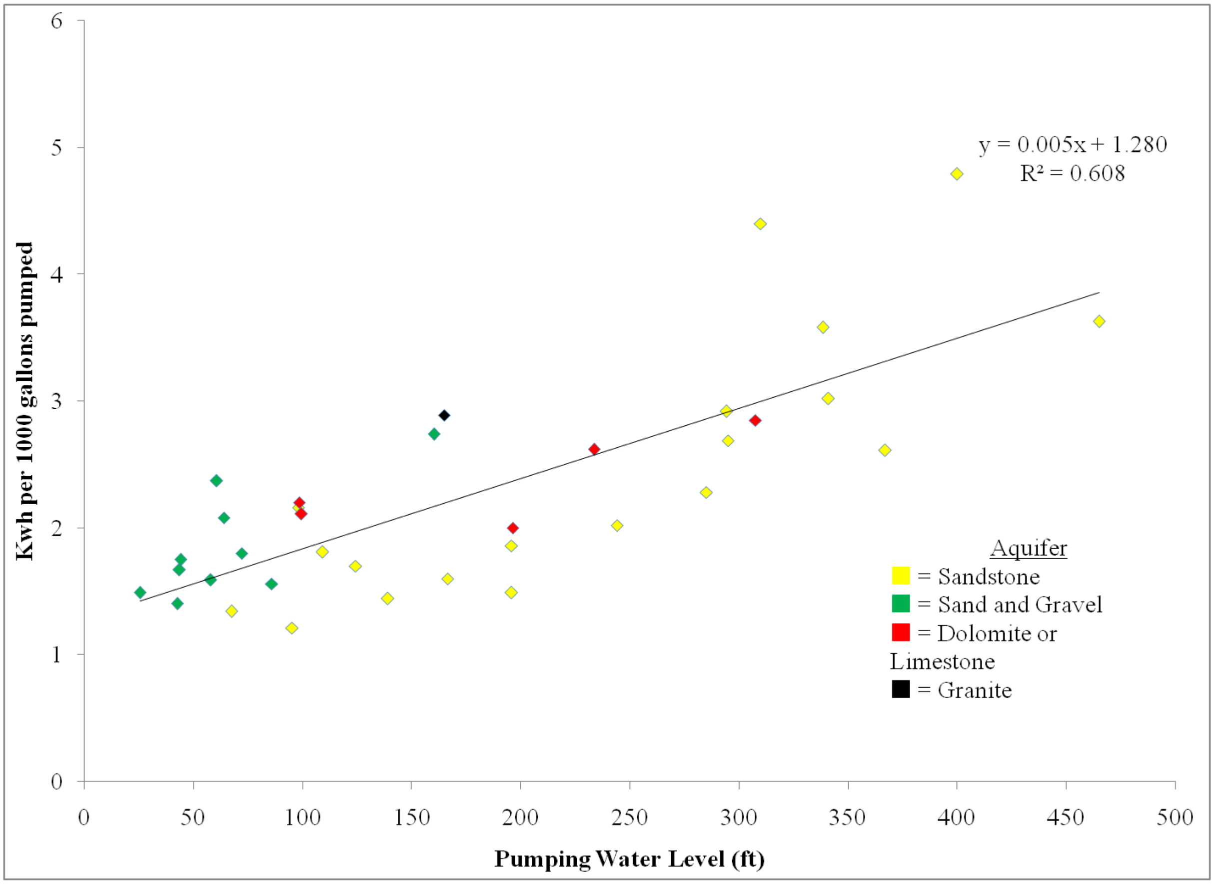


Figure 4. Influence of aquifer type on energy use at groundwater utilities in Wisconsin.

determine whether this is due to chance or whether there is a rational explanation for this observation. Data from all aquifer types lie above the trend line, suggesting that there are opportunities for improved energy efficiency regardless of aquifer type. The equation shown in Figure 4 may be used as a first-cut approximation of energy used per 1000 gallons pumped in Wisconsin's groundwater utilities.

