POWER QUALITY ANALYSIS REPORT

FOR

MEAT PACKING PLANT

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CONFIDENTIAL AND PROPRIETARY

O&M INTRODUCTION

Established in 2010, O&M Resources is an Electrical Power Quality and Reliability consulting firm with corporate offices in Houston, Texas. O&M is focused and dedicated on providing its clients with solutions that are both Energy Efficient and Cost Effective.

Power and Power Quality are extremely important in facilities for enhancing efficiency of all electrical systems as well as assuring your electrical equipment and major assets continue to operate without unnecessary spend on maintenance issues. We are your energy and power specialists and in business specifically with one goal in mind, and that is to…Save You "WATTs" of Money! ®

EXECUTIVE SUMMARY

The Meat Packing Company is specializing in meat processing and packaging solutions. With over decades of experience, knowledge, and innovation, Meat Packing Company has implemented state-of-the-art equipment and solutions over the years to provide a superior quality product to food service customers and retail industries.

PURPOSE FOR ANALYSIS

O&M was retained by Meat Packing Company to conduct an onsite assessment of a portion of the electrical system at the facility. Numerous costly equipment (computers, motors, etc.) failures had been reported by maintenance crews and IT personnel at this location. It is the belief by maintenance personnel that the equipment failures are due to the "wet environment" and are therefore considered "normal". However, in comparison and in contrast to the Meat Packing Company facility, the one location experiences a lower number of equipment failures. The high operational costs and unusually high equipment failures at the North location caught the attention of the Meat Packing Executive team which prompted them to take a closer examination into the root cause.

Based on conversations with maintenance personnel, it is O&M's understanding that the North facility experiences an average of 20-25 motor failures on the factory floor on a monthly basis and 3 to 4 relay failures on the Multi-Vac system on a weekly basis. In addition to motor and relay failures, IT personnel have also reported equipment failures on the factory floor and within the office administration areas. O&M requested maintenance records from both departments in an attempt to calculate the cost of operational downtime. Unfortunately, such records are neither available nor recorded.

In O&M's experience, proven studies show, costly equipment failures, high utility costs, and unplanned downtime are usually the result of poor power quality and harmful electrical noise harmful harmonics (i.e. harmonics, waveform distortions, transients, high frequency noise, and surges) within an electrical system. Harmonics within an electrical system often originate from non-linear loads (systems or equipment that convert AC to DC voltage) such as LED lights, computer systems, and Variable Frequency Drives (VFD's), to name a few. Electrical equipment such as motors switching on and off also contributes to power surges and voltage transients. Transients can have a huge detrimental effect on sensitive electronic equipment. According to a 24-month IBM study, 85% percent of power quality issues originate from inside of the facility. See "Appendix B" in this document for a technical discussion on Power Quality and the Negative Effects of Higher Frequency Noise.

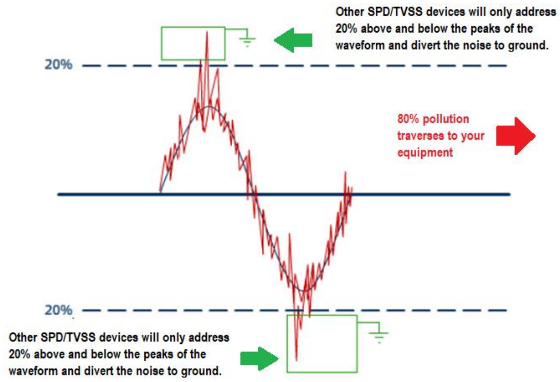
PROOF OF CONCEPT

Given that operational and maintenance records are limited or non-existent, Meat Packing Plant opted on a "before and after" data analysis of the electrical system. O&M recommended the implementation of Waveform Correction filtration with built-in Surge Protection. The Meat Packing Plant agreed to a Proof of Concept (POC) which included the purchase of Environment Potential (EP) Waveform Correction filtration on the condition that O&M show a reduction in any of the following; energy, heat, harmonics, or a reduction in factory downtime.

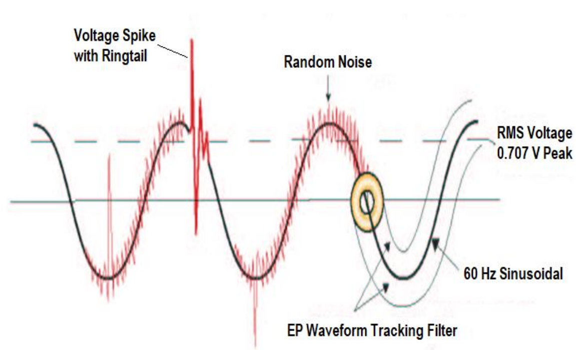
ENVIRONMENTAL POTENTIALS – WAVEFORM CORRECTION AND SURGE PROTECTION

Environmental Potentials patented waveform correction technology devices have been implemented world-wide and in numerous industries including the US Military, Wal-Mart, Exxon Mobil, and Toyota production lines, to name a few.

