

MONITORING REPORT
FILTRONICA Inc.-City of San Luis, Az



MEASUREMENT REPORT

Filtronica Job# 10152018-001
Pump Removal-Cable Test-Power Quality Study
Wellsite #7-Well # 11

PERFORMED BY:
Filtronica Inc.

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FILTRONICA Inc.-City of San Luis, Az

Attention: Manuel Rojas, CPM, Asst. Public Works Director, City of San Luis, Az.

Subject: Pump Removal and PQ Measurement at Wellsite #7, Well # 11

Please find following our monitoring report which is based on the short-term data recorded at customer on 10-15-2018. Please note that the accuracy of our recommendations is reliant upon the information supplied and the limited long term, i.e. from 10-15-2018 to 10-30-2018, data recordings obtained.

Yours Faithfully on behalf of Filtronica, Inc.

Asmus-Peter Krickhuhn

Filtronica, Inc.

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SECTION I

SCOPE:

On **October 15, 2018** *Filtronica, Inc.* observed the pump and motor removal and performed power quality and cable testing at **the Wellsite #7, Well#11**

Detailed relevant data and observations of this project are contained within Section 2 of this document.

PURPOSE:

The purpose of this monitoring exercise was to determine the power quality/ power requirements for the **electrical system of the Wellsite #7**. Also, this study was to take into account possible system design issues, cable and associated connectors and termination issues. The pump and motor were removed by Shuck Drilling. The cable and motor resistance to Ground was measured every 40 feet or two pipe sections. The cable was rolled up onto a cable spool. The values of that measurement can be seen in section 2.2. of this report.

A power quality measurement was ordered to see what the issues are with the associated infrastructure, such as distribution center, utility power and such. The measurement was started on 10-15-2018 and stopped on 10-30-2018. The results of that measurement is shown in section 2.1 of this report

This report is intended to assist in the facility's desire to pin-point electrical issues associated with the overall system and specifically the associated issues with low resistance measurements of the motor and cable to Ground. This is accomplished by recommending the correct rating and type of systems required to offer long-term energy benefits and savings with low maintenance costs. Please note that our study is not intended to imply that other hazards or problems do not exist that are unrelated to the area of our inspection.

POWER QUALITY & ENERGY DEFINITIONS:

During our measurement and analysis activities, we hope to identify power quality issues that are known to have a significant impact on the overall energy consumption, electrical efficiency and facility maintenance costs of the total facility. These issues are discussed in general during this introduction, and more specifically later in this document.

Voltage Stability

Dynamic loads such as compressors, large motor startups and other load changes can cause decreased process output, increased scrap & rework, increase electrical system losses, reduce starting torques and can cause intermittent outages in voltage-sensitive equipment.

Under- & Over-Voltage

In large facilities, long feeder cables from the main step-down transformer to distributed switchgear is a major component of voltage drop. Motors operate efficiently (at nameplate rating) when the rated voltage is applied at its terminals. When voltage varies from that rating, not only does the motor run less efficiently, but it's insulation breaks down more rapidly, causing increased maintenance costs due to shorter-than expected longevity. (Please see chart below).

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	Voltage / Per Unit Values					
	456 V 0.950	468 V 0.975	474 V 0.988	480 V 1.000	486 V 1.013	492 V 1.025
Starting Torque	-10%	-5%	-2%	0%	3%	5%
Maximum Running Torque	-10%	-5%	-2%	0%	3%	5%
Percent Slip	11%	5%	3%	0%	-2%	-5%
Starting Current	-5%	-3%	-1%	0%	1%	2%
Full Load Current	5%	3%	1%	0%	-1%	-2%
Efficiency	-1.5%	-0.8%	-0.5%	0.0%	0.5%	0.8%
Temperature Rise <i>{approx}</i>	22.50 °F	11.25 °F	5.62 °F	0.00 °F	-4.37 °F	-8.75 °F

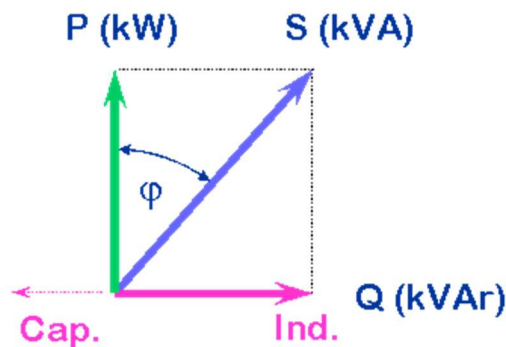
* Taken from McGraw-Hill's Electrical Engineer's Portable Handbook and EASA's Electrical Engineering Pocket Handbook

Harmonic Voltage & Current Distortion

Many modern item of plant include electronic controls that can and do generate distortion on the local network which can result in sporadic problems with failed components and inaccurate metering.