Influence of Wisconsin Focus on Energy Grants on Energy Use

Figure 5 compares control utilities with utilities that likely received a grant from Wisconsin Focus on Energy. In this figure, the number of control utilities above the trend line is

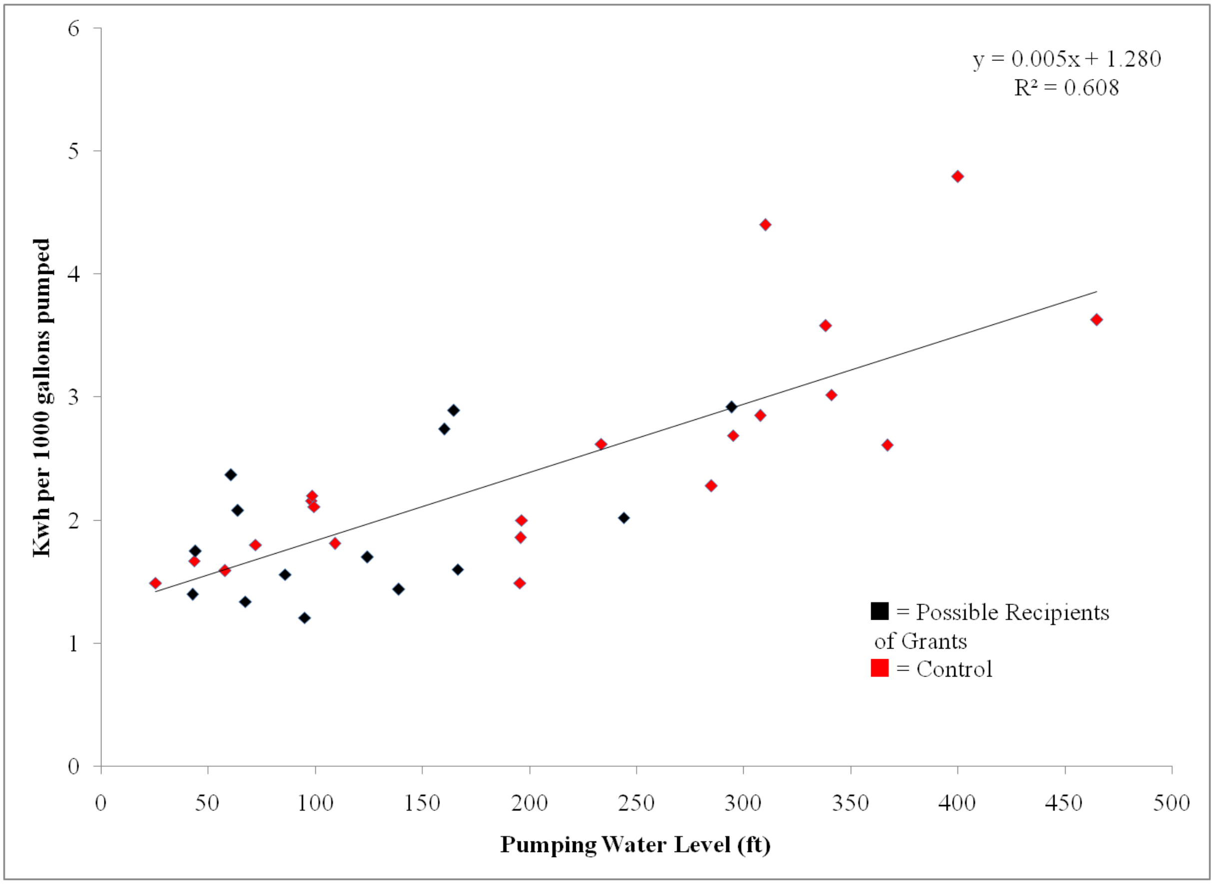


Figure 5. Comparison between possible grant recipients and control utilities.

approximately the same as the number of control utilities below the trend line. A similar result was obtained for those utilities that likely received a grant from Focus on Energy. The lack of a trend suggests that the grants did not improve energy efficiency enough to differentiate the grant-receiving utilities from the control utilities. However, for this study, there was no information available to indicate what the grant-receiving utilities actually used their grant money for. For example, if a utility used the grant money to improve energy efficiency at the wastewater treatment plant, then the energy savings would not be shown on their annual report to the Public Service Commission because the annual report only shows the energy used by the drinking water utility. Future cooperation with Focus on Energy will be needed to determine if the grants are having the desired impact on energy use.

As noted in the Methods Section, changes in energy use over the time period from 1997 to 2007 were evaluated for each of the 49 utilities. Of the 49 utilities, 25 showed some improvement and 17 of these had an improvement that was larger than the standard deviation. If the energy use at a utility decreased by one or more standard deviations during the 1997 to 2007 timeframe, the utility was recorded as having a significant decrease in energy use. An example of this is the municipal utility in Linden, which was using 3.03 kWh per 1000 gallons in 1997 and 2.61 kWh per 1000 gallons in 2007. The standard deviation for Linden was 0.17 kWh per 1000 gallons and, therefore, Linden had a significant reduction in energy use.

