NEW TECHNOLOGY REDUCES ELECTRICAL ENERGY CONSUMPTION OF SUCKER ROD PUMPS BY 22%

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ABSTRACT

In an effort to reduce lift costs, a project was created to determine if the energy consumption of a pumping unit could be reduced without effecting production. MotorWise began this project in 2008 by applying a patented motor management device to pumping units in southeast Texas. The project successfully advanced with significant electrical energy savings with final completion in the Permian Basin. After several multi-year studies, the savings has been determined to be on average 22%.

INTRODUCTION

The motor management device has its foundation in research and testing done at NASA in the ‘70s. Those results showed that the load on a motor could be determined by measuring the phase relationship between the current and voltage of any of the phases.

The pumping unit is a unique machine that has been optimized over the years to use the least amount of energy to lift the fluid. The prime mover and counter weight must work together to lift the fluid. The stored kinetic energy in the rod string when lifted is recovered to some extent when it falls and assists in the lifting of the counter weight.

The pump off controller was introduced several decades ago to turn the well off when there was no fluid available at the pump. This technology has saved significant energy and reduces the wear and tear on the equipment.

The MotorWise device begins the next step in reducing energy and minimizing wear and tear on the equipment. The device monitors the load on the motor during the pumping cycle and only provides power when the prime mover needs it. This method also removes the voltage from the motor when the motor generates. This generation is a result of the momentum of the pumping unit causing the motor’s RPM to exceed its name plate synchronous speed.

TYPICAL POWER FACTOR USAGE

This phase relationship is commonly referred to as Power Factor (PF). Power Factor is usually associated with a penalty charge that is imposed on an industrial facility that consumes most of its energy with motors. This poor power factor requires the electric utility company to install larger transformers with higher current handling capability. The monthly penalty charge is used to cover the higher cost of this equipment. These industrial facilities can have these penalties reduced or eliminated by adding Power Factor Correction Capacitors at the metering point of the building. This saves money by eliminating the power factor penalty, but does not reduce the energy consumption or the peak demand charges the building is already incurring.

POWER FACTOR MONITORING OF A PUMPING UNIT

By monitoring the power factor while a pumping unit is operating, it can be determine when the motor is loaded and how heavily the motor is loaded. The Digital Signal Processor in the technology can then calculate when the pumping unit needs power and when it is unloaded or generating a small amount of power. This allows the power to the pumping unit to be reduced even as the loading changes from stoke to stroke.

POWER FACTOR EFFECTS CURRENT AMPLITUDE

In an effort provide a more complete understanding of power factor, the following examples show how power is calculated in different types of electrical systems. The power factor is always between 1 and 0.

Example 1: DC System

Figure 1 shows the typical DC system that everyone is familiar with in a vehicle's electrical system. A 12 volt battery starts the vehicle, and an alternator charges the battery and operates the electronics. If you have a 12V system connected to a 100 ohm load the current that flows is 0.12 amps. The power delivered by the battery (Power (Watts) = Voltage x Current) is 1.44 watts. The power dissipated by the resistor is 1.44 watts. By measuring the current and voltage in a DC system, the power consumed can be easily calculated.

Example 2: AC System with Resistive Load

The basic AC system is the electrical system in a house. This single phase system has alternating current and voltage. The meter used provides amplitude of current and voltage in Volts RMS and Amps RMS units. If the load is resistive then the current and voltage are in phase and the power factor is 1. Figure 2 shows a 100 watt incandescent light bulb connected to the outlet. Here the current is 1.2 Amps RMS. The power consumed (Power (Watts) = Voltage x Current x Power Factor) is 100 watts.

Example 3: AC System with Motor Load

The more complex case is a three phase system that is driving a motor shown in Figure 3. The motor will have a power factor that changes with the load on the motor. When the motor is loaded the power factor will be near 1 and typically will be 0.8. When the motor is unloaded the power factor is reduced to approximately 0.2. A detailed power example will be provided below.

Power Factor Calculations

Figure 4 shows the relationship between the different types of power in an AC system. The real power is what is charged by the electric utilities. The reactive power is what reduces the power factor of a system. The more the reactive power the lower the power factor. If there is no reactive power, the power factor is 1 and the apparent power is equal to the real power.

$$Power\ Factor = \frac{RealPower}{Apparent\ Power} \emptyset$$

$$Power\ Factor = \frac{kw}{\sqrt{(kW)^2 + (kVAR)^2}}$$

$$Power\ Factor = \cos \emptyset$$

AC Motor Power with Different Currents

Figure 5 will illustrate better what happens when the power factor changes and how it affects the current amplitude and power consumed by the motor.