EP filters are designed to track the waveform and filter remove or dissipate the harmful harmonic pollution from the electrical system. *Other waveform devices on the market will attempt to send harmful harmonics to ground. which in effect creates a harmful ground loop The ground is not an adequate means of removing harmonic noise, leaving electrical resonance in the power system resulting in damage to other equipment and could result in damage to other systems. Other surge protection devices on the market will only catch the upper 20% of a transient spike, leaving the remaining 80% of noise and transients to traverse through the electrical system, in addition they divert these surges to the ground system thereby creating a possible ground loop that will damage equipment.* In contrast, Environmental Potentials devices are designed to actively minimize harmonics and transients within an electrical system and NOT allow them to build to a harmful state. EP filters will capture the harmonic noise and transient spikes and dissipate the noise and transients in the form of heat within the unit. See "Appendix C" in this document for a technical discussion on the Operating Principles of EP Filters – Waveform Correction and Surge Protection.



Other SPD/TVSS Devices



EP Waveform Correction

EXECUTIVE SUMMARY OF PANEL ANALYSIS

The Meat Packing Company identified the Main Service area, the Administration area, and the Chicken Production area, whereby EP filters could be installed, and initial data gathered. The EP installation was performed and initial data gathered on August 7th and August 8th, of this year. While on site, the maintenance foreman noted the Multi-Vac area as being very problematic. According to the forman, SMC technicians were having to continuously replace point relays on the Multi-Vac system to the tune of 3 to 4 per week. With SMC's permission, O&M extended the test to include the Multi-Vac panel. We returned approximately thirty (30) days later to gather post installation data. The data was then extensively analyzed and summarized below for your convenience. Please see the Readings and Observations area of this document for a complete analysis of each panel.

Analyzation of the data was accomplished using the Elspec G4500 Power Quality Analyzer and Sapphire software. The G4500 PQ meter is capable of gathering 1024 data points per cycle on all phases. Measurements include continuous waveform analysis on voltage, amperage, and harmonics analysis up to the 511th harmonic.

Main Service: For optimal performance, O&M recommends the installation of the EP 2800 unit to be installed directly on the load side of the main service electrical bus. Please note that installation of the EP2800 on the electrical bus requires a complete scheduled shut-down of the facility and the main service panel. For the purposes of this test and to avoid a shutdown of the facility, O&M instructed the electrical contractor to install a 100Amp breaker in the main service panel. The EP 2800 unit was then attached to this breaker and activated. The following is a summary of results for the Main Service. Please see the "Readings and Observations" section in this document for a complete analysis of results.

As evidenced by the illustrations in the "Readings and Observations" section of this document, the following can be expressly noted:

- The voltage and current transients are removed (transients are known to have catastrophic effects on equipment)
- The voltage and current lower order harmonics are significantly reduced (resulting in reduced power bills)
- The voltage and current higher order harmonics are significantly reduced (resulting in reduced equipment failure)
- The voltage and current fundamental waveforms are mere sinusoidal and thus waveform shape is corrected
- The temperature of the system is reduced, thus increasing the efficiency of the electrical system, and extending the lifespan of any equipment connected to the system.

Multi-Vac - Panel CL: This particular panel was identified by maintenance staff as requiring continuous replacement of burned-out relays which resulted in the production factory line to be taken off line for repairs. Upon return to the facility to obtain post installation data, it was noted by the factory floor technicians that the Multi-Vac area has not experienced the same level of downtime compared to past experience. To confirm, O&M also had a follow up discussion with the parts procurement manager. The procurement manager also indicated a reduction in re-stock of spare relay parts. In support of these statements, the data analysis does show that voltage and current higher order harmonics are significantly reduced. A decrease in transformer and breaker temperature was also noted. (see Figures 23, 24). Please see the "Readings and Observations" section in this document for a complete analysis of results.

Administration Area – Panel OL: - Plant personnel reported some flickering lights in the cubicle Administration area. As requested, O&M installed some EP filtration units on the administration Panel OL and gathered the required data for analysis. Our analysis and evidence revealed that this panel does not have a significant load to influence a significant reduction in harmonics. However, due to the nature and sensitive computer equipment in this area, O&M recommends the installation of EP filters in the administration area to protect from lightning and surge transients. As for the flickering lights in the cubicle Administration area, more investigation is warranted and recommended. O&M believes the flickering could be caused by an improper connection within the cubicle walls or a faulty light fixture. For the purpose of this analysis, the administration data has been omitted from this report.

ENERGY USAGE ANALYSIS

The Meat Packing Plant provided energy bills and production data for the months of June through October. Oncor provided 15-minute KWH data and 12-month summary data. An energy bill is comprised of actual KWH used, TDSP charges, Congestive Settlement charges, Metering charges, taxes, and many others. Inclusive of some of the TDSP charges are Power Factor penalties. O&M noted that the plant had an average Power Factor of 0.87. After the EP units installation of 30 days, the power factor improved to 0.89 on the October power bill.

In electrical engineering, the power factor of an AC electrical power system is defined as the ratio of the real power absorbed by the load to the apparent power flowing in the circuit and is measured from zero to one (a.k.a. Unity). A power factor of less than one indicates the voltage and current are not in phase. In layman terms, a power factor less than one means that the plant is not using the supplied energy efficiently and therefore the energy company will assess a power factor penalty and congestive charges in accordance with the power factor. As indicated earlier, TDSP charges include but not limited to power factor penalties. The table below shows charges for actual KWH used and the Total Bill.