Of the 24 utilities that received grants from Focus on Energy for either water or wastewater treatment, 15 improved and 10 of these had improvements that were larger than the standard deviation. For the 25 control utilities, 11 showed some improvement with 7 of these improvements being larger than the standard deviation. The data also revealed that 24 of the 49 utilities increased energy use per 1000 gallons and 12 of these increases were statistically significant. Thus, more of the selected utilities improved energy efficiency rather than reduced energy efficiency, but not by a large margin.

Figure 6 analyzes those utilities having an energy reduction larger than the standard deviation and compares them with utilities having no significant change or an increase in energy use. In this figure, 11 of the 13 utilities that significantly reduced energy use fall under the best fit line. For those 22 utilities having no significant change or an increase in energy use, only 7 were below the trend line. This suggests that improved energy efficiency may be a viable strategy for those utilities that are operating above the best fit line. Utilities that are already

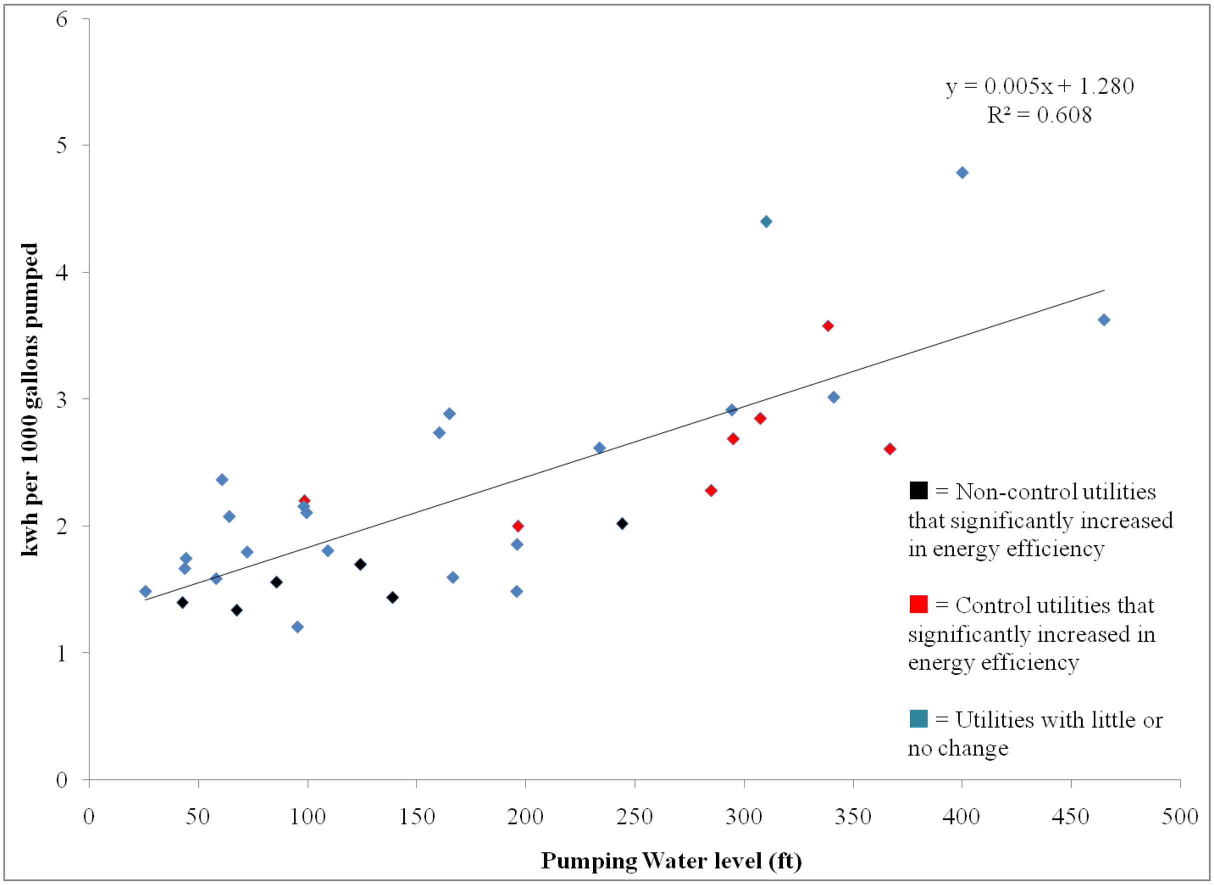


Figure 6. Utilities that have changed in energy efficiency over the 11-year period.

below the best fit line, may find that variable frequency drives or new pumps and motors will not change energy efficiency as much as desired.

A summary of results from the 49 utility data set suggest one of two things. One, utilities that are above the best fit line may be capable of improving their technology and/or operations to increase their energy efficiency. This may be achieved by replacement of old motors, reduction of high frictional losses, or replacement of constant speed drives with variable frequency drives. Second, utilities that fall under the best fit line may wish to invest in other green practices such as reducing water losses or supplementing their energy use with alternatives such as solar or wind power.