The blue dash line represents the 480V phase to phase voltage in a three phase system. The black line is the current going into the motor with a power factor of 1. The current and voltage are in phase. Each of them cross the zero point together. The red line is the current in another motor where the power factor is 0.6. This red current is out of phase with the voltage and it is said to "Lag" the voltage since the zero cross happens later than the voltage zero crossing.

The two equations below calculate the power consumed by each of the motors in this example.

Motor 1	Motor 2
RMS Current (Irms) = 55A	RMS Current (Irms) = 92A
PF=1	PF = 0.6
P (watts) = 55 x 1 x 480 x 1.7 = 45kW	P (watts) = 92 x 0.6 x 480 x 1.7 = 45kW

The power consumed by both motors are the same. The motors are doing the same amount of work at the shaft. This example shows the current can be very different between two motors. It is important <u>not</u> to assume that the current is a good representation of the power in an AC system. Lower current does not always mean lower power. The power factor must be known in order to calculate power. This helps explain why the addition of power factor correction capacitors do not reduce power consumption, despite the apparent reduction in current draw.

RESULTS

Figure 6 illustrates one cycle of a pumping unit's rotation. Image A is when the unit is lifting the rods, and the counterweight is helping the motor lift the rod weight. Image B is as the unit transitions from the upstroke to the downstroke. Image C is when the unit is lowering the rods and lifting the counterweight. Image D is as the unit transitions from the downstroke to the upstroke.

Figure 7 and Figure 8 below show a pumping unit cycle captured using the MotorWise device. The top plot in both figures shows power consumed by the motor in kW, the bottom plot shows the power factor. In Figure 7, the MotorWise device is operating in "unmanaged" mode where it passes 100% of the line voltage through to the motor, just as if the motor were connected directly to a line starter. The most work is done by the motor during portions A and C, lifting the rods and lifting the counterweight respectfully. During the transitional periods B and D, the power requirement decreases and the power factor begins to decrease and lag. There are portions of the stroke where kW and power factor are negative, this is where the pumping unit is driving the motor above its synchronous speed and generating voltage back onto the line.

In Figure 8, the MotorWise device is operating in "managed" mode where it controls the voltage output to the motor based on the observed power factor throughout the stroke. During periods B and D, as the power factor begins to drop the MotorWise device removes voltage from the motor, allowing the unit to "coast" during these portions of the stroke and eliminating any power consumption during this time. At the beginning of period A and C, the MotorWise device soft-starts and applies voltage to the motor again to provide the power to raise and lower the rods. It is the elimination of power consumption during periods B and D that allows the MotorWise device to reduce overall electrical consumption.

A side effect of driving a motor above its synchronous speed is that the motor begins to exert a braking moment on the system as it tries to keep the rotor turning at the synchronous RPM. This braking moment creates additional heating in the motor, and wear on the motor and gearbox of the pumping unit. By removing voltage to the motor during these periods, these side effects can be eliminated in addition to the primary goal of reducing electrical consumption.

ENERGY COST AND SAVINGS EXAMPLES

The cost of energy for a pumping unit can vary substantially, but **Error! Reference source not found.** shows example savings for 100HP, 60HP and 30HP motors that operate 24hours and 18 hours per day, seven days per week. The savings are calculated across a range of utility rates of $0.10, $0.12, and $0.14 per kWh. Using an average energy savings of 20%, the MotorWise device can provide a significant reduction in operating expenses related to power consumption, especially when installed on a wide-spread basis. The far right columns show the payback in number of years, which is generally less than two years. On large horsepower motors, especially in areas with high utility rates, the payback is significantly quicker.

