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Power Factor Correction for Pumpjacks
Results from the Field

1 SUMMARY AND FINDINGS

While capacitor banks are not new and are installed at many industrial sites throughout Alberta, there have been some concerns from oilfield operators that pumpjacks could prematurely wear out capacitor banks or cause damage. To address these concerns, Cos Phi and Citrine set out to demonstrate the effectiveness of Cos Phi capacitor banks at an oilfield test site.

TECHNICAL RESULTS	**After the 6-month demonstration at our client's site, Cos Phi's capacitor banks proved their capability to manage pumpjack cycles without degradation or fault. There was no downtime for the installation and Cos Phi's capacitor banks could easily installed by field staffs trusted local electricians.**
	~ 40% improvement in the power quality at the pumpjack
COST SAVINGS	**~ 20% savings potential on Fortis wires costs for this site, plus the additional energy savings attributed to I^2R loss reductions**
PAYBACK	**If there were no ratchet penalties, the payback would be in the order of 6 months for these types of low power quality pumpjacks which makes this an easy decision for field operators.**
	Improving field power quality also improves utility efficiencies.
	NOTE: Unfortunately, Alberta utilities who charge penalties for low power factor do not relieve customers from their 12-month ratchets. Companies must wait an additional year or more after installing for the financial payback. Metering can cause the lag to be even longer. Possibly this test case will serve to remind utilities of the mutually beneficial value -- and how they might provide a constructive, customer-centric response to what is unquestionably the right thing to do.

2 QUICK REVIEW

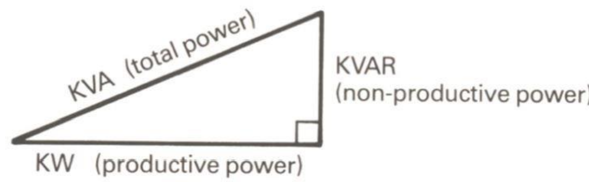
2.1 Power Factor

By way of review, power factor[1] (PF) is the ratio of working power to apparent power. It measures how effectively electrical power is being used.

The ratio is usually described as a percent.

A high-power factor signals efficient utilization of electrical power (90-100%), while a low power factor indicates poor power quality.

[1] To determine power factor (PF), divide working power (kW) by apparent power (kVA).



$$\text{Power Factor} = \frac{\text{KW (productive power)}}{\text{KVA (total power)}}$$

***Ideally* you want the ratio to be as close to 1 (or 100%). For billing purposes, a minimum of 90% PF is required in order for demand to be billed by 100% kW, rather than 90% kVA.**

2.2 Potential Savings

To demonstrate the potential value of power factor correction, a rate impact before and after correction is shown below. This is an example of a pumpjack with a 60 kW and 80 kVA demand. The power factor then is 75% (60/80).

Before explaining how you can save, it is necessary to explain how rates are calculated under Rate 45. The rate code for Fortis effective as of Nov 2017 is in the next figure. As you can see the kW-day charge is actually based on <u>a maximum of the metered kW and kVA readings over the last twelve months</u>. The calculation is described under the rate sheet.

After power factor correction, the wires charges would be 20% lower.

Rate 45

	Transmission Component	Distribution Component	Total Distribution Tariff
Service Charge for the first 3 kW of Capacity	$0.2914 /kW-day	$0.79400 /kW-day	$1.08540/kW-day
For the next 12 kW of Capacity	$0.2914 /kW-day	$0.57167 /kW-day	$0.86307/kW-day
For all additional kW of Capacity greater than 15 kW	$0.2914 /kW-day	$0.54022 /kW-day	$0.83162/kW-day
For all kWh delivered	0.3927¢/kWh	—	0.3927¢/kWh

The **kW of Capacity** is based on the greatest of:

1. the Metered kW Demand in the billing period;
2. 85% of the highest Metered Demand in the past 12 months including and ending with the billing period;
3. the Contract Minimum Demand as specified by the Terms and Conditions; or
4. the Rate Minimum of 3 kW.

The Metered Demand is the greater of:

i) the registered demand in kW, or
ii) 90% of the registered demand in kVA.

