ENERGY SAVINGS ON BEAM PUMP SUCKER ROD SYSTEMS / CONTROL SOLUTIONS WITH FIELD CASE STUDIES

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Abstract

The study examines efficiency of line starters, soft starters, standard variable frequency drives and variable frequency drives with advanced embedded controllers. Electrical average voltage(V), power factor, maximum current(A), average current(A), total apparent power(KVA), total reactive power(KVAR) and total real power(KW) will be show for each variation. Apparent costs and ROI of implementing and/or changing to a new control system will be presented.

Introduction

One of the largest lease operating expenses is electrical cost. (Fig.1) Only a small portion of electrical cost is value-added conversion of electricity to fluid lifting power. The rest is lost to downhole friction, fluid flow friction, pumping unit, and electrical to mechanical power conversion inefficiencies. Overall "line to fluid" system efficiency will typically range from 20% to 40%. Some cases will be as low as 10%.

Some of those energy losses are inevitable. Some can be reduced through improved operation and controls. This paper will present power studies of various control schemes on actual wells, highlighting the best solutions for reducing power consumption.

Scope of work

Beginning in January, 2019, an oilfield producer allowed testing on five wells. Using a calibrated Fluke 434 power analyzer, testing was conducted for two hours intervals for every well with each form of motor control. First, motor starters were implemented and analyzed on all five wells. Next, one well was chosen to evaluate a soft starter and three common "off the shelf" variable speed inverter drives. Lastly, all five wells were evaluated with an application specific drive with embedded control, first running at the same constant speed, and next running in an optimized mode with power management. The embedded drives continue to run and additional results will be released in the future.

Conclusion

(Fig.2) When choosing motor control think about the long term 15year cost of operation
Standard - Motor starters have the highest current draw and cost the most to operate.
Good - Soft Starters reduce some max current draw and do not offer any speed or torque control.
Better - Off the shelf drives offer versatility of speed control and starting current limiting.
Best - Application specific drives offer complete current, speed and torque control

(Fig.3)
Shows a comparison on well A of each control systems max current

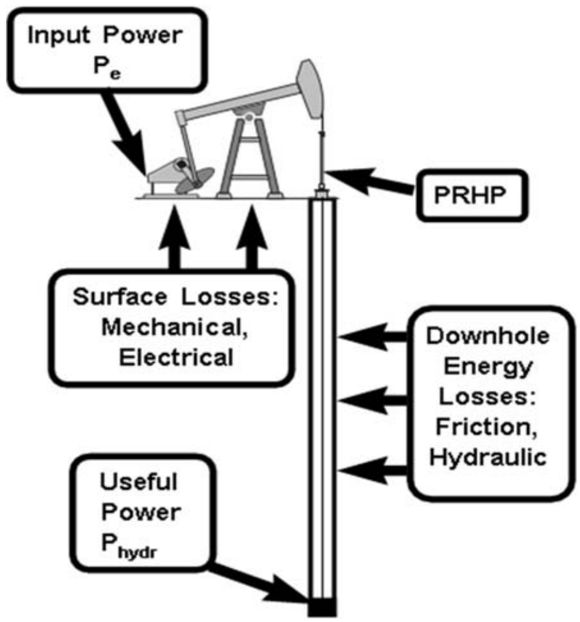
(Fig.4) Full study results

Optimum Electrical Efficiency Requires Counterbalancing of Pumping Units

Proper counterbalancing of a pumping unit evens-out the torsional loads on the speed reducer during the pumping cycle. Without counterbalancing, the torque loading on the gearbox would be excessively positive in the upstroke and excessively negative in the downstroke. Since no motor or gearbox can be expected to operate under such heavily fluctuating loads, some means of counterbalancing the pumping unit had to be devised. These can take the form of beam or crank (rotary) counterweights, or an air cylinder. The crank on a properly balanced pumping unit will lift the weight of the rods plus ½ the weight of the fluid in the upstroke, and lift the counterweights (similar torque) in the downstroke.

When counterbalancing a pumping unit, ideal counterbalance conditions are desired that can have many beneficial effects on the operation of the sucker-rod pumping system:
• Reduced energy consumption
• Reduced size of the required prime mover
• Smoother operation of a properly balanced speed reducer lowers maintenance costs and increases equipment life.

The advanced system tested with power management has a patented power control feature that manipulates speed and inertia to achieve a flat power draw while keeping a requested average speed. This operation has shown the best results in current draw and power consumption.

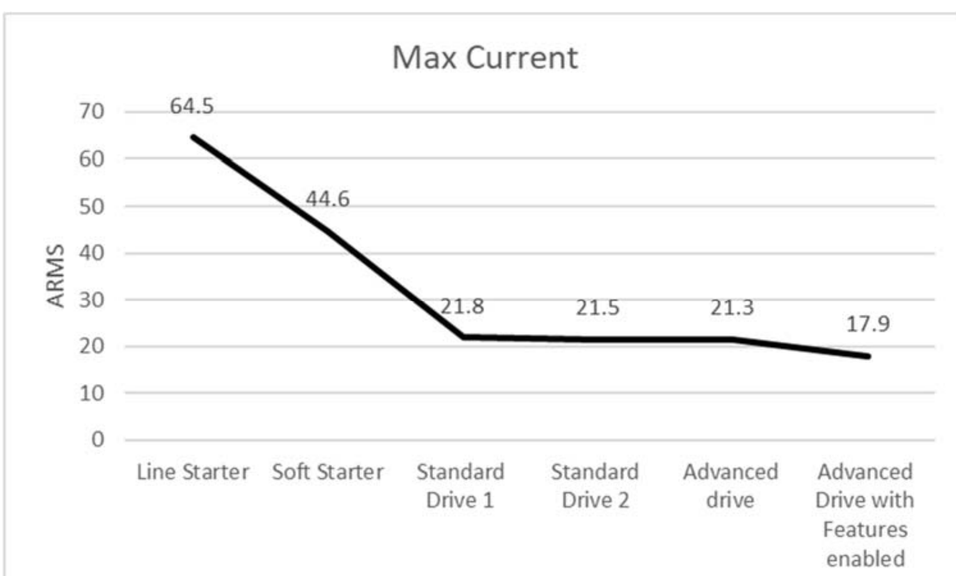


(Fig.1)

