Wireless Motor Power-Current-Voltage Measurements and Analysis

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Abstract

Wireless high-frequency motor power-current-voltage measurements are used to analyze the electrical and mechanical performance of pumping units. The sensors can be mounted permanently in the electrical box with a water-tight connection on the side of the electrical box for attachment of a small plug-in radio for wireless communication to a PC base station. These measurements can be performed without opening the electrical box. In addition, starter boxes without internal sensors can be analyzed using portable sensors that require opening the box and attachment of two current and three voltage sensors.

TAM Software in the PC receives and analyzes the data to determine power usage, power generation, pumping unit balance, gear box upstroke and downstroke torques, motor loadings, and power line loss. Power line loss is an analysis performed to analyze the power line loss between the electrical system and the pumping unit motor. The counter-weight movement for gear box balance is determined easily without use or knowledge of the pumping unit dimensions.

Introduction

In those wells where the pumping system is powered by electrical motors, current (Amps) and power (kW) measurements have been used routinely for many years as a tool to achieve balanced torque conditions at the gearbox of pumping units. These measurements require connecting instruments to live electrical circuits, which always involves the associated risk of electrical shock. It is important that all safety procedures be followed and instrument instruction and operation manuals be read and understood prior to performing these measurements. To increase the safety of working conditions, all shocks and defective equipment should be reported. A shock means that something is wrong. The slightest shock when operating an electrical device might, under other circumstances, result in instant death if part of the body makes only slightly better contact with the ground or a grounded metallic object.

One of the objectives of the new Wireless Power/Current/Voltage/ is to minimize the risk of electrical shock and eliminate the need to open the switch box to install the electrical sensors by providing a permanently installed electrical connector external to the switch box where the wireless sensor may be plugged in during the time when records are being acquired. In addition, the wireless instrument can also be connected to the wires and terminals inside a box that is not outfitted with the external connector via a cable harness consisting of two current probes and three voltage sensing clips.

General Considerations

Electrical current measurements, made by using a hand held multi-meter, are commonly used to monitor peak amperage values during up-stroke and down-stroke while the pumping unit is operating and determine whether the existing counterbalance is sufficient to smooth out the torque applied to the unit's gear box. Since the advent of portable computers and digital instrumentation software applications have been available to acquire current and power data simultaneously with dynamometer records to provide the necessary information to perform a very complete analysis of the beam pumping system that includes the balancing analysis, motor performance, operating cost, and overall pumping system efficiency.(McCoy, 1992)(Podio, 1994) (Ott, 1995)

Motor Current and Power Measurement

Since the majority of beam pump motors are operated with 3-phase alternating power, quantitative measurement of instantaneous power requires using sensors that consist of two current probes and three voltage leads, which are connected to the three phase leads inside the pumping units switch box

The conventional instrument generally used to measure current flowing to a motor consists of a split-jaw transformer (Figure 1a), installed around one of the power wires, which feed electricity to the electric motor. (Lea, 1988)The probe generates a millivolt signal that is proportional to the instantaneous current flowing through the wire around which the probe is clamped. When using this portable instrument always make sure that the sensor probe is free of moisture before making any connections. In order to obtain consistently accurate results, it is recommended that, whenever attaching a current probe, the power cable should be kept within the center line of the jaws and perpendicular to the probe as much as possible. Once the measurement has been completed the probe is removed from the cable.

The new Wireless Power Sensor instead uses two current probes that consist of toroidal secondary transformer coils that are permanently installed surrounding the leftmost and rightmost wires that feed power to the motor. The two current transformers are isolated by double insulation from the motor power.

Their millivolt output is fed (via the white wires) to the pins of the electrical connector that is mounted on the side of the electrical switch box as shown in Figure 1C. The measured current is the average value of Phase C stated in RMS units assuming a sinusoidal waveform.

Figure 1a-Split jaw transformer

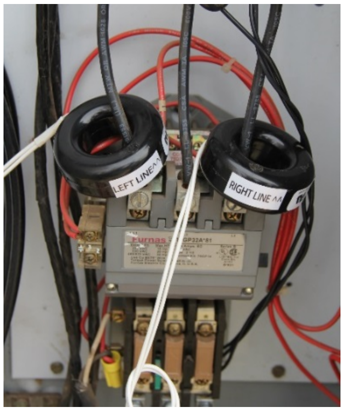


Figure 1B-Permanent Current probes

Figure 1C- External Feed-through

Three voltage leads (black wires) are connected directly to the terminals on the downstream side of each of the three fuses and fed to the permanent connector pins through a resistance of 664 Kohms. At 480 Volts RMS, the RMS current is limited to 0.72 mA to ground, which is a safe value.

The connector is an 8 pin water tight MS series connector. A sealed cover protects the female pins from weather induced corrosion as shown in Figure 2a.

Permanent installation of the current and voltage sensors within the electrical switch box and connecting the corresponding wires to the external feed-through mounted on the side of the switch box as shown in Figure 2b insures increased safety of the Wireless Power Probes and allows a field technician who may not be a licensed electrician to attach the Wireless Power Transmitter to the external connector without having to open the electrical switch box as shown in Figure 2b.

Figure 2a –External Connector with cover.

Figure 2 b Wireless Power Transmitter

To complete the power measurement, simply remove the sealed connector cover and attach the Wireless Power Transmitter making sure the pins make good contact by hand tightening the locking nut until snug. Press the power switch and verify the battery charge then and verify communication with the base station that is connected to the laptop that is running the TAM program. Ensure that the sensor is in line of sight of the base station for best communication.

Portable Wireless Power Sensor

The Wireless Motor Power measuring system can also be provided with a wiring harness that permits installing two split-jaw current sensors and three voltage clips once the switch box has been opened by a licensed electrician. All the safety considerations discussed earlier must be implemented when installing the sensors as shown in Figure 3.

Figure 3 – Wireless Power Sensor connected to the wiring harness used to attach the current and voltage leads when an external connector is not permanently mounted outside the electrical switch box.

When using this wiring harness to complete motor power measurement, the following steps should be taken:

1. Turn off the pumping unit and wait for the motion to stop and for the cranks to come to rest.
2. Disconnect the main power switch and open the switch box carefully.
3. Visually inspect the wiring, fuses, cables, relays, switches etc., looking for indications of loose connections, overheating, damaged insulation on cables, and any other clue that suggests possible electrical faults. If there are any doubts about the safety of the wiring, stop the test and report the findings to a supervisor, or have a qualified electrician repair the problem.
4. Using the cable harness, attach the current probes with care by clamping them around the leftmost and rightmost cables coming from the line and going to the motor. Note the marking on the current probes that indicate which side of the current probe faces the power line or energy source. If the current probes are not installed correctly, the system will indicate power incorrectly. For the best results, the probes should be attached to a section of wire which is straight and fits in the center of the probe.
5. Ensure that the jaws are completely closed and that the wire is centered within and perpendicular to the jaws. A slight loss of signal can occur if not installed properly.

6. Attach the voltage sensing clips to the left, center and right terminals as shown in Figure 3.
7. Connect the cable harness to the Wireless Power Sensor and press the power switch to verify the battery condition.
8. Once communication with the TAM software is established and verified, the system is ready for use.