Comparative Analysis of Annual Wires Charges

Pumpjack Assumption

Demand =	60	kW
kVA =	80	kVA

Oilfield Rate (100% Power Factor)				Oilfield Rate (75% Power Factor)			
Per Unit Cost	Units	kW	Item Cost ($)	Per Unit Cost	Units	kW	Item Cost ($)
1.0854	/kW-day	3	$ 1,188.51	1.0854	/kW-day	3	$ 1,188.51
0.86307	/kW-day	12	$ 3,780.25	0.86307	/kW-day	12	$ 3,780.25
0.83162	/kW-day	>15	$ 13,659.36	0.83162	/kW-day	>15	$ 17,301.85
Total Cost			$ 18,628.12				$ 22,270.61
Potential Reduction in Costs							20%

*Using Rate 45

3 CONCERNS AND SOLUTIONS

3.1 Expressed Concerns

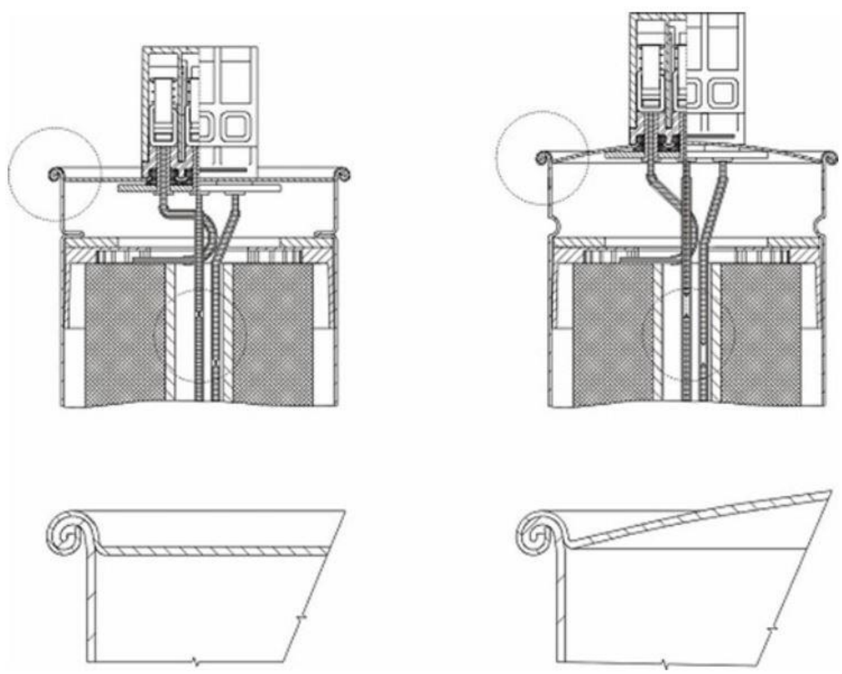
Our client identified concerns surrounding wear and operation of capacitor banks given the pumpjack cyclic power draw as well as the potential for blowing up.

3.2 Cos Phi/Citrine Field Test

To address these concerns, Cos Phi has agreed to test the capacitor bank at our client's pumpjack. The President of Cos Phi personally installed a 480V, 16 kVAR capacitor bank on June 29th, 2017.

This capacitor is actually a 600 V, 25 kVAR capacitor, derated to 480V 16 kVAR. Due to this deration, the capacitor can handle voltage fluctuations during the cycling between up-stroke and down-stroke of the pump jack.

Should the capacitor suffer an internal arc, the heated inert N_2 gas within the capacitor will expand, causing the casing to expand and an internal disconnect will open, extinguishing the arc. *See picture to the right.*



4 RESULTS

4.1 Improvement in Power Factor

On January 15, the client's ENMAX billing data was gathered to investigate the test results. The following table shows that the 40% improvement in the power factor.

Power Factor Analysis

TRANSACTION DATE TIME	KWH	MAX KVA	MAX KW	POWER FACTOR	LAST METER READ DATE
1/6/2018	2195	16.98	15.58	0.91755	12/26/2017
12/28/2017	8672	18.3	16.23	0.88689	12/1/2017
12/8/2017	1771	16.58	14.9	0.89867	11/26/2017
11/28/2017	9271	17.08	15.62	0.91452	11/1/2017
11/8/2017	1858	16.54	14.83	0.89661	10/26/2017
10/28/2017	8063	18.73	16.29	0.86973	10/1/2017
10/6/2017	690	17.91	16.29	0.90955	9/26/2017
9/28/2017	8637	16.75	15.12	0.90269	9/1/2017
9/9/2017	2108	16.75	15.12	0.90269	8/26/2017
8/28/2017	8799	16.98	15.26	0.89870	8/1/2017
8/9/2017	2120	16.86	15.13	0.89739	7/26/2017
7/28/2017	8868	24.8	15.52	0.62581	7/1/2017
7/8/2017	1723	24.8	15.52	0.62581	6/26/2017
6/28/2017	9084	25.32	15.93	0.62915	6/1/2017
6/8/2017	2145	24.93	15.53	0.62294	5/26/2017
5/28/2017	7405	25.41	16.15	0.63558	5/1/2017
5/6/2017	1402	22.6	12.82	0.56726	4/26/2017
4/28/2017	7615	23.8	14.1	0.59244	4/1/2017
4/7/2017	1951	23.8	14.1	0.59244	3/26/2017
3/28/2017	8684	24.12	14.67	0.60821	3/1/2017
3/8/2017	798	24.12	14.67	0.60821	2/26/2017
2/28/2017	7951	24.88	15.62	0.62781	2/1/2017
2/8/2017	1877	24.6	15.18	0.61707	1/26/2017
1/28/2017	9010	25.15	15.93	0.63340	1/1/2017
1/7/2017	2169	25.15	15.83	0.62942	12/26/2016
12/28/2016	9083	25.47	16.45	0.64586	12/1/2016
12/8/2016	1818	24.88	15.56	0.62540	11/26/2016
11/29/2016	7483	26.63	17.56	0.65941	11/2/2016
11/8/2016	351	27.34	18.58	0.67959	11/1/2016
11/8/2016	11457	27.34	18.58	0.67959	10/25/2016
11/5/2016	11457	27.34	18.58	0.67959	10/25/2016
11/8/2016	11106	27.34	18.58	0.67959	10/25/2016
12/1/2016	1917	27.34	18.58	0.67959	10/25/2016
12/1/2016	11106	27.34	18.58	0.67959	10/25/2016