CONCLUSIONS

1. Current is not a direct measurement of power consumed by an AC motor. Power factor correction capacitors reduce current but do not reduce consumed power.
2. A small portion of the stroke causes the motor to generate power back to the utility
3. When the motor is generating, it acts as a brake which generates heat in the motor
4. This braking action puts wear and tear on the motor and gear box
5. Removing voltage from the motor when it would normally be generating can reduce electrical consumption and wear and tear on the system

ACKNOWLEDGEMENTS

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Table 1 - Energy Cost and Savings Examples

Pumping Unit Operating 24/7 — **20% SAVINGS**

	kWh	Unmanaged			MotorWise Managed			Savings/Year			Revenue/ 2000 Wells	Payback (Years)		
HP	24/7 for 30 days	$ 0.10	$ 0.12	$ 0.14	$ 0.10	$ 0.12	$ 0.14	$ 0.10	$ 0.12	$ 0.14	$ 0.10	$ 0.10	$ 0.12	$ 0.14
100	18774	$1,877	$2,253	$2,628	$1,502	$1,802	$2,103	$4,506	$5,407	$6,308	$9,011,520	1.06	0.88	0.76
60	11264	$1,126	$1,352	$1,577	$ 901	$1,081	$1,262	$2,703	$3,244	$3,785	$5,406,912	1.27	1.06	0.90
30	5632	$ 563	$ 676	$ 789	$ 451	$ 541	$ 631	$1,352	$1,622	$1,892	$2,703,456	1.87	1.56	1.33

Pumping Unit Operating 18/7 — **20% SAVINGS**

	kWh	Unmanaged			MotorWise Managed			Savings/Year			Revenue/ 2000 Wells	Payback (Years)		
HP	18/7 for 30 days	$ 0.10	$ 0.12	$ 0.14	$ 0.10	$ 0.12	$ 0.14	$ 0.10	$ 0.12	$ 0.14	$ 0.10	$ 0.10	$ 0.12	$ 0.14
100	14081	$1,408	$1,690	$1,971	$1,126	$1,352	$1,577	$3,379	$4,055	$4,731	$6,758,640	1.41	1.18	1.01
60	8448	$ 845	$1,014	$1,183	$ 676	$ 811	$ 946	$2,028	$2,433	$2,839	$4,055,184	1.69	1.41	1.21
30	4224	$ 422	$ 507	$ 591	$ 338	$ 406	$ 473	$1,014	$1,217	$1,419	$2,027,592	2.49	2.08	1.78

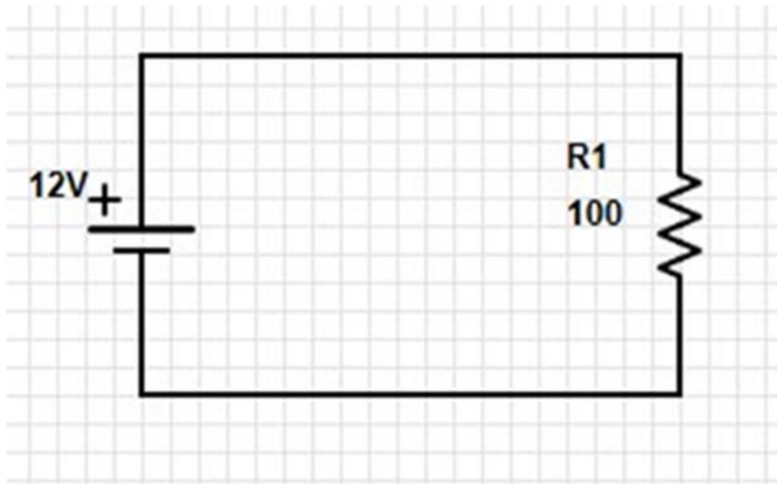

Figure 1 - DC Electrical System (Power (Watts) = Voltage x Current)

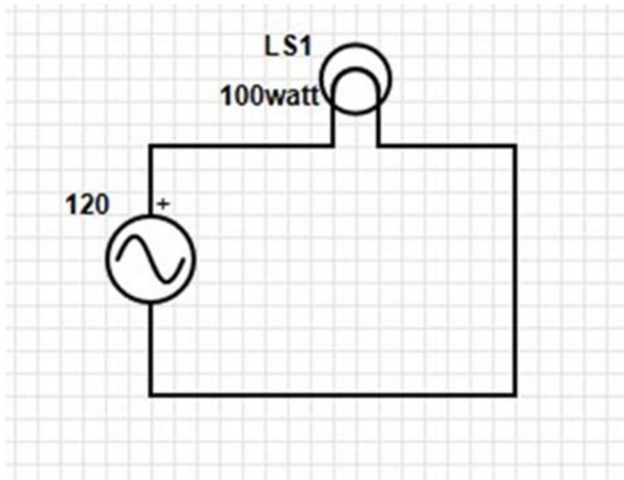

Figure 2 - Single Phase AC Electrical System (Power (Watts) = Voltage x Current x Power Factor)