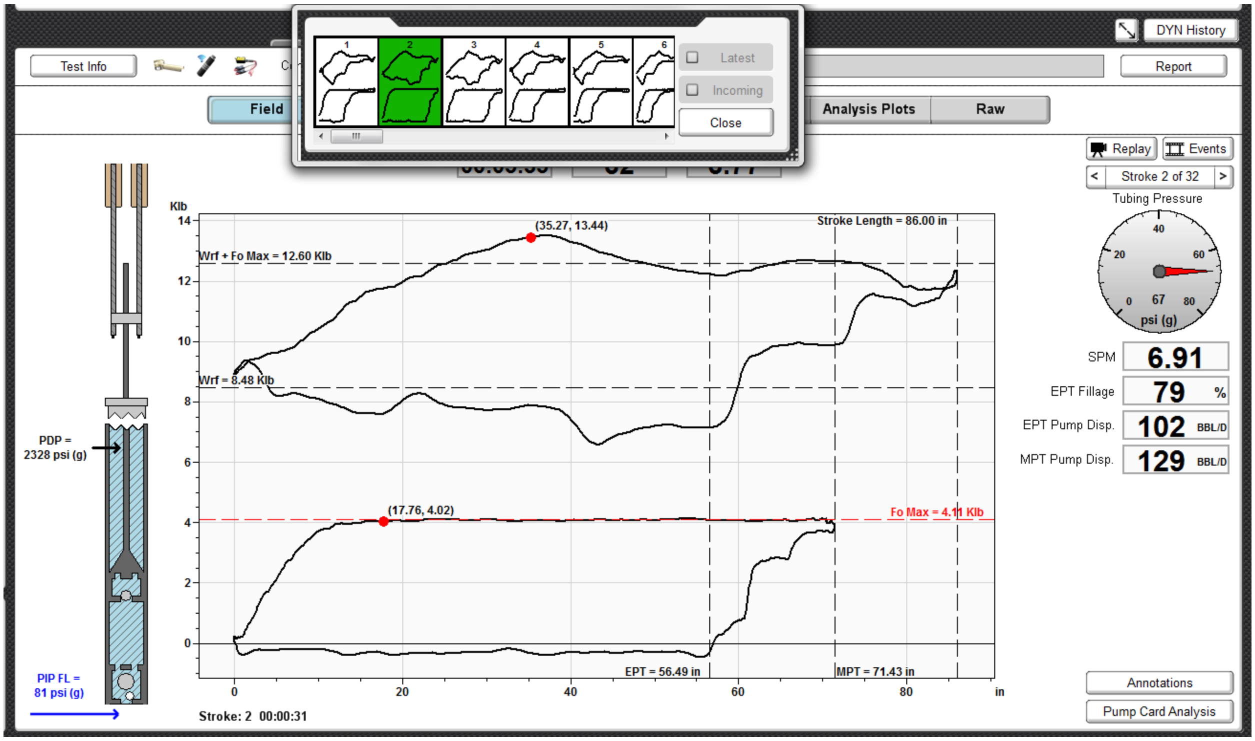
Test data indicates linearity of about 0.1% power. The variation expected from the use the Fixed Power Adapter due to variation in current transformers is expected to be about 1 percent. The dropping resistors are rated 0.1%. I would expect the absolute error to be better than 2 percent worse case.

Data Sampling and Transmission

The power, voltage, and current are the average of the last two power line cycles. They may be sampled at various rates but have little meaning if sampled above the power line frequency. The data is transmitted to the Wireless Base Station that is connected to the USB port of the user's laptop computer. Generally the power measurement is performed in conjunction with acquisition of dynamometer data but it can also be performed as a standalone measurement that is synchronized with the motion of the polished rod. This is performed by the user indicating to the acquisition software the time when the polished rod is at the bottom of a stroke and the time when it returns to the bottom after two strokes have been completed.

Analysis of Motor Current for a Single Pump Stroke

In beam lift applications, the most advantageous method of motor current analysis is to acquire the current data simultaneously along with the dynamometer data or to provide means for synchronizing the current values with the position of the polished rod. Figure 4 shows dynamometer data acquired simultaneously with power and tubing pressure during a pump stroke where the barrel is almost filled with liquid.



Tubing Pressure 67 psi (g)

SPM 6.91

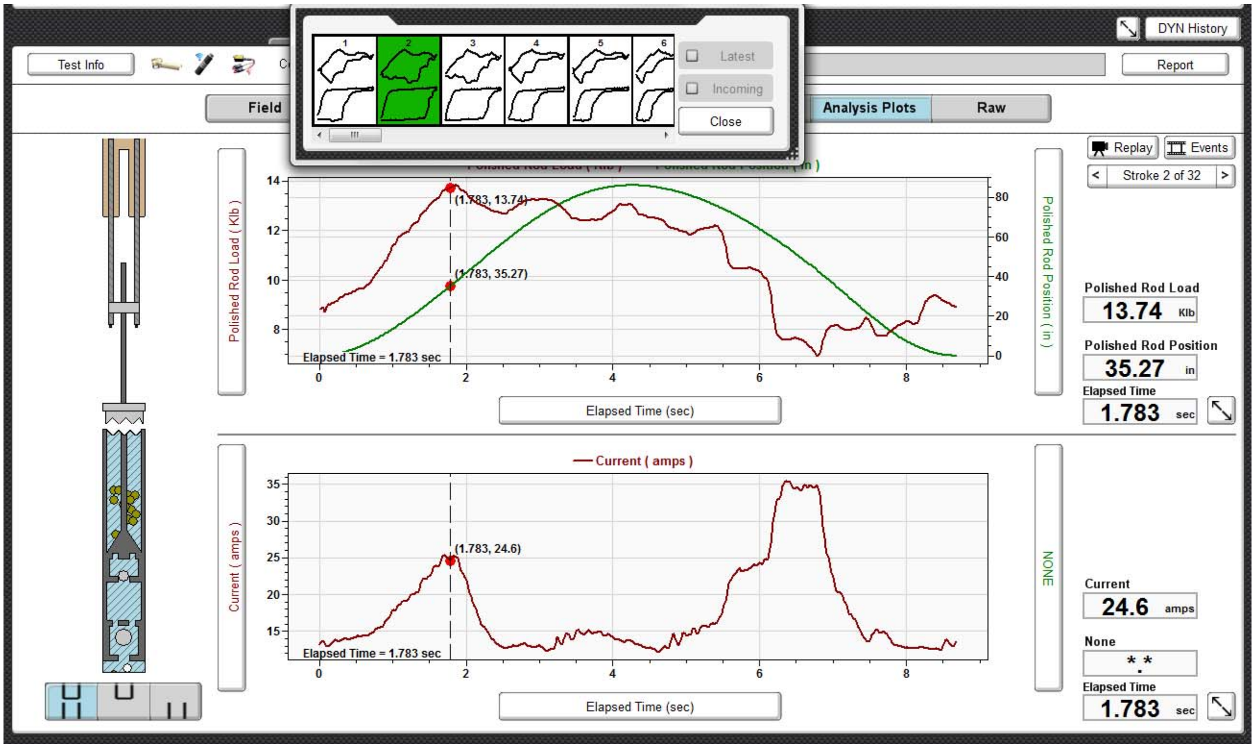
EPT Fillage 79 %

EPT Pump Disp. 102 BBL/D

MPT Pump Disp. 129 BBL/D

Figure 4 – Surface and pump dynamometer acquired simultaneously with Wireless Power and Wireless Pressure Sensors

Figure 5 shows the motor current data (lower panel) for the same stroke as shown in Figure 4 and the corresponding polished rod load and polished rod position (upper panel) plotted as a function of time; the first half of the record corresponds to the upstroke and the second half to the downstroke. The vertical dashed line can be positioned manually to display the plot values recorded during the stroke. In the figure is located at the time where the maximum value of current is measured during the upstroke: the polished rod position is at 35.27 inches from the bottom, the polished rod load is 13,700 Lbs. and the motor current is 24.6 amps.