A full explanation of TDSP energy bill charges can be found at the following:
http://www.oncor.com/en/Documents/About Oncor/Billing Rate Schedules/Tariff for Retail Delivery Service.pdf

Energy consumption is monitored and metered at a single ingress point (Main Service). The plant does not have a mechanism in place to monitor energy usage on each individual systems. Therefore, the data presented below is an analysis of production and energy usage for the entire facility. Based on the acquired data, O&M calculated a slight reduction in energy spend by approximately 6617.7 KWH per month. Factoring in 38% for TDSP charges equates to a Total Energy Savings of $4,931.51.

$\boldsymbol{Energy\ Savings} = 6617.7KWH\ x\ 12\ Months\ x\ \$0.045 = \$3{,}573.56 + 38\%\ TDSP\ Charges = \$\mathbf{4,931.51}$ **(at 2022 energy average rates of $.014 per/KWH the annual savings would be approximately $11,116.56)**
Estimated

In contrast, the production numbers for the entire plant have increased throughout the test period by approximately 1801.8 cases on a monthly basis. Based on information provided by the plant, it is O&M's understanding that each case has an average profit margin of $8 per case. Multiplying the profit margin per case times the number of additional cases per month equates to an additional $172,972.8 profit margin for the year.

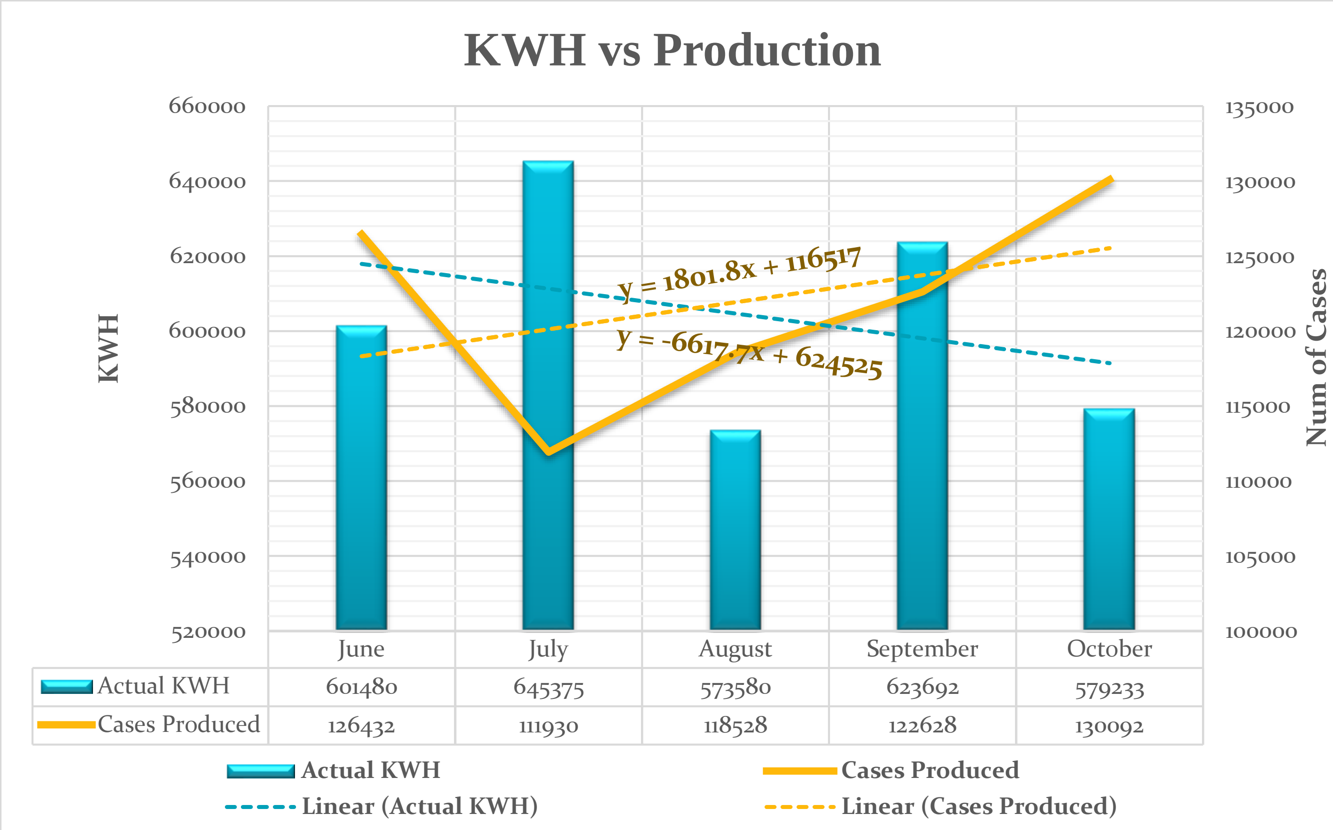
$\boldsymbol{Annual\ Production\ Increase} = 1801.8\ additional\ cases\ x\ 12\ months\ x\ \$8\ profit\ margin = \$\mathbf{172,972.80}$
Estimated

The cost of downtime, labor cost, maintenance, and equipment replacement cost are also a huge factor in this analysis. Unfortunately, not enough data was available to calculate the aforementioned. Therefore, the cost savings is unknown, however the equations below are shown as noteworthy components to this analysis.