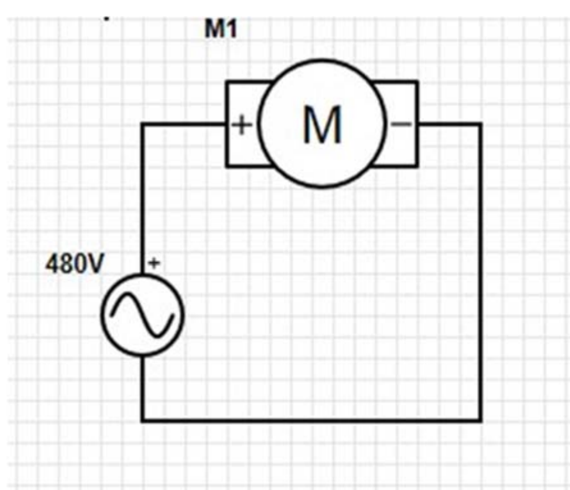

Figure 3 - Three Phase AC Electrical System (Power (Watts) = 1.73 x Voltage x Current x Power Factor)

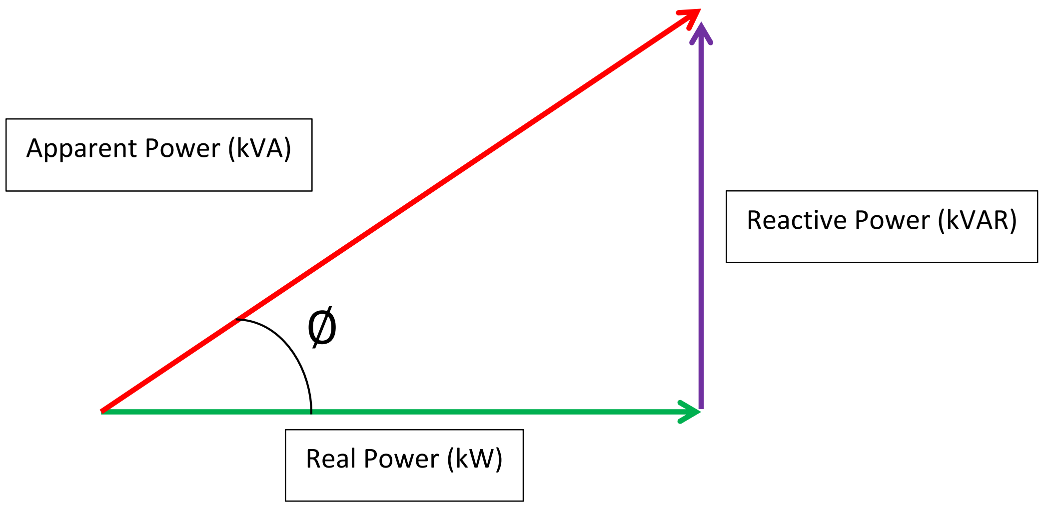

Figure 4

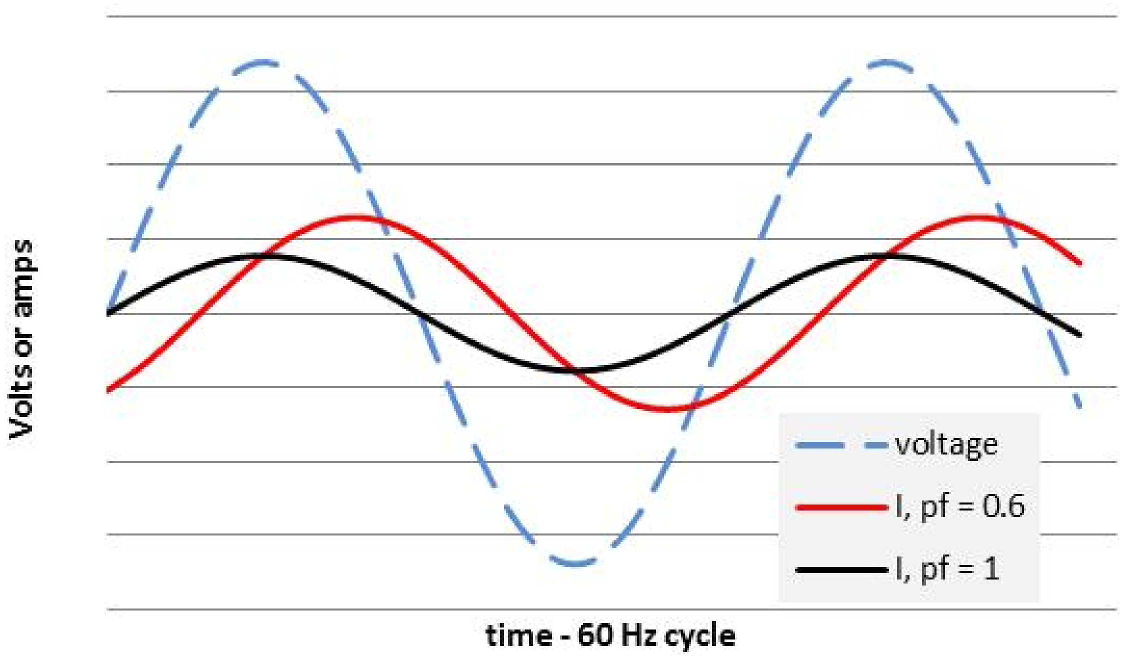

Figure 5 - Relationship of