Polished Rod Load
13.74 Klb

Polished Rod Position
35.27 in

Elapsed Time
1.783 sec

Current
24.6 amps

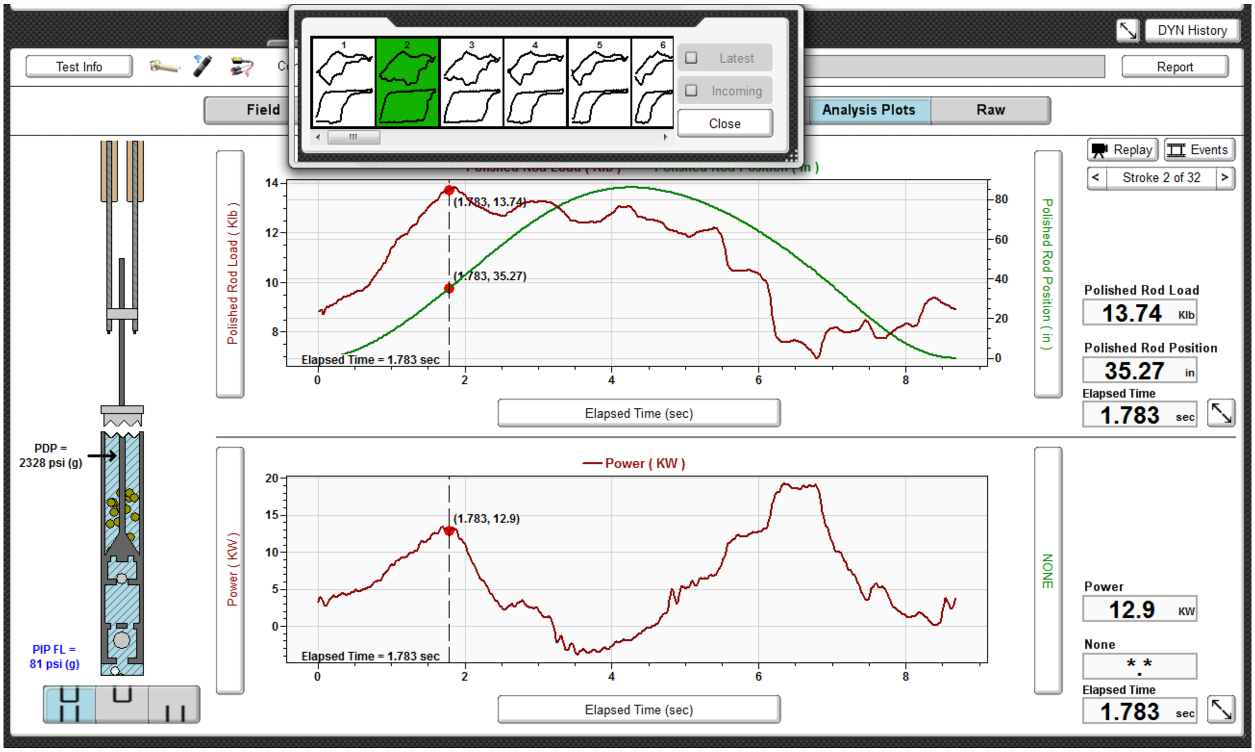
None
* *

Elapsed Time
1.783 sec

Figure 5 Polished rod load, polished rod Position and motor current versus time

Figure 5 shows that more current (peaks at about 35 amps) is flowing during the downstroke (4.5 to 8.5 seconds) than the upstroke (0 to 4.5 seconds), although the polished rod load is lower (about 7,500 Lbs.) during the downstroke. This is an indication that the unit is overbalanced or weight-heavy and that the counterweights need to be adjusted in order to reduce the moment they produce at the crank.

The combination of the measured current, measured voltage and the phase angle yields the data required to compute power at the electrical motor which is displayed as a function of time in the lower panel of Figure 6. The upper panel shows the corresponding polished rod load and position. Notice the similarity between the power curve and the amps curve vs. time that are displayed in Figure 5. More power is being used by the motor to lift the counterweights (about 19 kW) during the downstroke than to lift the polished rod (12.9 Kw) during the upstroke. In addition it can be noticed that during the time when the polished rod is traversing the top of the stroke from 3.2 to 4.6 seconds the power is indicated as negative which means that the motor is being driven, by the beam pump cranks, at a speed greater than its synchronous speed (1200 RPM) and thus is generating electricity that is fed back to the power line.



Polished Rod Load 13.74 Klb
Polished Rod Position 35.27 in
Elapsed Time 1.783 sec
Power 12.9 KW
None * *
Elapsed Time 1.783 sec

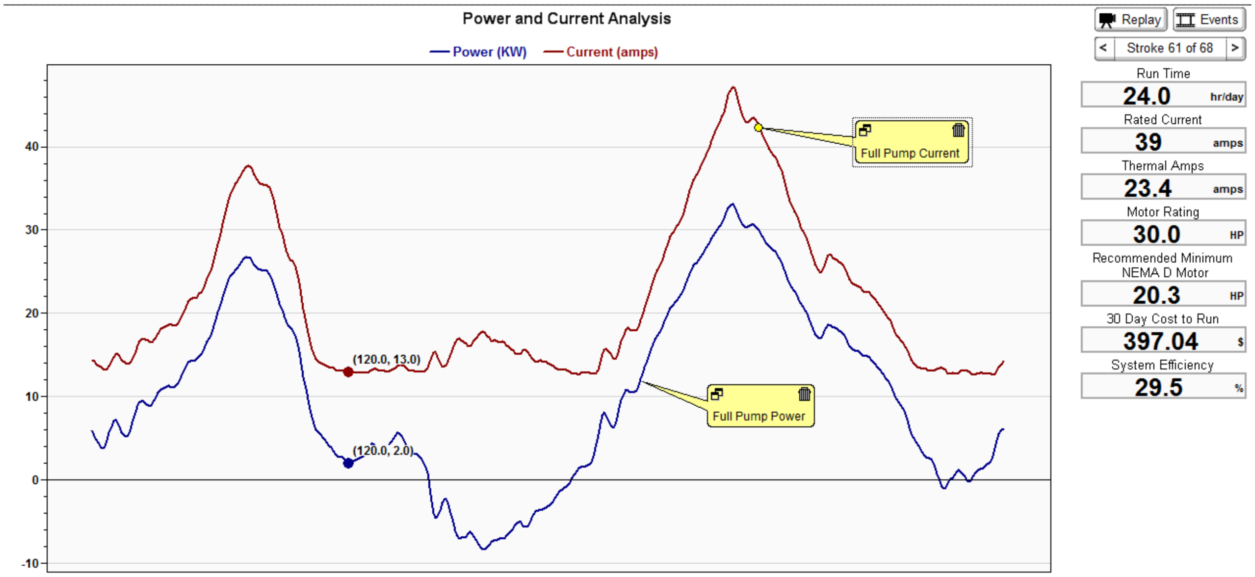
Figure 6 - Polished rod load, polished rod Position and motor power vs. time

Quantitative Power and Current Analysis

In general, the operator is interested in establishing the power use and the balance condition of the pumping system when it is operating at steady state. In cases in which the well is initially pumping a full barrel of liquid and then begins to pump a partial barrel, the measured power will vary from stroke to stroke and may not be representative of normal operating conditions. Therefore, it is advisable to ensure that, during testing, the well being tested is produced under conditions that are the same as during normal operations. This can easily be undertaken by running dynamometer measurements simultaneously with the power measurement, but this is not a requirement. If the well is operated with a pump-off controller or timer the analysis should be undertaken using a stroke that corresponds to full liquid fillage. If the pumping unit is operated On-hand and the pump operates most of the time with partial liquid fillage the analysis should be done for a stroke that exhibits partial fillage. (Podio, 2001)

Quantitative analysis of the current data yields the electrical loading of the motor that is determined by calculating the thermal amps or root-mean-square (RMS) of the individual current samples of the stroke (23.4 amps in this example) by taking the square root of the average of the instantaneous current squared which, compared with the rated full load (39 amps), results in a motor load that is 65.1% of the rated value. This quantity is the *heat loading* of the motor. The average power is computed as the voltage multiplied by the RMS current corrected for power factor and, when compared with the rated power of the motor, results in a mechanical loading of 30% for this example.

Figure 7 is an example of the quantitative analysis related to energy utilization during a single pump stroke. Displayed on the figure as a function of time are the instantaneous apparent current and power measured over one complete stroke of the pumping unit. Time increases from left to right. Thus, the first half of the plot corresponds to the upstroke and the second half to the downstroke. The horizontal line corresponds to zero power and current. Values below this line indicate electrical generation when the motor is driven by the counterweights to speeds above the synchronous speed.