$\boldsymbol{Downtime\ LAbor\ Cost} = Number\ of\ people\ on\ productin\ line\ x\ Hourly\ Rate\ x\ Time = \$\boldsymbol{Unknown}$

$\boldsymbol{Maintenance\ and\ Capitol\ Cost} = Equipment\ replacement\ cost\ x\ maintenace\ personnel\ cost = \$\boldsymbol{Unknown}$

Based on the provided data, it is O&M's opinion that the increase in production can be attributed to an increased efficiency within the electrical system and a decrease in maintenance and downtime. The graph below is a representation of the aforementioned discussion.



	June	July	August	September	October
Actual KWH	601480	645375	573580	623692	579233
Cases Produced	126432	111930	118528	122628	130092

CONCLUSION AND RECOMMENDATIONS

O&M will concede that some equipment failure is due in part to a ”wet environment”. However, based on the data gathered during this power quality study, the presence of higher order harmonics (high-frequency noise) is the root cause and reason for the high volume of electronic equipment failure.

Left untreated, the noise will cause further damage to the facility in the form of burned-out relays, issues with PLCs', heated transformers, etc. It is imperative to remove the higher order harmonics from the electrical system in order to protect all electrical equipment, but more importantly protect sensitive electronic equipment. Unfortunately, high frequency noise does not emanate from a single source, therefore a pin-point solution is not possible. High frequency noise emanates from many sources and needs to be addressed accordingly and attenuated to safe limits. As previously mentioned, 85% of all power quality issues and high frequency noise originates from within the facility.

The proof of concept and analyzed data is conclusive and shows that the addition of Environmental Protection filtration has made a significant impact on the reduction of transients, higher order harmonics, the reduction in heat, and corrected the fundamental voltage and current waveforms. Motors and sensitive electronic equipment are running more efficiently, thus increasing the lifespan of the equipment. Factory personnel have confirmed that maintenance, labor, and capital costs were also reduced thus minimizing downtime on the factory floor and increasing operations and productivity.

As a reminder, Environmental Potential filters were installed in a very small subset of the electrical system. Yet, it made an impact on the entire system and produced positive results. O&M recommends that the Meat Packing Plant should proceed with the purchase of the currently installed EP filters and expand the installation of EP filters to include other areas of the facility. It is recommended to install EP filters at all seperately derived systems, thus providing complete surge protection from outside anomolies such as lighting strikes, and or power company transformer surge fluctuations. The HVAC and refrigeration plant areas are especially prone to a lot of high frequency noise and transients, and should be investigated and addressed. Minimizing harmoincs and voltage transients on the HVAC system would have a massive impact on lowering operational cost, balancing motor currents and voltages thereby reducing bering failer, including energy consumption cost.

READINGS AND OBSERVATIONS – MAIN PANEL

HARMONICS WAVEFORM ON VOLTAGE

The illustration readings captured below (Figure 1) shows voltage transients of 85.64, 51.91 and 70.76 on the Harmonics Voltage Waveform on the Main Panel. The transients are completely removed (Figure 2) after proper installation of EP filtration.