Power Factor to Current

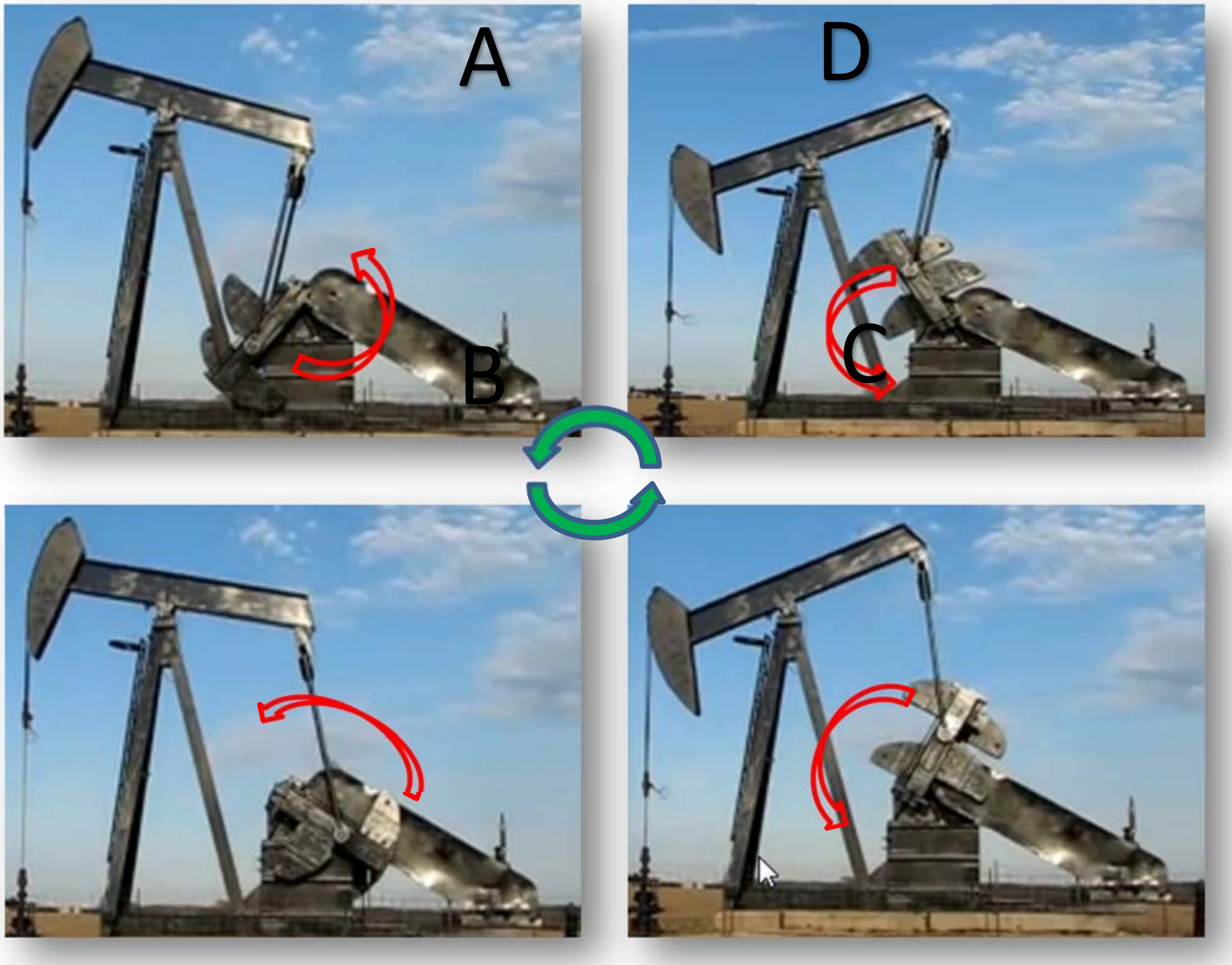

Figure 6 – Pumping Unit Cycle

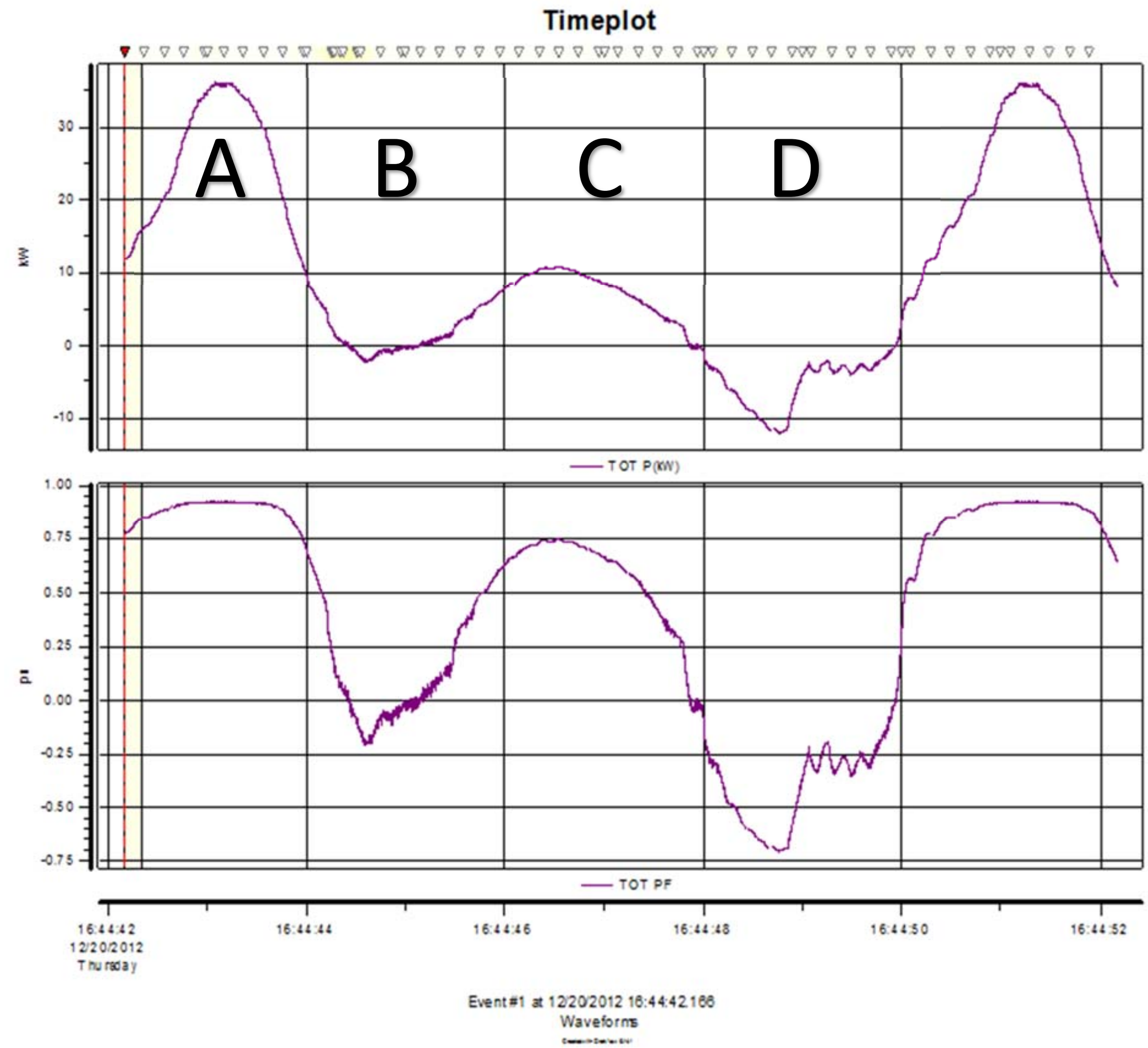