Run Time 24.0 hr/day

Rated Current 39 amps

Thermal Amps 23.4 amps

Motor Rating 30.0 HP

Recommended Minimum NEMA D Motor 20.3 HP

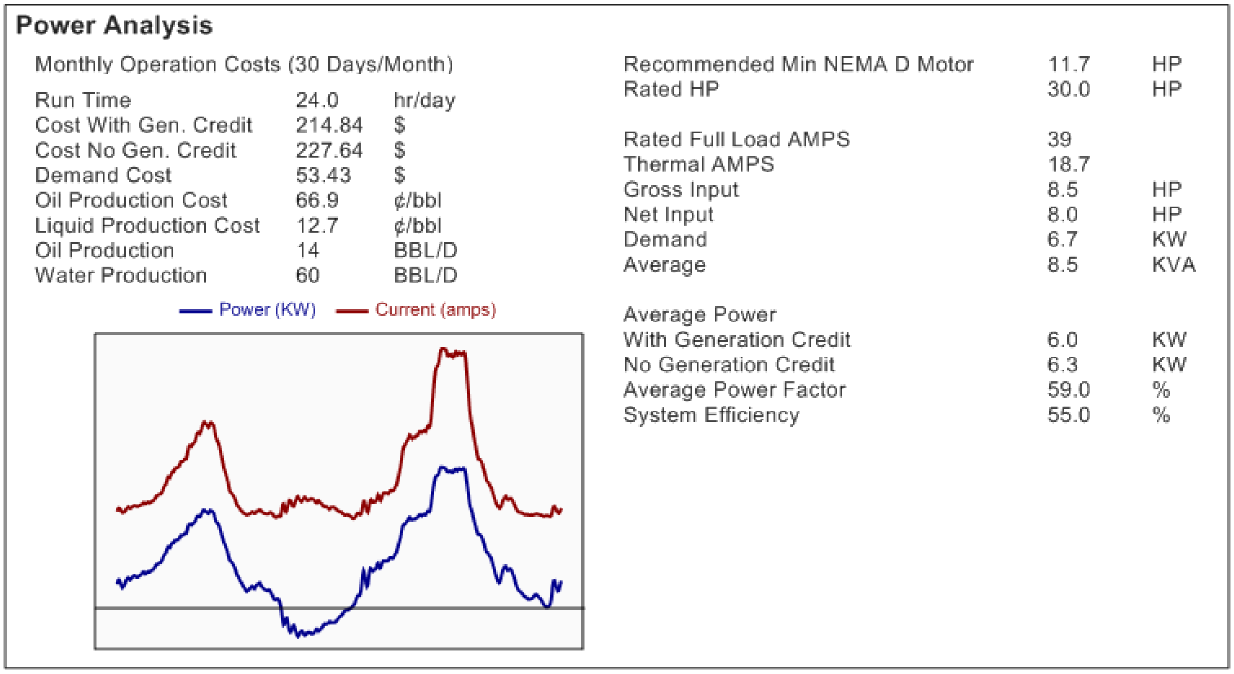
30 Day Cost to Run 397.04 $

System Efficiency 29.5 %

Figure 7 - Quantitative analysis of electrical motor loading, power use and cost

On the right side of the figure, the principal electrical loading and efficiency parameters are summarized. The energy cost per month, which corresponds to the indicated daily run time and based on the cost per kilowatt hour and the kW demand cost input by the user is shown.

The detailed power analysis report in Figure 8 includes all relevant values required to analyze the efficiency of the system and evaluate its performance. The operating cost is calculated on the basis of a barrel of fluid pumped and a stock tank barrel of oil produced and also considers whether credit is applied for power generation during the stroke. The credit for power generation is not a consideration when the power company metering supplies several pumps operating at the same time as the generated energy will be absorbed by other pump motors, reducing power purchased. In that case, the generation credit values may be used whether or not the power company offers credit for generated power. These cost values are calculated from the production rates, based on the most recent well test. It should be noted that, often, well test data is not as accurate as is desired. If dynamometer measurements were undertaken simultaneously with the power measurement, the downhole pump displacement is calculated from the pump dynamometer card. This displacement should be reasonably close to the volume reported from the well test. If this is not true, then either the well production may have changed significantly or the well test was not reported accurately or a high clearance pump plunger is being used that allows significant pump leakage.


Power Analysis

Monthly Operation Costs (30 Days/Month)

Run Time	24.0	hr/day
Cost With Gen. Credit	214.84	$
Cost No Gen. Credit	227.64	$
Demand Cost	53.43	$
Oil Production Cost	66.9	¢/bbl
Liquid Production Cost	12.7	¢/bbl
Oil Production	14	BBL/D
Water Production	60	BBL/D

Recommended Min NEMA D Motor	11.7	HP
Rated HP	30.0	HP
Rated Full Load AMPS	39	
Thermal AMPS	18.7	
Gross Input	8.5	HP
Net Input	8.0	HP
Demand	6.7	KW
Average	8.5	KVA
Average Power		
With Generation Credit	6.0	KW
No Generation Credit	6.3	KW
Average Power Factor	59.0	%
System Efficiency	55.0	%

Figure 8- Detailed Summary Report of Power Analysis and Operating Cost

Power measurements are instrumental in minimizing operating costs, since they pinpoint wells that are not operating efficiently. The System Efficiency of 55% displayed in the report corresponds to the overall efficiency by comparing the power supplied to the motor to the effective power delivered by the pumping system when lifting to the surface 74 Bbl/day (14 Oil, 60 Water). The value of the efficiency should be as high as possible. When this value drops below a certain threshold (for example 40%) it is an indication that the pumping system should be analyzed in detail to identify the cause of the inefficiency and perform necessary adjustments to the operating parameters or perform equipment maintenance.

Torque Calculation from Motor Power Measurement

Pumping unit counterbalancing has always been an integral part of those field activities designed to reduce operating costs. Most commonly, counterbalance adjustment has been undertaken using an indicating ammeter to monitor the peak values of motor current during the upstroke and downstroke. Adjustment of the counterweights is typically a tedious procedure of trial and error that often does not result in an improved mode of operation. Problems are especially prone to arise if the unit is significantly out of balance. In certain instances, the peak current indications of a common ammeter can be confusing as a result of the presence of a large generating current, which cannot be distinguished from current peaks corresponding to high motor demand. (McCoy, 1995, 2000)

Accurate balancing of beam pumping systems is greatly simplified by the acquisition of instantaneous electrical power used by the prime mover and converted to torque; recall that, in a rotating system, the instantaneous power is given as torque multiplied by rotary speed. In a beam pumping system, the instantaneous torque at the gearbox can be calculated from direct measurement of the power and the speed of rotation by the following relation:

$$T = 84{,}520\left(e\right)\frac{P}{N\left(SV\right)}$$

$T =$ torque $\left(\text{inch-lb}_\text{f}\right)$

$e =$ efficiency $\left(\text{dimensionless fraction}\right)$

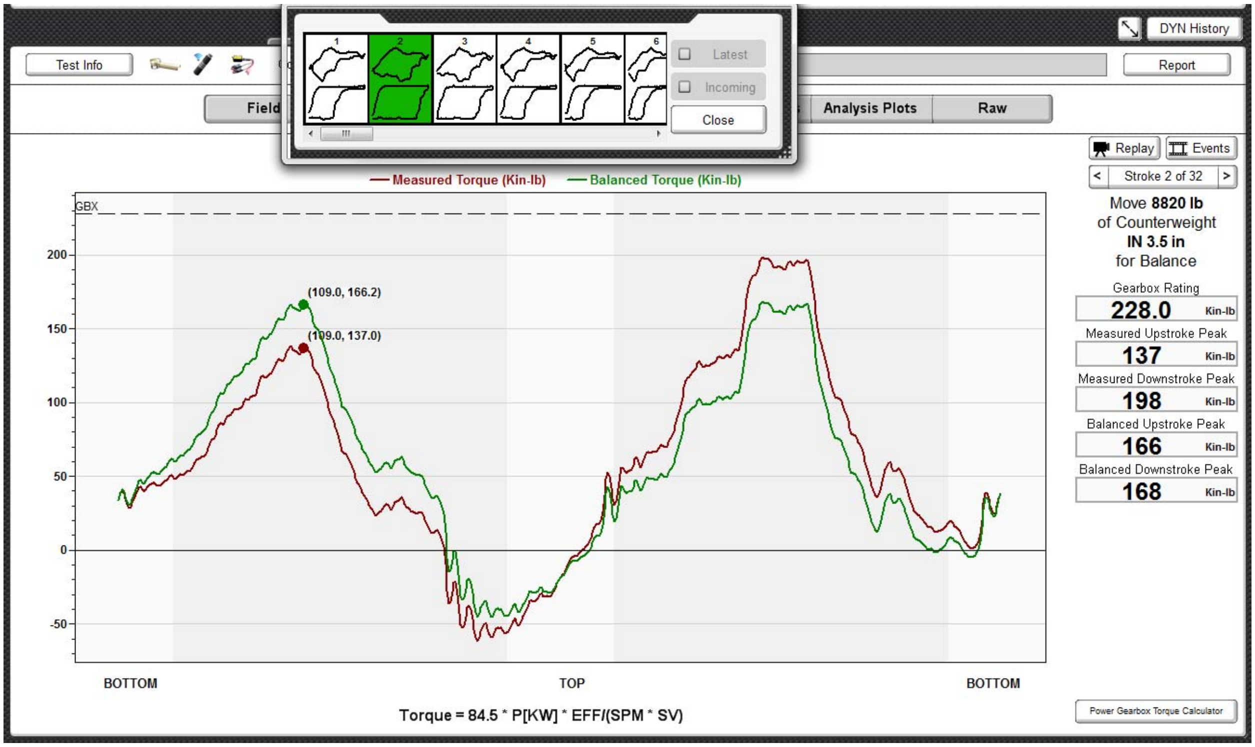
$P =$ power $\left(\text{kilowatts}\right)$

$N =$ pumping speed $\left(\text{spm}\right)$

$SV =$ speed variation factor $\left(\text{dimensionless}\right)$

The efficiency (e) of power conversion by the motor and power transmission through the belt drive and the gear reducer varies with each installation and with the loading of the system. In general, efficiency decreases as loading decreases. For a normally loaded and properly installed system, the efficiency has been estimated at 77% but can be much lower if the unit is not properly maintained. The calculation also requires knowledge of the instantaneous crank speed. This quantity is directly related to the average pumping speed (N) and is multiplied by the speed variation factor (SV), which is determined from the dynamometer measurement as the ratio of the minimum to the average crank speed. If dynamometer data is not available, the speed variation factor is assumed to be unity.