(Fig.2)

Starter	**Soft Start**	**VFD**	**VFD with Embeded control**
Low upfront cost	More upfornt expensive	More upfront expensive	Most upfront expensive
No speed control	Start / Stop speed control	Full motor speed control	Independent speed control through stroke
Minimal monitoring	Limited monitoring	Full monitoring	Full modbus map with access to trends and guages
Highest motor damage/wear	Moderate motor damage/wear	Minimal motor damage/wear	Minimal motor damage/wear
Least efficient	Moderate efficiency	Better efficiency	Best efficiency
Highest operating cost	Moderate operating cost	Lower operating cost	Lowest operating cost, Best production result, Gearbox and rod string protection
Upfront cost 10HP	Upfront cost 10HP	Upfront cost 10HP	Upfront cost 10HP
POC Kit: $4,000	POC Kit: $4,000	POC Kit: $4,000	POC Kit: Not needed
Pump Panel: $1,500	Pump Panel: $2,000	Pump Panel: $2,500	Pump Pannel: Not needed
Total: $5,500	Total: $6,000	Total: $6,500	Total: $8,500

(Fig.3)



(Fig.4)

Well	A Vertical	B Vertical	D Vertical	E Vertical	F Horizontal
Pumping unit					
Make	Lufkin	Lufkin	National	American	Lufkin
Model	228	40	57	114	228
Stroke Length	74	40	44	86	120
Strokes Per Minute	7.8	7.5	8	10	6
Downhole					
Pump Depth ft	2571	1295	1554	2088'	2398'
Plunger diameter	1.5	2	2	2.25	2.25
Motor					
Rated HP	15	15	5	20	30
Rated Voltage (V)	480	480	480	480	480
Rated Current (A)	22	18.29	6.7	26	39
Rated RPM	1105	875	1100	1105	1185
Nema Rating B/D	D	D	D	D	B
Line Starter					
Voltage (V) average rms input 95% percential	485	465	494	470	475
Average Power Factor	0.4	0.29	0.54	0.57	0.71
Maximum Current (A) RMS	64.5	44.2	40.9	104.3	220
Average Current (A) 95th percental	22.2	8.2	6.5	20.4	24.92
Average Total Real power (KW)	1.68	0.62	0.97	2.82	4.54
Average Total Reactive Power (KVAR)	3.85	2.05	1.52	4.07	4.51
Total Apparent Power (KVA)	4.2	2.15	1.8	4.95	6.4
Strokes per miniute (SPM)	8.72	7.5	8	9.22	6
Advanced drive					
Voltage (V) average rms input 95% percential	487	468.4	493.4	484	486
Average Power Factor	0.38	0.58	0.77	0.74	0.58
Maximum Current (A) RMS	21.3	10.7	10.3	24.1	44.7
Average Current (A) 95th percental	15.1	4.8	5.8	16.7	15.9
Average Total Real power (KW)	0.48	1.8	3.16	2.81	1.74
Average Total Reactive Power (KVAR)	1.16	2.52	2.61	2.56	2.44
Total Apparent Power (KVA)	1.26	3.1	4.1	3.8	3
Strokes per miniute (SPM)	8.72	7.5	8	9.22	6
Advanced Drive with Features enabled					
Voltage (V) average rms input 95% percential	487	468	494.4	485	482
Average Power Factor	0.49	0.58	0.78	0.78	0.67
Maximum Current (A) RMS	17.9	8.3	10.1	23.4	10.7
Average Current (A) 95th percental	8.1	4	2.9	16.5	4.7
Average Total Real power (KW)	1.08	1.57	1.79	2.96	2.41
Average Total Reactive Power (KVAR)	1.92	2.2	1.44	2.38	2.67
Total Apparent Power (KVA)	2.2	2.7	2.3	3.8	3.6
Strokes per miniute (SPM)	8.72	7.5	8	9.22	6
Standard Drive 1					
Voltage (V) average rms input 95% percential	491	470			
Average Power Factor	0.39	0.19			
Maximum Current (A) RMS	21.8	16.9			
Average Current (A) 95th percental	15	8			
Average Total Real power (KW)	1.63	0.4			
Average Total Reactive Power (KVAR)	3.84	2.08			
Total Apparent Power (KVA)	4.18	2.12			
Strokes per miniute (SPM)	8.72	7.5			
Standard Drive 2					
Voltage (V) average rms input 95% percential	497				
Average Power Factor	0.33				
Maximum Current (A) RMS	21.5				
Average Current (A) 95th percental	14.7				
Average Total Real power (KW)	1.37				
Average Total Reactive Power (KVAR)	3.93				
Total Apparent Power (KVA)	4.16				
Strokes per miniute (SPM)	8.72				
Soft Starter					
Voltage (V) average rms input 95% percential	487				
Average Power Factor	0.38				
Maximum Current (A) RMS	44.6				
Average Current (A) 95th percental	21.4				
Average Total Real power (KW)	1.59				
Average Total Reactive Power (KVAR)	3.87				
Total Apparent Power (KVA)	4.18				
Strokes per miniute (SPM)	8.72				