Service Utilization / Power Factor

The power factor of a facility, in effect, is a measure of the overall efficiency of a facility's use of power. Quite simply, it is a measure of the ratio of kW (active power) to kVA (apparent power). kVA is the actual energy utilities provide to their customers. Many utilities charge some sort of penalty for poor power factor, defined in different regions of the country in significantly different ways and levels.



Distribution/Energy Losses in Industrial & Commercial Facilities

There are fundamental differences between simple DC resistance values of various conducting elements and actual 'apparent' AC resistances of the same elements. Motors, lighting, facility wiring, distribution panels, protective devices, transformers and switchgear all experience a wide range of phenomena that combine to create wattage (energy) losses. Identifying and calculating the total of all losses is an extremely challenging engineering proposition that requires knowledge of all factors that impact operating efficiencies. Note that all of the loss items presented on the following pages are current (Amps) and frequency (Hz) dependent, and can be reduced by utilizing techniques that reduce facility current usage and filter harmonics.

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a) Hysteresis Losses

Hysteresis losses are heat losses associated with the magnetic properties of an AC motor armature. When an armature core is in a magnetic field, the magnetic particles of the core tend to line up with the magnetic field. When the armature core is rotating, its magnetic field keeps changing direction. The continuous movement of magnetic particles as they try to align themselves with the magnetic field produces molecular friction, causing heat. This heat is transmitted to the armature windings, increasing armature resistance.

b) Skin-Effect Losses

The apparent resistance of a conductor is always higher for Alternating Current (AC) than for Direct Current (DC). The magnetic flux created by AC interacts with the conductor, generating a back Electro-motive Force (EMF), tending to reduce the current in the conductor. The center portions of the conductor are affected by the greatest number of lines of this force. The EMF produced in this manner (self-inductance) varies both in magnitude and phase through the cross-section of the conductor, being greater toward the center and smaller towards the outside. The current, therefore, tends to crowd into those parts of the conductor in which the opposing EMF is a minimum. That is, into the 'skin' of a circular conductor or the edges of a flat strip. This phenomenon is known as 'skin' or 'edge' effect. The resultant non-uniform current density has the effect of increasing the apparent resistance of the conductor, causing increased losses. Harmonic loads amplify skin effect losses by the square of the increase in frequency above nominal line frequency. Because of this, harmonics are the cause of substantial energy losses in any facility with nonlinear equipment loads, such as VFDs, DC drives, rectifiers, induction heaters or other arcing or switching power supply devices.

c) Proximity Effect Losses

Proximity effect exists when conductors are close together, particularly in low voltage equipment, where the interaction between the magnetic fields of conductors causes further distortion of current density. In the same way as an EMF can be induced in a conductor by its own magnetic flux, another conductor can produce an EMF in any other conductor.

If two such conductors carry currents in opposite directions, their electromagnetic fields are opposite, tending to force one another apart. This results in a decrease of flux linkages around the adjacent parts of the conductors and an increase in the more remote parts. This forces a larger concentration of current to the adjacent parts where opposing EMF is at a minimum. If the currents in the conductors move in the same direction, the above action is reversed. This effect, known as the 'proximity effect', (or 'shape effect'), increases the apparent AC resistance. If the conductors are arranged edgewise to one another, the proximity effect increases. As an additional note, in many cases the proximity effect will also tend to increase distribution network stresses under short-circuit load conditions.

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d) Transformer Losses

The two primary types of transformer losses are core losses and load losses. Core losses occur because a magnetizing current must exist in the primary winding of a transformer. This current is additional to current which flows to balance the current in the secondary winding. The magnetizing current is required to take the core through the alternating cycles of flux at the rate determined by system frequency. In doing so, energy is absorbed. Core-losses are present whenever the transformer is energized.

Transformer load losses occur because of current flow in an electrical system and depend on the magnitude of that current. Load losses are caused by the windings in the transformer, and are only present when loaded. The magnitude of losses is proportional to the load squared. The three categories of load losses that occur in transformers are:

- Resistive losses - often referred to as I^2R losses
- Eddy-current losses due to the alternating leakage fluxes
- Stray losses in leads, core-framework and tank due to the action of load-dependent stray alternating fluxes

e) Line Losses

Cables exhibit the same I^2R resistive heating losses reviewed in the Transformer section above and dielectric losses. For single conductor cables, where conductors are not operating close to each other, proximity effect can be considered to be negligible.