Figure 9 shows typical torque analysis output. On the left side of the figure, two torque curves have been plotted as a function of time; the solid red line corresponds to the calculated electrical torque, and the green line corresponds to the torque that would be observed if the unit were counterbalanced in such a way that the peak upstroke torque was equal to the peak downstroke torque. Note that the negative torque corresponds to the portion of the stroke at which the gear reducer is driving the motor into the generation region.



Move **8820 lb** of Counterweight **IN 3.5 in** for Balance

Gearbox Rating: 228.0 Kin-lb

Measured Upstroke Peak: 137 Kin-lb

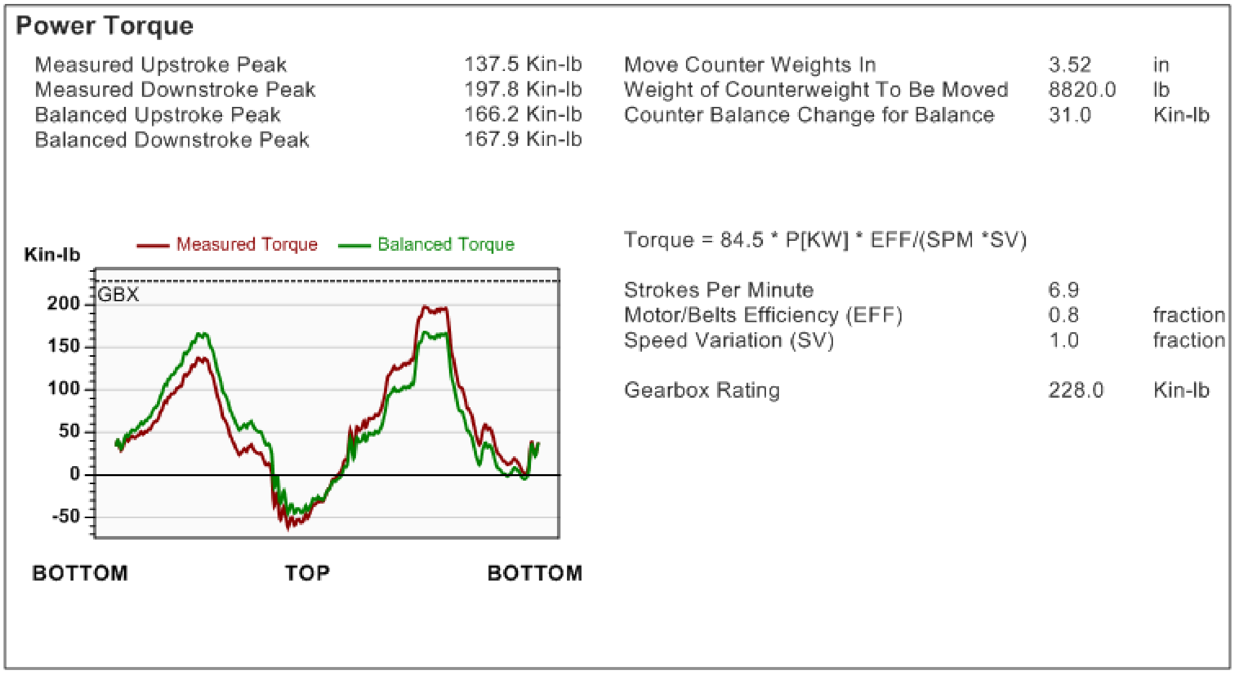
Measured Downstroke Peak: 198 Kin-lb

Balanced Upstroke Peak: 166 Kin-lb

Balanced Downstroke Peak: 168 Kin-lb

Figure 9 Single Stroke Torque analysis from motor power measurement

On the right side of the figure, the tabulated torque analysis gives the upstroke peak torque and the downstroke peak torque values in thousands of inch-lbs. that occur during the stroke. The difference between these values is a measure of the unbalance of the system. If the upstroke peak is greater, the unit is underbalanced or “rod heavy.” If the downstroke peak is greater, the unit is overbalanced or “crank heavy.” In this example, the unit is slightly overbalanced and has an upstroke peak of 137,000 inch-lbs. and a downstroke peak of 198,000 inch-lbs. The torque that would be experienced if the counterbalance were adjusted so that the two peaks were equal is displayed as the balanced peak value and is estimated at 166,000 inch-lbs. Assuming that the weight of the existing counterweights that can be moved is 8820 Lbs., they should be displaced inwards a distance of 3.5 inches from their existing location to achieve the balanced condition.



Power Torque

Measured Upstroke Peak	137.5 Kin-lb
Measured Downstroke Peak	197.8 Kin-lb
Balanced Upstroke Peak	166.2 Kin-lb
Balanced Downstroke Peak	167.9 Kin-lb

Move Counter Weights In	3.52	in
Weight of Counterweight To Be Moved	8820.0	lb
Counter Balance Change for Balance	31.0	Kin-lb

Torque = 84.5 * P[KW] * EFF/(SPM *SV)

Strokes Per Minute	6.9	
Motor/Belts Efficiency (EFF)	0.8	fraction
Speed Variation (SV)	1.0	fraction
Gearbox Rating	228.0	Kin-lb

Figure 10, Detailed Analysis of gearbox torque computed from electrical power measurement

Efficiency (shown in the figure as “EFF”), which is the ratio of the power input at the motor and the power delivered at the crank, and the calculated pumping speed (SPM) are also given.

The analysis also indicates the distance and direction of the counterweight movement required to change the counterbalance by the indicated amount of torque. When multiple counterweights are to be moved, each counterweight will have to be moved by the distance displayed by the program.

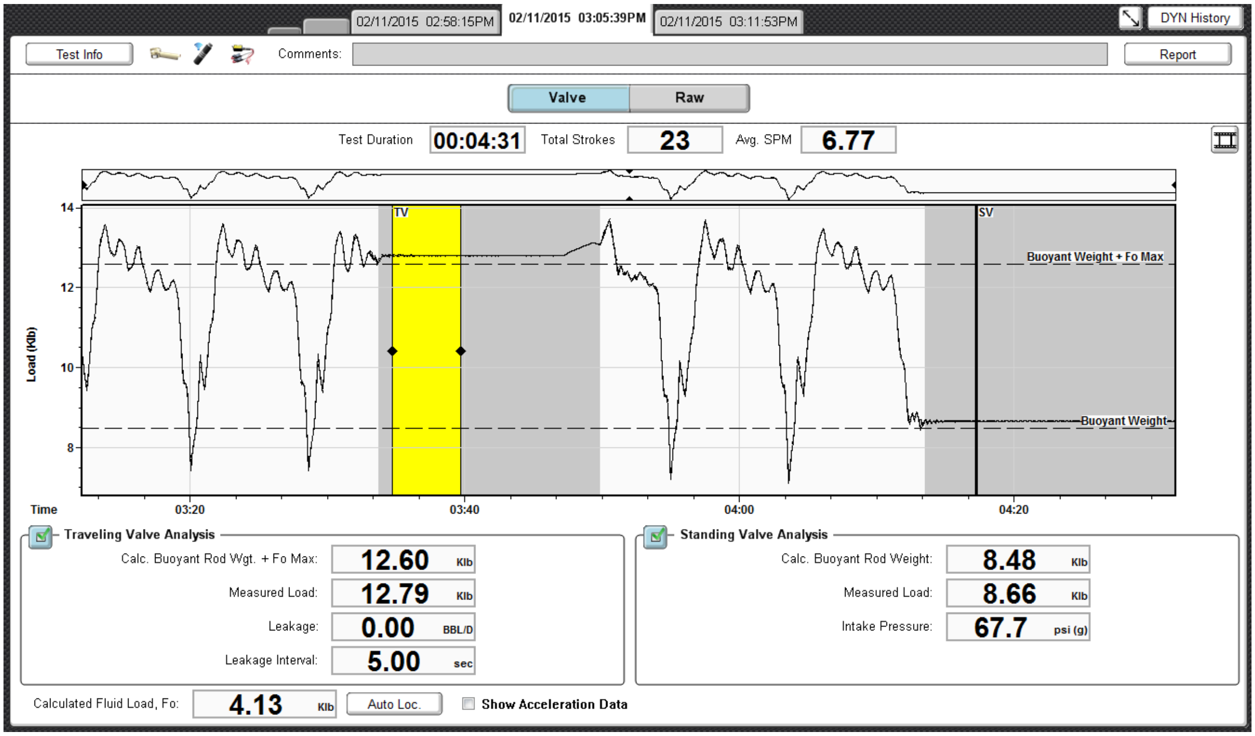
Knowing that the unit in the example well is equipped with 4 counterweights totaling 8,820 lbs., the analysis recommends a movement of 3.5 inches in for all counterweights.