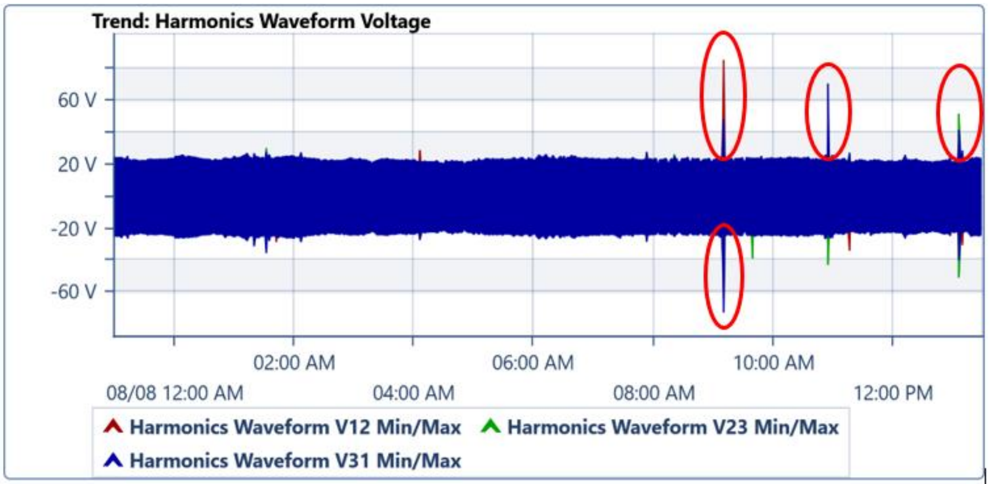


Figure 1
Harmonics Waveform Voltage before installing EP

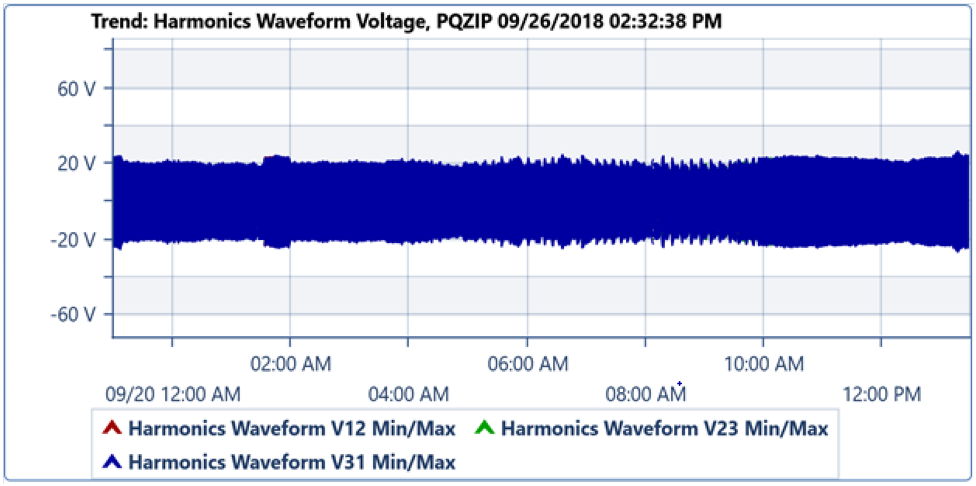


Figure 2
Harmonics Waveform Voltage after installing EP

Figure 3 and 4 shown below are zoomed in graphs showing the transient events from the previous graphs (Figures 1 and 2). The measurements show the high peak amplitude of 85.64v on one of its phases. The high energy harmonics noise are removed to a permissible range after installation of EP filtration.

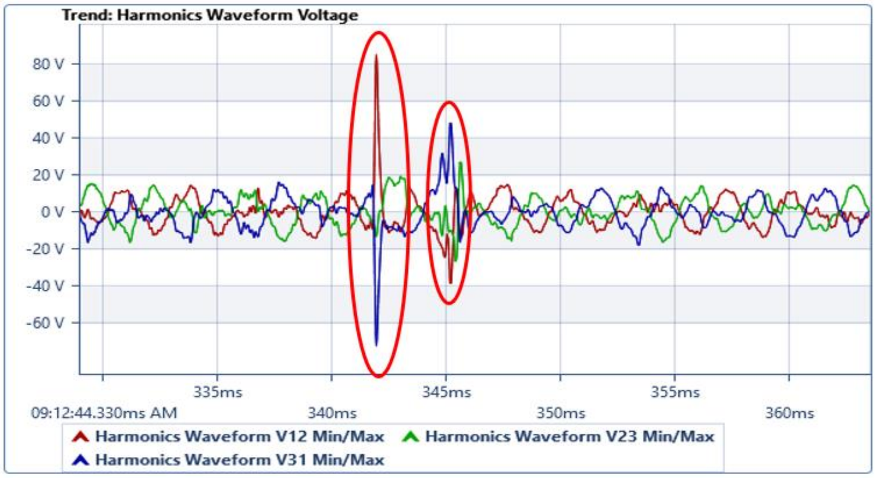


Figure 3
Harmonics Waveform Voltage before installing EP units.

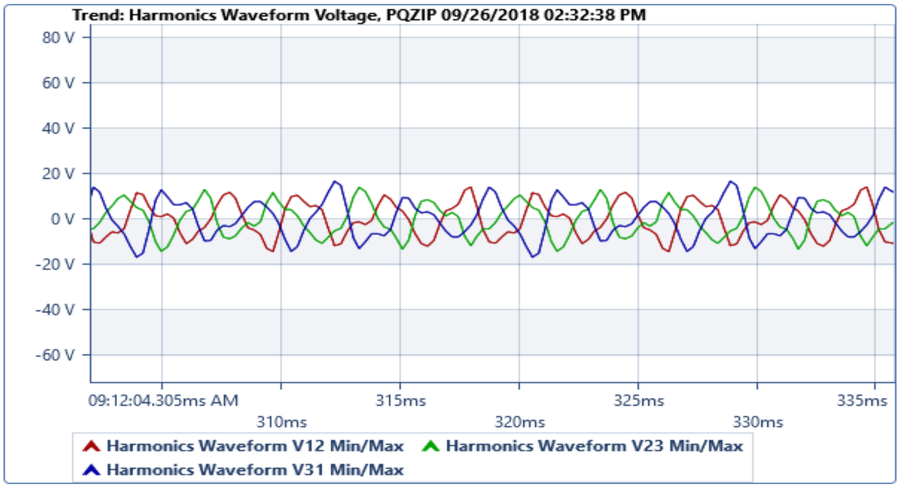


Figure 4
Harmonics Waveform Voltage after installing EP units.