Operating together in a typical industrial conduit-enclosed distribution system, these various line loss factors can sufficiently increase the facility electrical distribution wiring's apparent AC resistance to more than an order of magnitude above nominal DC resistance values. As a result, typical I^2R wiring losses are often far greater than simple chart-based values.

f) Eddy-Current Losses

Flux will flow in any electrical system component comprising an iron or steel frame and an electrical coil as a result of the alternating current in the coil. The flux in the steel will itself induce an EMF in the material following the basic laws of induction. Since the material is essentially an electrical circuit itself, the induced EMF will cause a circulating electrical current called an eddy-current. Its total magnitude is dependent on the value of EMF and on the resistivity of the current path. As in any other electrical circuit, the losses can be calculated as the square of the current times the resistance. In a similar manner to hysteresis losses, the eddy-current loss manifests itself as heat, and contributes to the maximum operating temperature limit of the device. Eddy current losses occur in protective circuit breakers, lighting ballasts, power supply transformers, magnetic motor starters, voltage reduction or isolation transformers, current overload relays, control contactors and relays, and motor windings. They can also exist in facility wiring if it is in proximity to steel or iron structures such as electrical enclosures, distribution panels, or terminal or distribution blocks.

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Summary / General Comments

The components of an electrical system are contributors to energy losses in any facility. Measures can be taken to reduce current and harmonics in many facilities that will help minimize distribution losses and save energy. I^2R heating losses in many facilities contribute from 1 - 3% of a facility's overall kW usage. Hysteresis and skin-effect losses are greatly impacted by current harmonics, and in facilities with high harmonic content, can add 5% or more to overall kW consumption. Overall, employing devices such as real-time harmonic filtration systems can help a facility reduce their energy consumption.

The facility has had motor failures for some time. Facility management has installed passive harmonic filters on the input side of each VFD and have installed sinewave filters between the VFD output and motor. The facility management has also decided to install a "Franklin" motor in Well #11. Since this install, some resistance measurements have shown a low value. This report intends to find the cause of the low values.

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SECTION 2 DATA FROM MEASUREMENT POINTS

2.1 Motor Control Center MCC #2

Motor Control Center MCC#2 is a 480V service with 600A main breaker (full load rating). Loads consist mainly of non-linear loads, such as VFD-controlled pump systems (2 ea.), other pumps (3ea., direct started) and compressors.

The following table indicates the Average, Minimum and Maximum conditions recorded during the period of our measurements at the MCC#2.

TABLE 2.1.1

Name	Min	Max	Average
L12 RMS Voltage (Cycle by Cycle), MCC-#7(Volt)	378.8348999	504.4840088	491.7106934
L23 RMS Voltage (Cycle by Cycle), MCC #7(Volt)	449.7655945	508.6220093	495.4831848
L31 RMS Voltage (Cycle by Cycle), MCC #7(Volt)	448.0303040	505.3651123	491.9227905
L1 RMS Current (Cycle by Cycle), MCC #7(Ampere)	0.0000000	740.4448242	84.6584396
L2 RMS Current (Cycle by Cycle), MCC #7(Ampere)	0.0000000	699.6035767	71.8107300
L3 RMS Current (Cycle by Cycle), MCC #7(Ampere)	0.0000000	744.5355835	75.9226913
Total Active Power (Fundamental+ harmonics) (Cycle by Cycle), MCC #7(Watt)	-1420.4229736	244046.5937500	57862.0312500
Total Reactive Power (Fundamental+ harmonics) (Cycle by Cycle), MCC #7(VAr)	-119364.2031250	496943.1875000	-19880.1894531

Table 2.1.1 shows the minimum, average and maximum values recorded during the measurement period. If one looks at the voltages alone, one can see where there are many an instance where the voltage is either too low (at 378 Volts) or too high (at 508 Volts). Any VFD is programmed to shut off when voltages of about 450 Volts on the low end or 505 Volts at the high end are reached. The large voltage differential is primarily due to a somewhat weak infrastructure. The infrastructure, i.e. utility can not supply the required reactive power during a motor start-up and that causes the voltage to drop. See graph below in Figure 2.1.1.

Also measured was an externally caused voltage drop. This drop is as low as 378 Volts and was caused by an external source. See Figure 2.1.2.