For the 49 utilities described in the previous sections, no conclusions can be made as to whether variable frequency drives were responsible for any increase in energy efficiency over the past 11 years. To determine this, dates of installation will be needed and that can only come from Focus on Energy and their grant recipients.

Case Studies at the Madison Water Utility.

With cooperation from Alan Larson, principal engineer at the Madison Water Utility, three Madison wells with variable frequency drives and one well with an energy efficient motor were investigated. All of Madison's unit wells include an intermediate ground-level reservoir as shown in Figure 1b. Thus, energy efficiency measures can be taken with the deep well pump and/or the booster pump.

Unit Well 13

One of the wells studied was Unit Well 13, which pumps 2300 gallons per minute at a pumping water level of 110 feet. The well has one vertical turbine pump and one horizontal split-case centrifugal booster pump, with 250 and 200 horsepower motors, respectively. Before a variable frequency drive was installed on the booster pump in January 2004, operators controlling the pump throttled the flow of water to reduce the number of times that the pump was turned on and off. After installation of the variable frequency drive, the need to throttle the flow was significantly reduced. Two years before the variable frequency drive was installed, the well used 2.08 kWh of energy to pump 1000 gallons. Two years after the variable frequency drive was installed, the same well consumed 1.89 kWh per 1000 gallons, a 10% increase in efficiency.

Using the equation shown in Figure 3, this unit well is expected to have an energy use of around 1.75 kWh per 1000 gallons of water pumped. With the variable frequency drive installed on the booster pump, the well is within 10% of that amount. Thus, while the installation of a variable speed drive on the booster pump helped to reduce electrical use at Well 13, additional reductions in energy use may be possible at this well.

Unit Well 18

Well 18 pumps 2200 gallons per minute at a pumping water level of 240 feet. The vertical turbine pump has a 200 hp electric motor and the two centrifugal booster pumps are powered by 150 and 125 hp electric motors. A variable frequency drive and a new electric motor were installed on each booster pump in 2003. In September 2002, the well used 2.04 kWh per 1000 gallons of water. After the variable frequency drives and motors were installed, electricity use at the well increased to 2.53 kWh per 1000 gallons in September 2008. According to Alan Larson, principal engineer at the Madison Water Utility, the reasons for the 24% decrease in efficiency were twofold. When the variable frequency drives and motors were installed, the system was also outfitted with a set of automatic controllers that were not as precise as manual controllers. Lastly, the pumps are producing an increased water pressure because of the lower flow rate used, moving the pumps away from their peak wire-to-water efficiency point.

Again, using the equation derived from Figure 3 (with boosters) the expected energy use for this well is 2.40 kWh per 1000 gallons. Prior to installation of the variable frequency drives, the well was running at an electrical consumption rate that was 15% lower than this. With the variable frequency drives installed, the energy use has been 5% higher than the expected value. Thus, the installation of variable frequency drives on the booster pumps at Well 18 actually led to an increased consumption of electricity per 1000 gallons of water pumped.

Comparison of Unit Wells 28 and 30

Two recently constructed wells in Madison, one with a variable frequency drive and the other without, can be compared to provide a qualitative analysis of energy savings associated with a variable frequency drive. Well 30 was constructed in 2006 and pumps 2200 gallons per minute at a pumping water level of 292 feet. The vertical turbine pump has a 250 hp motor and the two centrifugal boosters have 150 hp motors. The well was built with a variable frequency drive on the vertical turbine deep well pump and constant speed drives on the booster pumps. In September 2008, the pumps in this well used 2.13 kWh per 1000 gallons at a total of 426 feet of head. Well 28 was constructed in 2002, has a pumping water level of 275 ft, uses a constant speed drive on all pumps and has no throttled valves. In September 2008, this well pumped 1000 gallons with 2.23 kWh at 476 feet of total head in the same month. Electricity use at Wells 28 and 30 are 13% and 20% lower, respectively, than the values calculated from the equation shown in Figure 3, suggesting good energy efficiency in both cases.

Based on the kWh used per 1000 gallons pumped, the pumps in Well 30 use 4% less energy than the pumps in Well 28. However, because Well 30 has 11% less total head to pump against, the variable frequency drive does not seem to be significantly more energy efficient than the constant speed drive in Well 28.