This suggested counterbalance change should be undertaken in stages. After each counterweight is moved, a power measurement should be taken in order to check that the desired effect is being achieved. Experience has shown that proper balancing can be performed quickly when proper equipment is available.

It is impossible to obtain consistent results if the well is not pumping at steady-state conditions. As the well's producing conditions change, the unit should be rebalanced. (Takacs, 2003, Rowlan, 2005)

Estimation of Transmission Line Power Losses

A possible source of inefficiency and additional operating cost is an improperly sized electrical line from the transformer to the switch box. This loss can be estimated from the drop in voltage measured at the switch box when the motor is operating compared to the voltage when the motor is turned off. When the Wireless power measurement is performed simultaneously with a wireless dynamometer test, the line voltage data is automatically acquired while performing the valve test since this test involves turning ON and OFF the motor several times. Figure 11 shows the result of a typical TV/SV test.



Test Duration 00:04:31 Total Strokes 23 Avg. SPM 6.77

Traveling Valve Analysis

Calc. Buoyant Rod Wgt. + Fo Max: 12.60 Klb

Measured Load: 12.79 Klb

Leakage: 0.00 BBL/D

Leakage Interval: 5.00 sec

Standing Valve Analysis

Calc. Buoyant Rod Weight: 8.48 Klb

Measured Load: 8.66 Klb

Intake Pressure: 67.7 psi (g)

Calculated Fluid Load, Fo: 4.13 Klb

Auto Loc.

☐ Show Acceleration Data

Figure 11 – Typical Load Record Acquired During Traveling Valve and Standing Valve Test.

Using the Wireless Motor Power acquisition the voltage and current are also acquired vs time and show the points when the motor was operating and when the motor was stopped. Figure 12 shows all the raw data signals that are normally acquired during wireless dynamometer acquisition. They include polished rod load, polished rod position, motor power, motor current and motor voltage.

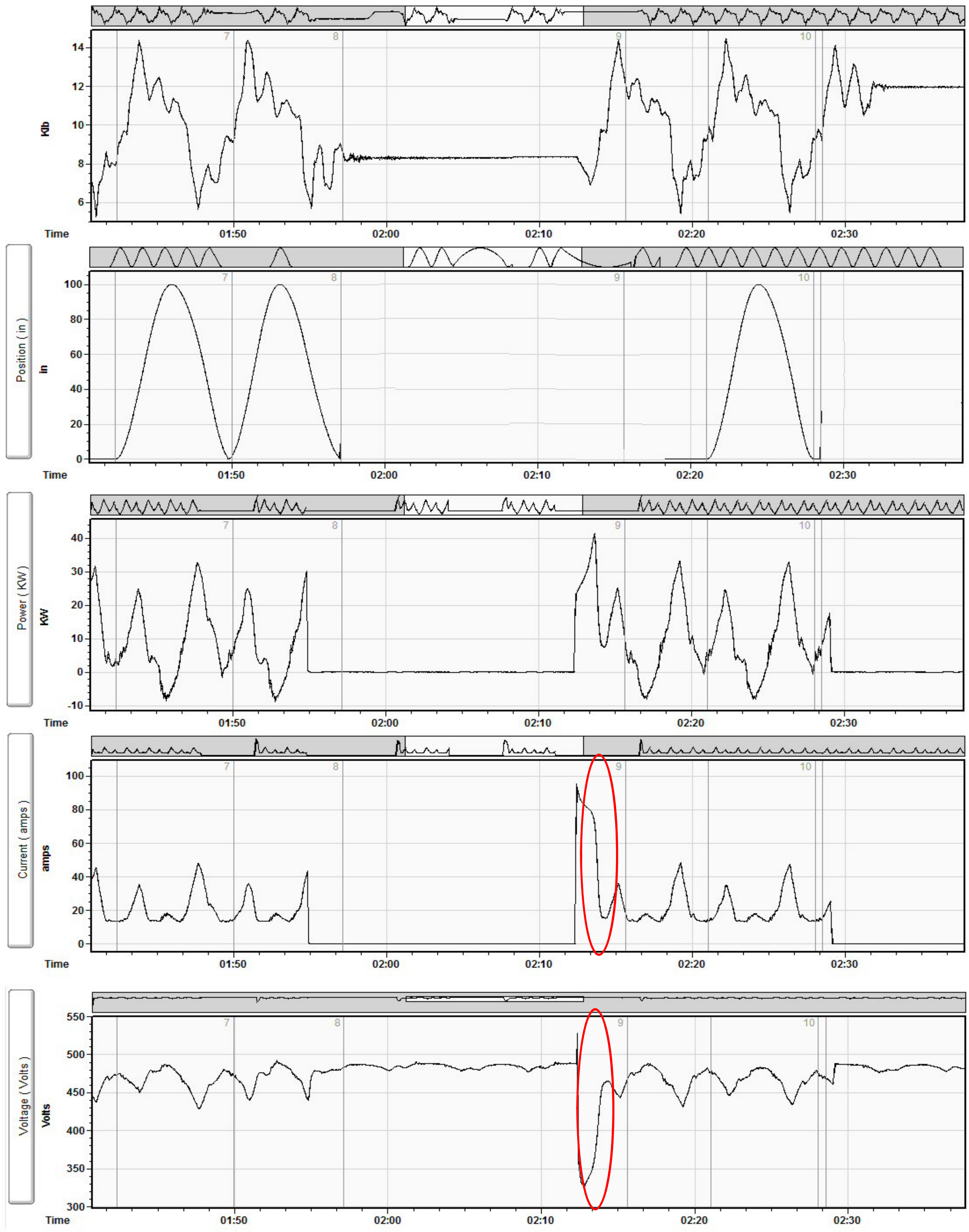
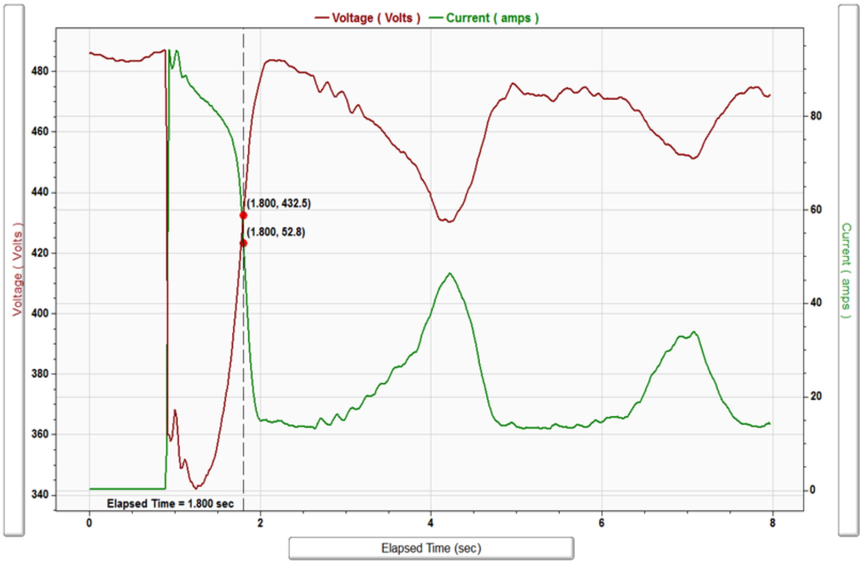


Figure 12 – Simultaneous Wireless Acquisition of Polished Rod Load, Polished Rod Position, Motor Power, Motor Current and Motor Voltage while Performing Valve Test.