HARMONICS WAVEFORM ON CURRENT

Initial measurements indicate that the harmonics waveform on current is continuously **in excess of 150Amps** or more on all phases. (Figure 5). After installing the EP units, the noise is significantly **reduced by approximately 50amps** (Figure 6). However, there is still some scope to remove the leftover current noise further when equipped with a greater number of EP filters.

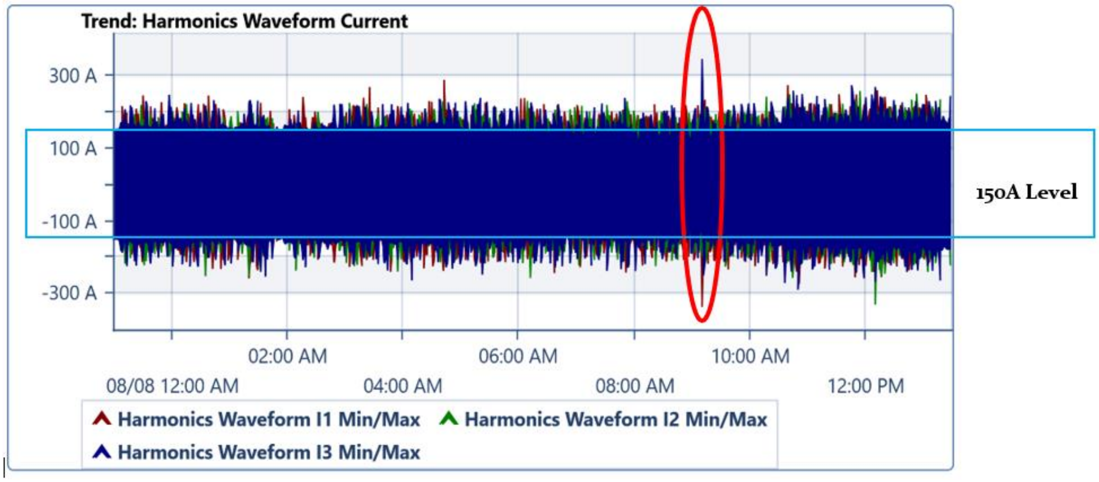


Figure 5
Harmonic Waveform Current before installing EP units.

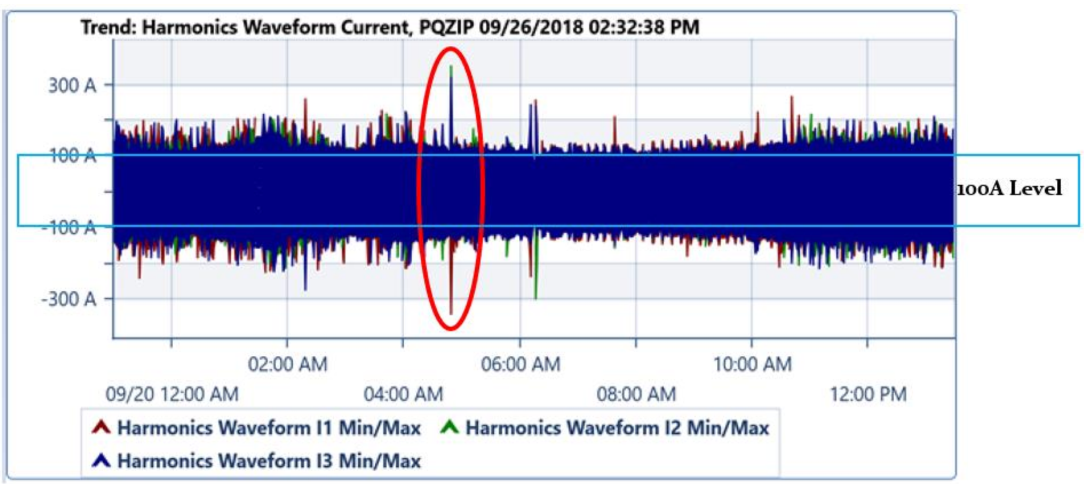


Figure 6
Harmonic Waveform Current after installing EP units

Figure 7 and 8 shown below are zoomed in graphs showing the harmonics noise events from the previous graphs (Figures 5 and 6). Note that the waveform is significantly smoothed out and amperage has been reduced by approximately 50 Amps after installation of EP filtration.