4.2 Potential Cost Savings

In preparing the potential return on investment (ROI), rather than follow the very complex calculations, a simplifying assumption was made. It was assumed that the kVA equaled the billed kW. That is reasonable because:

1. The kW recorded was reasonably stable over the year, so there would not be a material difference in the 12-month peak, and
2. The .85*kVA was reasonably close to the kW.

For the purposes of preparing a potential savings, it is reasonably close. (Note the analysis ignores all the rate riders which are added to the bill. Reducing the kW will also reduce the demand weighted rate rider charges as well.)

Additionally, there will be I^2R (heat) loss savings by placing capacitors at the load. For example, at the test site mentioned above, there will be roughly an 18% decrease in current. If the length and size of the supply wire was known between the meter and motor, a fairly good estimate of energy savings could be made by installing a capacitor. Alternatively, a before and after energy metering could be performed in order to estimate the monthly savings per motor or site.

The potential annual savings would have been about $1900 less over with the power factor correction – excluding the I^2R loss savings – for each pumpjack.

POTENTIAL SAVINGS AFTER POWER FACTOR CORRECTION

	ACTUAL BILLING DATA				AFTER POWER FACTOR CORRECTION		
MONTH	METERED DEMAND (kW)	BILLED DEMAND (kW)	WIRES CHARGES (Excl. Rate Riders)		METERED DEMAND (kW)	BILLED DEMAND (kW)	WIRES CHARGES (Excl. Rate Riders)
12/1/2016	16.45	22.94	$ 599		16.45	16.45	$ 437
1/1/2017	16.45	22.94	$ 599		16.45	16.45	$ 437
2/1/2017	15.62	22.41	$ 586		15.62	15.62	$ 416
3/1/2017	14.67	21.71	$ 568		14.67	14.67	$ 392
4/1/2017	14.1	21.43	$ 561		14.1	14.1	$ 377
5/1/2017	16.15	22.87	$ 597		16.15	16.15	$ 429
6/1/2017	15.93	22.79	$ 595		15.93	15.93	$ 424
7/1/2017	15.52	22.33	$ 584		15.52	15.52	$ 414
8/1/2017	15.26	20.92	$ 548		15.26	15.26	$ 407
9/1/2017	15.12	20.92	$ 548		15.12	15.12	$ 404
10/1/2017	16.29	20.92	$ 548		16.29	16.29	$ 433
11/1/2017	15.62	19.5	$ 513		15.62	15.62	$ 416
Total Cost			$ 6,846				$ 4,986
Total Savings							$ 1,860

Assumptions and Notes

(1) Assumed every month had 30 days.
(2) Assumed that billed demand equals metered demand after PFC for the rate calculations. Given how close the two are after PFC, it seemed a reasonable assumption to simplify the analysis.
(3) Ignored rate riders as these would make the analysis overly complex at this juncture.

5 KEY SITES FOR ANALYSIS

Power correction makes sense for oilfield operations. While the pumpjack was the focus of this paper, screw pumps also make good candidates.

Good candidates include:

1. **Sites operating at <90% power factor**. Pumpjacks or screw pumps at 90% or higher are not likely candidates. Getting a 100% isn't going to provide utility savings given the incremental costs.
2. **Services smaller than 10 kW**. Loads smaller than 10 kW without proximity to other low PF equipment are not likely to be worthwhile.

CONTACT FOR MORE INFORMATION

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