Figure 12 shows how the current spikes up for a short time (about 1/3 of a stroke period highlighted in the figure) during the start-up of the motor and then settles to normal levels after the first stroke is completed. At the same time the voltage drops from about 480 volts (switch is off) to approximately 340 volts, then rises to a value close to the line operating voltage of 440 volts, then oscillating about this value as the pump is stroking.

A detailed analysis of the relation between the current and voltage during the start-up time yields an estimate of the resistance of the line from the transformer to the motor. This value of resistance can then be used to estimate the losses that occur in the line and the corresponding operating cost. Figures 13 through 16 show in detail the procedure that can be followed to estimate the line loss and its portion of the operating cost.



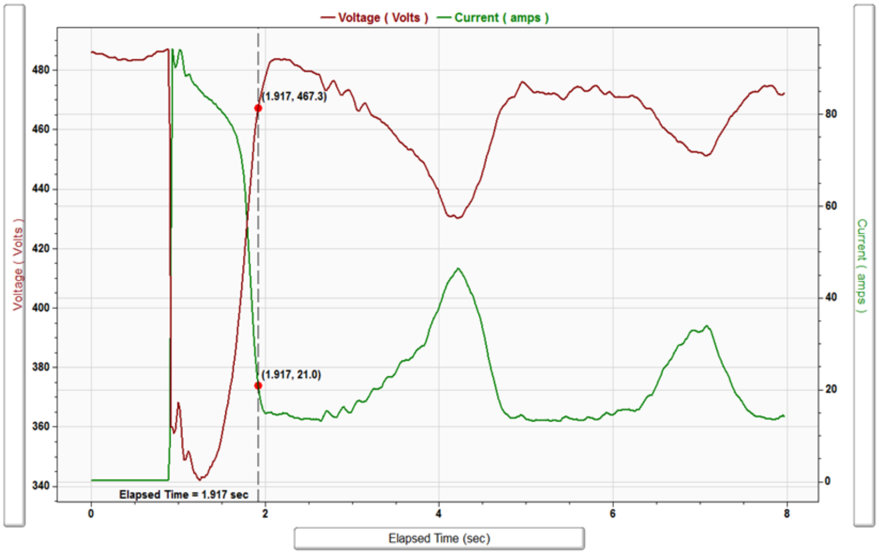
Step 1

To determine line loss, pick the voltage and current values after the motor is started when the current is dropping rapidly nearest 50A.

Volts = 432.5

Current = 52.8

Figure 13 – Voltage and current during motor startup.



Step 2

Next, pick a second point of voltage and current at a point prior to the next current minimum but no more than 100 mSec in time from the first value.

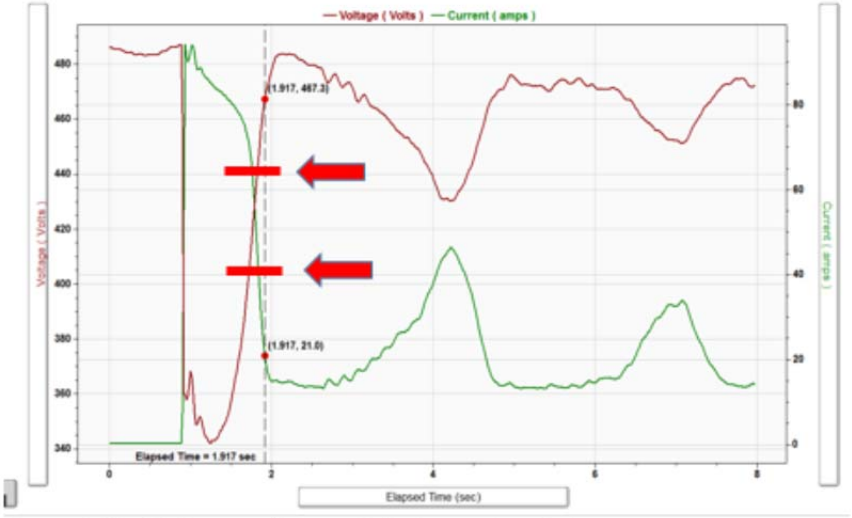
Volts = 467.3

Current = 21.0

Figure 14 – Voltage and current during motor startup.

The reason for picking the second point close in time to the first point is that other pumping units that share portions of the line, (when they are running) will cause slow line voltage fluctuations due to the varying current during their pumping cycle. By making both picks of voltage and current close in time, the change in voltage due to these relatively slow fluctuations will be minimal.

Smaller motors that draw less than 75 Amperes starting current, the current sampling points should bracket the middle third of the starting current falloff recovery as shown below. The technique is shown on the previous figure for convenience. Use this technique only when the startup maximum current is less than 75 amps.



For motors that have a maximum starting current less than 75 amps, use the middle third of the initial current surge falloff for selecting the two values of current.

The two voltage points are the value of voltage that correspond to the times of the current selections.

Figure 14A – Voltage and current during motor startup.

For motors that have a maximum starting current less than 75 amps, use the middle third of the initial current surge falloff for selecting the two values of current.

The two voltage points are the value of voltage that correspond to the times of the current selections.

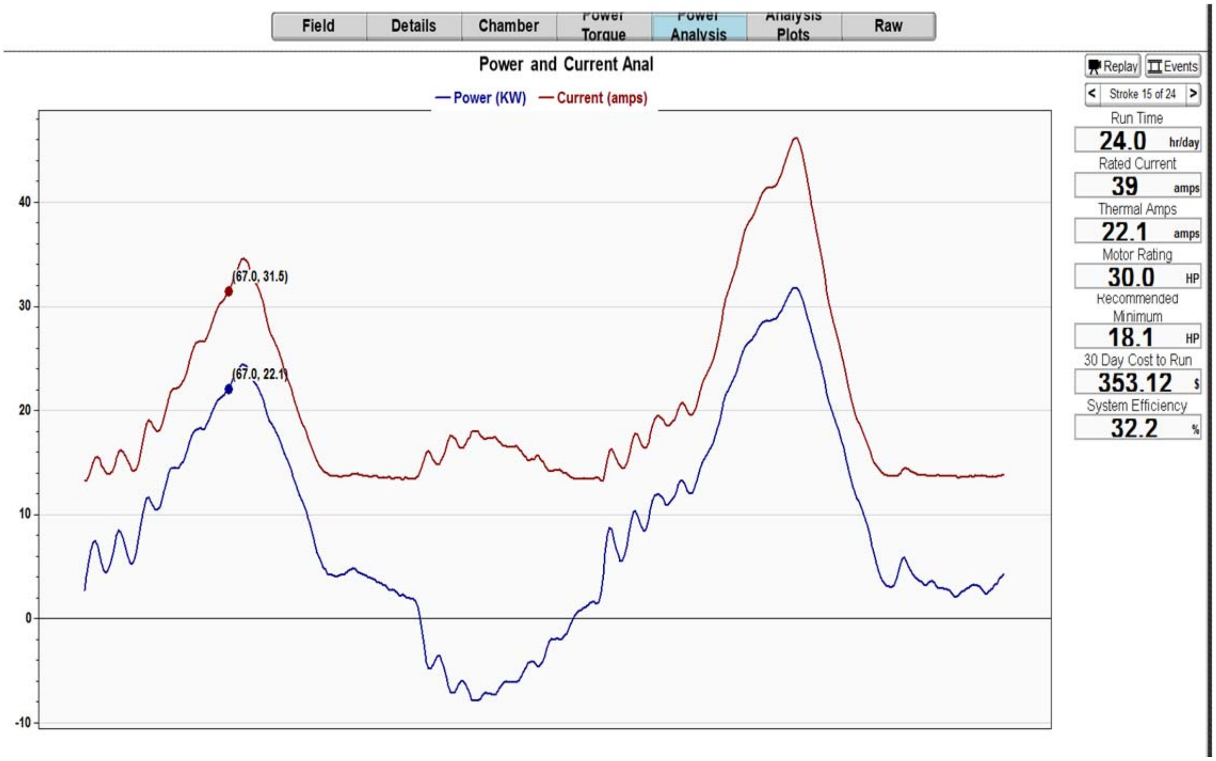
The resistance of the line is solved using Ohm's Law R = E / I where R is in Ohms, E is voltage in Volts, and I is current in Amperes. This equation also expresses the relationship of a change in current and a change in voltage where resistance is constant.