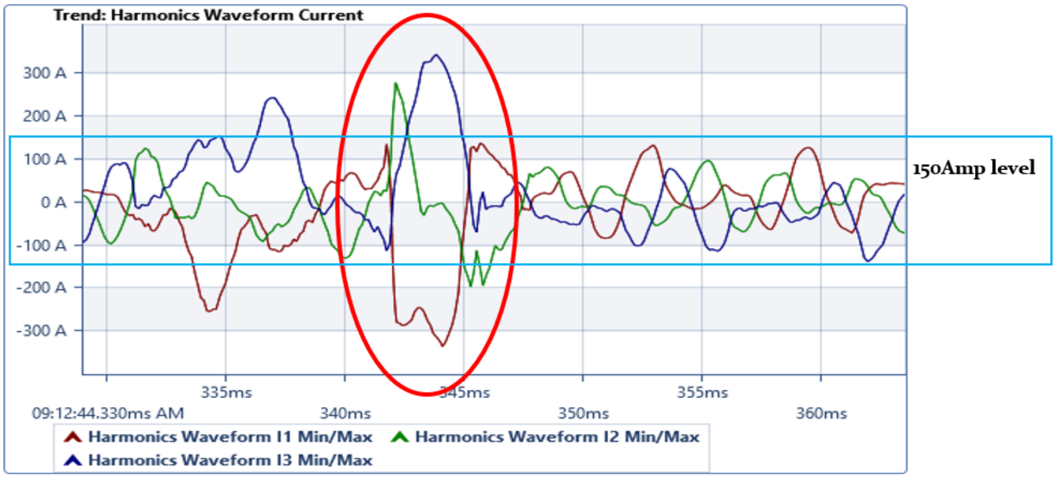


Figure 7
Harmonic Waveform Current before installing EP units.

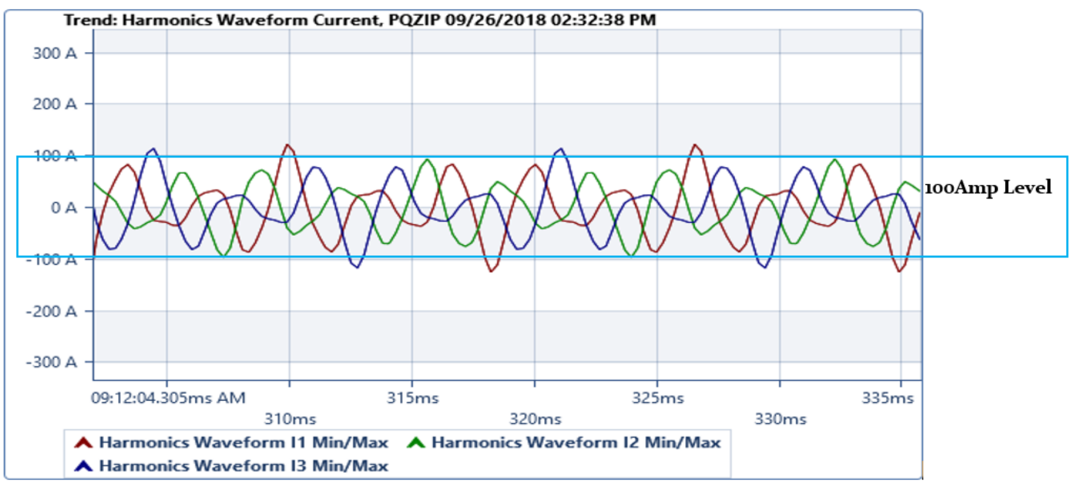


Figure 8
Harmonic Waveform Current after installing EP units.

FUNDAMENTAL VOLTAGE AND CURRENT WAVEFORMS

Both the voltage and current waveforms shown below (Figures 9-12) shows notches and non-linearity that are eventually removed after installing EP filtration. Note that the waveform is corrected to its nominal sinusoidal waveform.