Figure 2.1.3 shows the total measurement

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Figure 2.1.1 Motor Start-up

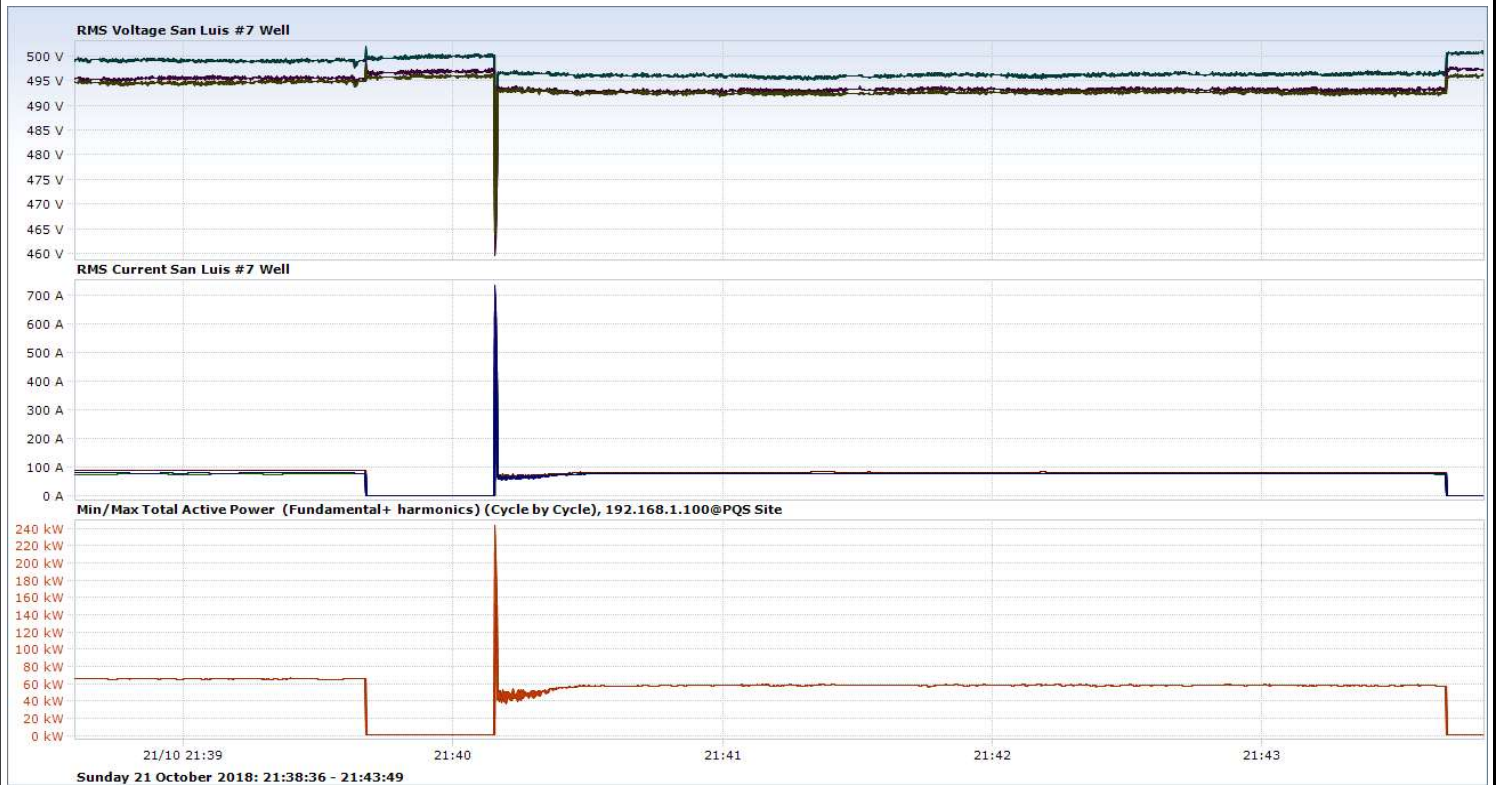
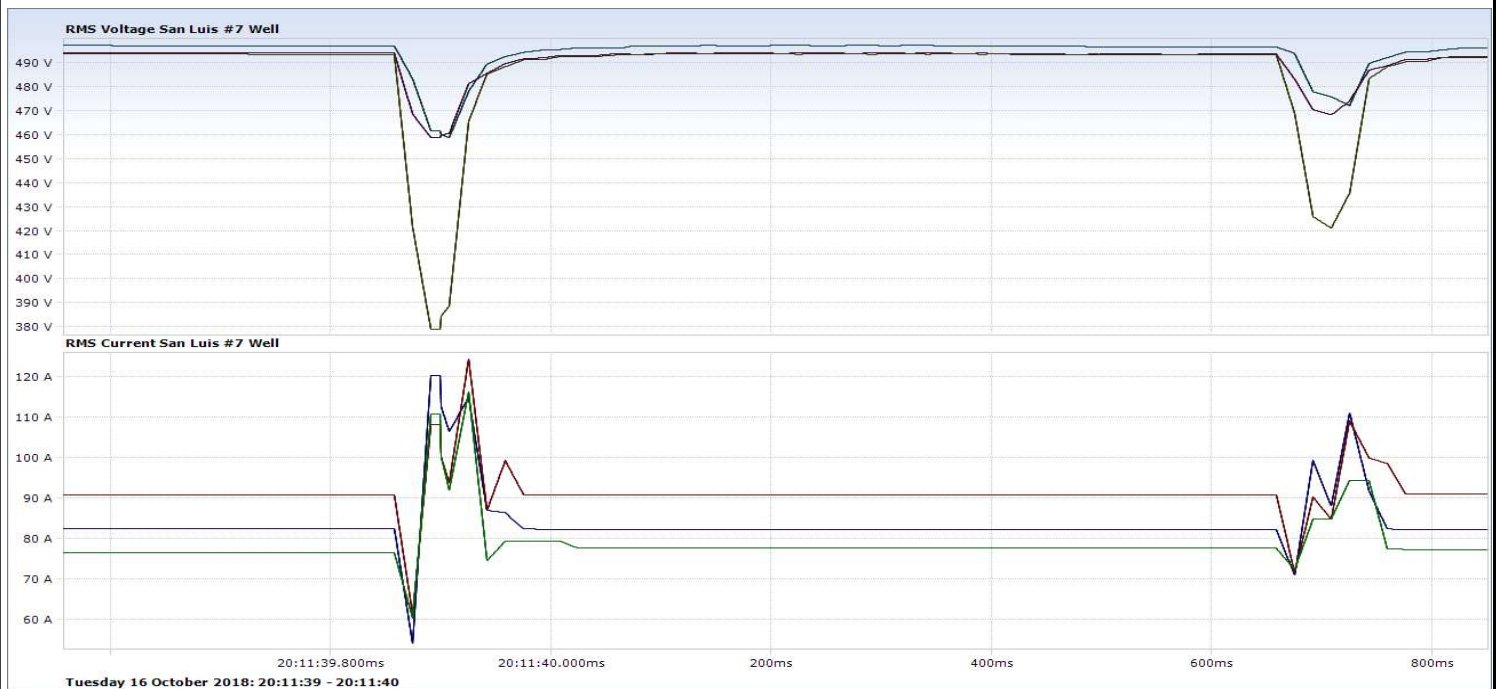
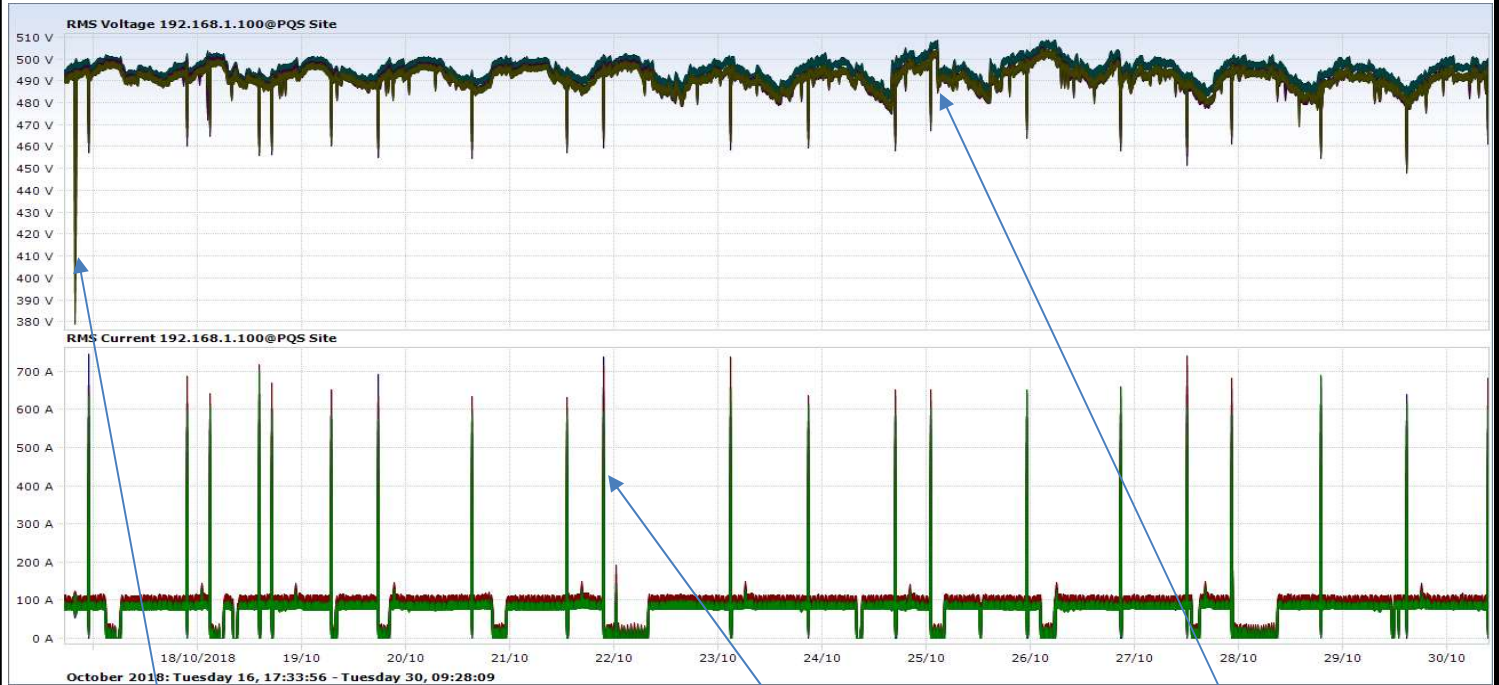