$R = \Delta E / \Delta I$

$\Delta E = (467.3 - 432.5) = 34.8$ Volts (the difference in voltage between Figures 13 and 14)
$\Delta I = (52.8 - 21.0) = 31.8$ Amperes (the difference in current between Figures 13 and 14)

$R_{line} = (\Delta E / \Delta I) / 2 = (34.8 / 31.8) / 2 = 0.547$ Ohm

Division by 2 is necessary as the voltage is measured between, and thus affected by the drop in two lines, while the current is sensed on only one line. The current is the same in both lines.



Run Time 24.0 hr/day
Rated Current 39 amps
Thermal Amps 22.1 amps
Motor Rating 30.0 HP
Recommended Minimum 18.1 HP
30 Day Cost to Run 353.12 $
System Efficiency 32.2 %

Figure 15 Power Analysis for Stroke 15

Line Loss is solved using the equation P = I^2 * R where P is in watts, I is in Amperes and R is in Ohms. The current, 22.1 Amperes is found above as the Thermal Amperes (RMS) averaged for a representative pump stroke. The resistance, R is line resistance solved above.

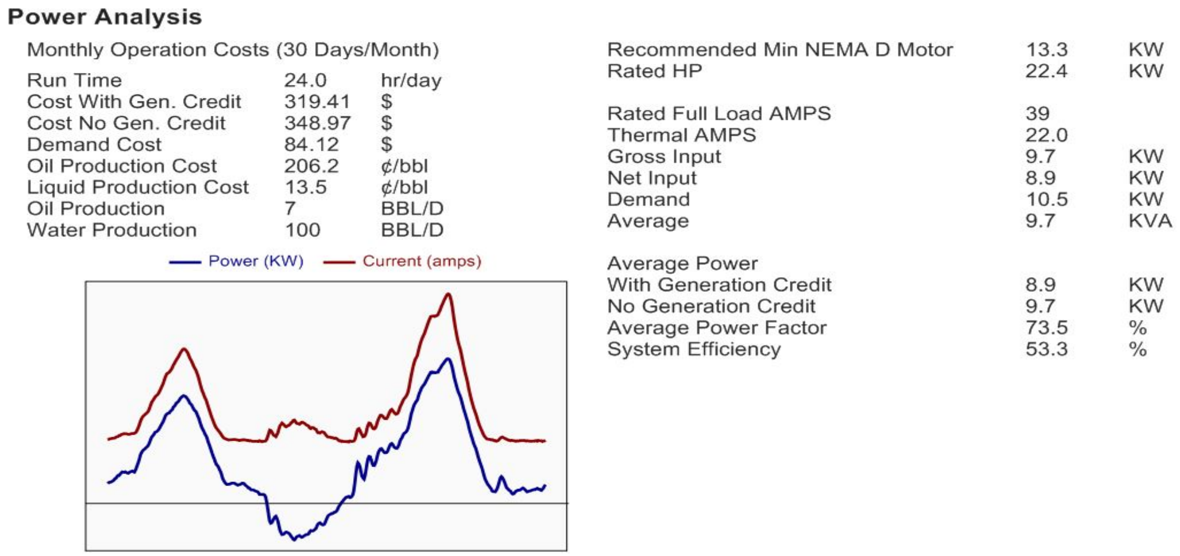
P = 22.1^2 * 0.547 * 3 = 801.5 W or 0.8015 KW
The multiplier of 3 is used because 3 phase power distribution uses 3 wires.

From above, Line Loss = 0.8015 KW

The Gross Input Power to the Motor is shown below as 9.7 KW

Avg. KW for stroke 16 is = 9.7 + .8015 = 10.502 KW @ $0.1/KWH 30 Days = $756.11 / Mo

Line Loss = 0.8015 /10.502 = 7.6% of Power Bill thus Line Loss Cost = $57.72 / Mo



Power Analysis

Monthly Operation Costs (30 Days/Month)

Run Time	24.0	hr/day
Cost With Gen. Credit	319.41	$
Cost No Gen. Credit	348.97	$
Demand Cost	84.12	$
Oil Production Cost	206.2	¢/bbl
Liquid Production Cost	13.5	¢/bbl
Oil Production	7	BBL/D
Water Production	100	BBL/D

Recommended Min NEMA D Motor	13.3	KW
Rated HP	22.4	KW
Rated Full Load AMPS	39	
Thermal AMPS	22.0	
Gross Input	9.7	KW
Net Input	8.9	KW
Demand	10.5	KW
Average	9.7	KVA
Average Power		
With Generation Credit	8.9	KW
No Generation Credit	9.7	KW
Average Power Factor	73.5	%
System Efficiency	53.3	%

Figure 16 – Comparison of Operating Cost and cost of Power Line Losses.

A Note about Electrical Safety

The level of current passing through a human body is the key factor in any electrical shock accident. Most of the more than 1,000 electric shock fatalities that occur in the U.S. every year are due to voltages less than 440 volts; the most common oil field voltage is 480 volts. It is imperative that respect be given to all electrical equipment and circuits and that adequate precaution be taken regardless of voltage.

Table 1 shows that even a very small amount of electrical current passing through the body can be hazardous.

Current in milliamperes (mA)	Physical effect
2 mA alternating current (AC) or 10 mA direct current (DC)	Threshold of a sensation (a strong tingling)
10 mA AC or 60 mA DC	“Let go” current, above which one freezes due to muscular contraction
100 mA AC or 500 mA DC	Death due to heart fibrillation and paralysis of breathing

Table 1 - Effects of electric shock

When dealing with electrically powered equipment—such as motors, switch boxes, control boxes, etc.—the integrity and grounding of which is unknown by the operator, prudent practice should result in the following precaution: if the operator has to touch electrically powered devices and is not wearing protective insulating gloves, the contact should always be made using the back of the hand. As seen in the table above, even a small current of 10 mA AC will cause a strong muscular contraction. Touching the device with the back of the hand will result in a contraction away from the electrified device rather than possibly “locking” the hand to a main switch handle.

Conclusions

This paper describes the development of a Wireless Electrical Motor Power measuring system that can be used by oil field technicians who may not hold an electrician license to monitor the operation and performance of beam pumping system in conjunction with dynamometer and valve testing that are routinely performed in the majority of wells.

The safety of the measurement is greatly increased since the technician does not have to open the switch box to attach the wireless sensor but instead connects it to an external multi pin plug that is permanently installed on the side of the motor control switch box.

In wells where this permanent connector is not present, the wireless power probe is connected to the internal wiring using a wire harness. Installation requires opening the door of the switch box and should be performed only by a qualified technician.

Measurement of motor power and current is a valuable tool to determine the existing motor torque and power yielding a very accurate and effective method for correctly balancing the pumping unit and determining the overall efficiency and the operating cost.

Detailed analysis of the amperage and voltage during start-up and normal steady state operation of the pump allows estimation of the power losses occurring in the transmission line from the transformer to the motor. This calculation then can be used to evaluate the need and economic benefits of upgrading the power line size for the well (or wells) in question or for designing a correct line size in future installations.

References

Lea J. F and J. F. Brown, “Dynamic Measurements of Beam Pump Parameters,” SPE 18187, Annual Technical Conference and Exhibition, 1988.

McCoy J. N. , A. L. Podio, J. Jennings, and Bill Drake, “Motor Power, Current and Torque Analysis to Improve Efficiency of Beam Pumps,” Proceedings of the 39th Annual Meeting of the SWPSC, 1992.

McCoy J. N. et al, “Beam Pump Balancing Based on Motor Power Utilization,” SPE 29533, Production Operations Symposium, 1995.

McCoy J. N. et al, “RotaFlex® Efficiency and Balancing,” Proceedings of the 47th Annual Meeting of the SWPSC, 2000.

Ott R. E, M. D. Woods, J. N. McCoy, and A. L. Podio, “Reducing Electrical Consumption of Beam Pumping Units by Properly Counterbalancing Using PC Software,” Proceedings of the 42nd Annual Meeting of the SWPSC, 1995.

Podio A. L. et al, “Application of Real-Time Measurement of Motor Power to the Determination of Beam Pump Efficiency,” SPE Latin America/Caribbean Petroleum Engineering Conference, April 1994.

Podio A. L., et al, “Total Well Management,” SPE 67273, 2001.

Rowlan O. L., et al, “Best Method to Balance Torque Loadings on a Pumping Unit Gear box,” Journal Canadian Petroleum Technology, July 2005.

Takács G., “Power Efficiency of Sucker Rod Pumping Systems,” Proceedings of the 50th Annual Meeting of the SWPSC, 2003.