Figure 7 - Motor Loading Without MotorWise

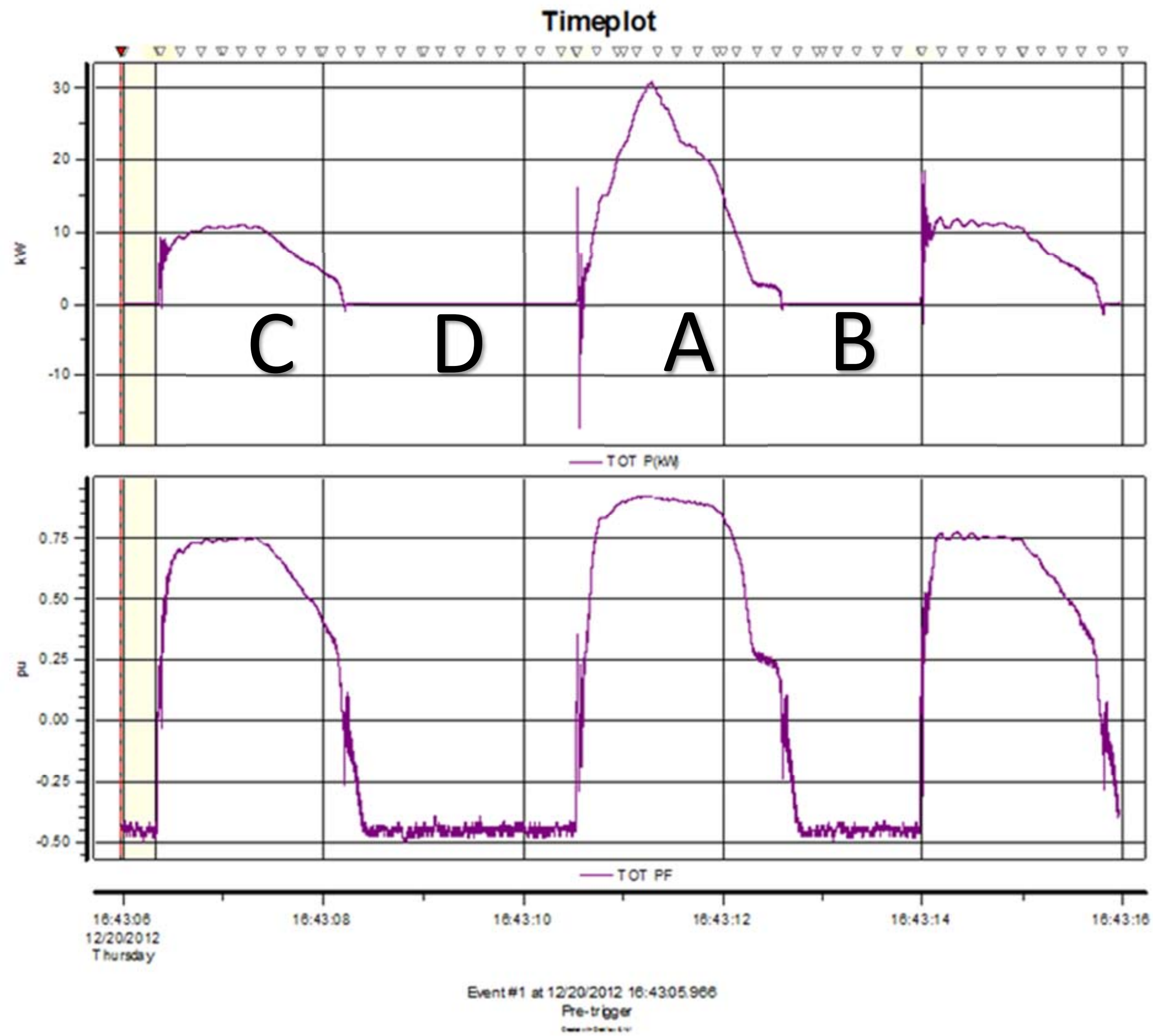

Figure 8 - Motor Loading With MotorWise