Figure 2.1.2 External Voltage Drop



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Figure 2.1.3 Total Measurement



Externally caused voltage drop

One of many motor starts and shut down

Utility capacitor switching
to adjust line voltage

Figure 2.3 is indicative of all of the motor starts during the measurement period

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Section 2.2- Pump Removal and Cable Test



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Figure 2.2.2-Test Apparatus and Procedure

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Figure 2.2.4-Pump and Motor removed, Motor hanging concentric in in well head shaft, no connection to ground

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Figure 2.2.4-Electrical connector from Cable to Motor

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Figure 2.2.5- View of the internal components of the connector. Note: Once the cable was removed, the resistance remained low as throughout the previous measurements, pointing to internal components of the motor.

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Table 2.1.1- Resistance Measurements during Motor/Pump removal

City of San Luis, AZ

Pump and Motor Removal- October 15, 2018 All measurements are made at 500 VDC and one-minute duration
 Step

#	Position	Depth	Volts	Resistance	Notes
		240			
1	Original	feet	500	2.2 Mohm	.8MOhm at start, going to 2.2Mohm after 1 minute
		240			
2	Original	feet	500	1.55 Mohm	Flange disconnected
		240			
3	Original	Feet	500	1.62 Mohm	Flange disconnected, feeder conduit disconnected
		180			
4	60' up	feet	500	1.23 Mohm	
		120			
5	120' up	feet	500	1.25 Mohm	
6	180' up	60 feet	500	1.29 Mohm	
7	240' up	0 feet	500	1.38 Mohm	
8	240' up	0 feet	500	1.55 MOhm	Motor out, hanging concentric in well head
9	240' up	0 feet	500	550 Mohm, motor 1.6 Mohm measured on connector pins to motor	

The above measurements were made with a City of San Luis owned instrument. That instrument was compared to a Filtronica, Inc. owned instrument and was found very close to that just calibrated instrument.

The measurements indicate that the low resistance is in the motor, not the cable. The motor has been presented to the manufacturer's representative for inspection. Filtronica Inc. has not been advised of any findings by the manufacturer.

Filtronica Inc was just now advised that a new motor will be installed on November 30, 2018, using the existing cable.

Summary:

The power quality measurement indicates a weak infrastructure. In most cases, such as this it is the responsibility of the owner (City of San Luis) to install equipment, designed to mitigate such conditions. It is Filtronica's opinion that a fast switching capacitor bank be installed. The capacitor bank should be able to compensate at least 600 kVAr of reactive energy and should be able to do that in less than 10 milli seconds to achieve best performance. Filtronica Inc is glad to assist the City of San Luis with the selection of such equipment.

Once the infrastructure is stabilized, no more failures/ faults are expected.

End of Report