Unit Well 20

In 2003, the 30-year-old electric motor at Well 20 was replaced with a 320 hp premium efficiency motor. The pipes were also cleaned and recoated. Before the rehab, the well consumed 2.45 kWh per 1000 gallons in 2002 and, after the rehab, the well used 2.23 kWh per 1000 gallons in 2003. The increase in energy efficiency was approximately 9%. The final price for the project was $32,000, which compares favorably with the cost of a new variable frequency drive, which Larson estimated to be around $76,000.

With the pumping water level at Well 20 being 387.5 ft, the expected energy use would be 3.22 kWh per 1000 gallons based on the equation shown in Figure 3. Energy efficiency was significantly better than this expected value before and after the motor change.

CONCLUSIONS

The Madison case study suggests that a number of items must be considered before water utilities implement variable frequency drives. First, if valves are throttled to stop hard startups or to decrease the frequency of pump startups, a variable frequency drive may increase energy efficiency. Second, adding automatic controllers and operating a pump away from the optimal efficiency point can reverse the positive effects of a variable frequency drive. Third, simply comparing wells without considering all possible variables can lead to misleading results. Fourth, a new energy-efficient motor may achieve more energy efficiency at a lower cost than a variable frequency drive.

The 49 utility study reveals that pumping water level, or drawdown depth, is a significant factor in determining energy use by groundwater utilities, as expected. Variable frequency drives may be used on deep well pumps to reduce the drawdown depth and improve energy efficiency. However, this improvement in energy efficiency will be offset to some extent by operating the pump at a flow rate away from the optimal wire-to-water efficiency point. Utilities need to fully evaluate the trade-offs associated with variable speed drive implementation before making a decision to replace a constant speed drive with a variable speed drive. Similarly, state regulators and energy efficiency grant programs need to consider these factors in determining whether a utility should be encouraged to implement variable frequency drives.

Figures 3 through 6 also reveal that it is inappropriate to say that there is a typical value of kWh used per 1000 gallons pumped that can be achieved by all utilities. The energy efficiency that can be attained by a utility depends on numerous factors including pumping water level, aquifer type, and surface topography. Utilities, state regulators, and grant program managers need to keep these factors in mind when making decisions.

RECOMMENDATIONS

The following is a list of recommendations for continued study in the 2009 Spring Semester. One possible direction is that future students should collect more data to determine whether having a booster pump and primary pump is more energy efficient than having only primary pumps as suggested by Figure 3. Another recommendation would be to collect more data on utilities to fill in the areas on the graphs that don't have that many data points. This can also help determine whether aquifers play anymore of a role in calculating energy efficiency. In addition to knowing the pumping water level, it would be beneficial to include the total head by including the height of the water tower or height of the reservoir. Then incorporating that data into the curves we produced would be more accurate.

The Wisconsin Public Service Commission should be aware of the preliminary results of this study. Greg Harington and David Denig-Chakroff should meet with the PSC to discuss the work thus far in an attempt to receive more cooperation. Thus far, the only data received to date is a table of utilities and businesses from 2006 to 2008 that received grants for energy savings equipment. The table does not provide contact info and does not indicate whether the grant was used for drinking water or wastewater purposes. A better understanding of the database is needed before it can be used effectively. Ideally, students will be given access to the database and to prior years for more effective data analysis.

Once an appropriate list of grant-receiving utilities is available, students will likely need to call each utility to determine all relevant information such as electricity use at specific wells, the use of throttled valves, and to note if the variable frequency drive was installed on a booster pump or primary pump.

REFERENCES

Denig-Chakroff D. 2008. *Reducing Electricity Used for Water Production: Questions State Commissions Should Ask Regulated Utilities.* National Regulatory Research Institute.

Elliott T, B Zeier, I Xagoraraki, and GW Harrington. 2003. *Energy Use at Wisconsin's Drinking Water Utilities.* Rept. No. 222-1. Energy Center of Wisconsin: Madison, WI.

APPENDIX A

List of municipal utilities who have possibly been awarded grants by Focus on Energy.

Benton	Orfordville
Cleveland	Osceola
Darlington	Palmyra
Durand	Prairie du Chien
Edgar	Prentice
Genoa City	Rhinelander
Green Lake	Sharon
Horicon	Suring
Independence	Thorp
Marshall	Wisconsin Rapids
Montello	Wautoma
Oconto	West Salem

Contacts

Chuch Sasso – Energy Conservation 249-9322 x 324 email: chucks@weccusa.org

Joe Cantwell – 1-262-786-8221

Madison Water Utility – 266 – 4653
-Alan Larson – 266 – 4651

Focus on Energy - 1-800-762-7077

Energy Services, Department of Administration

- Susan Brown – 266 -2035
- Sherce Dallas Branch 261-6357

Alliant Energy Center – 1-800-255-4268