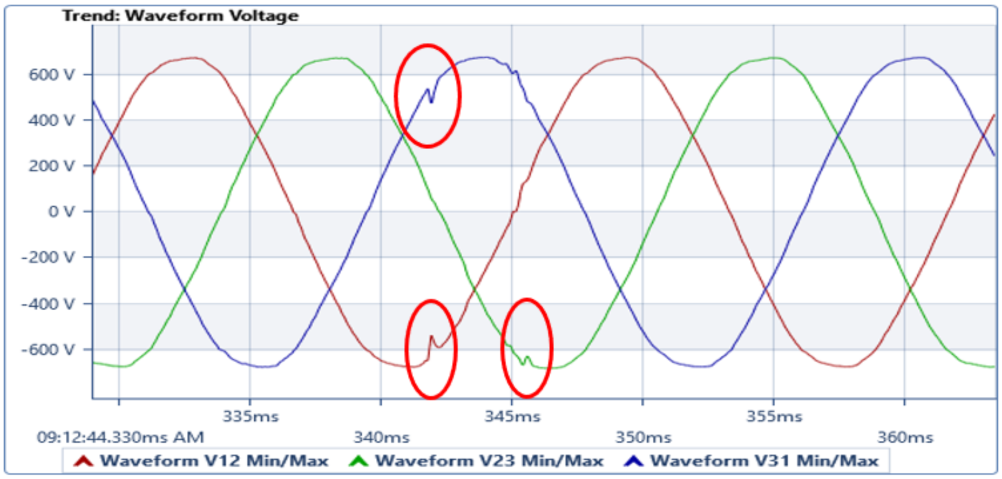


Figure 9
Fundamental Waveform Voltage before installing EP units

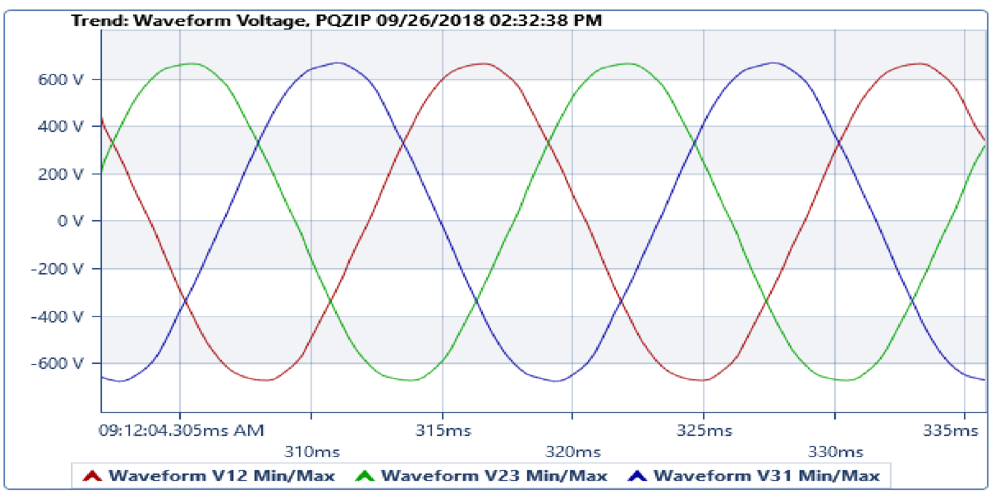


Figure 10
Fundamental Waveform Voltage after installing EP Units.

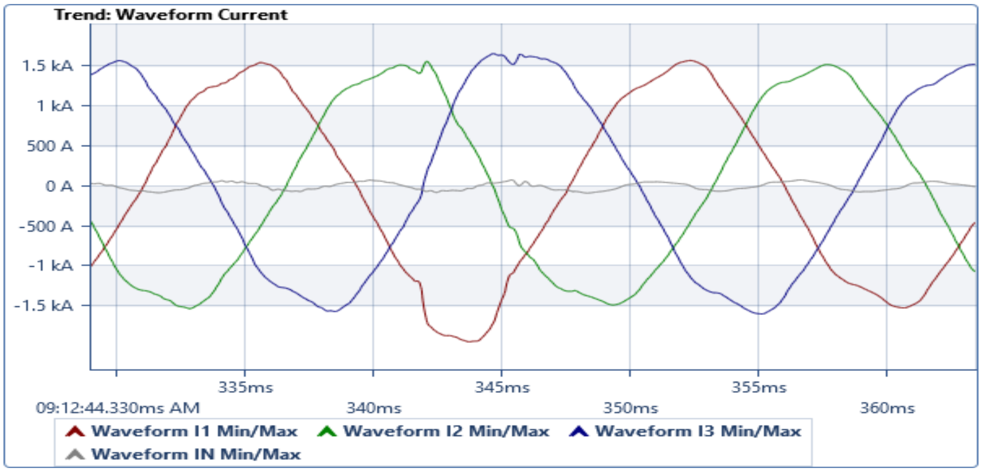


Figure 11
Fundamental Waveform Current before installing EP Units

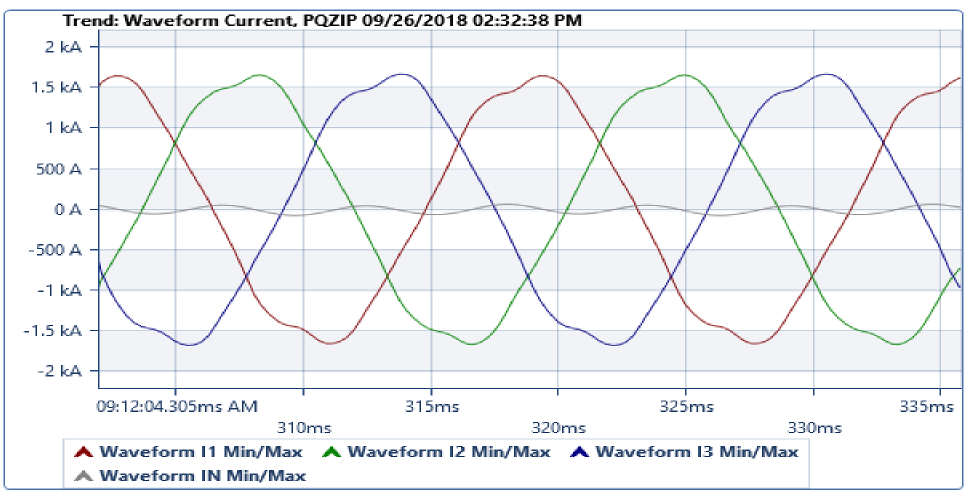


Figure 12
Fundamental Waveform Current after installing EP units.

HIGH FREQUENCY NOISE ON VOLTAGE AND CURRENT

The green area shown on the graph below (Figure 13) indicates the Fast Fourier Transform analysis of voltage up to 30,000Hz. The red circled areas indicate the Ferro-electro magnetic resonance in the system that amplifies the electrical noise at frequent intervals. The red circled areas also indicate the resonance phenomenon on the voltage spectrum. The purple area on the graph shows the FFT analysis on the current up to 30,000Hz. Note that the 16th to the 48th harmonics is significantly large (as pointed by the red arrow mark). The noise shown (Figure 14), has been significantly reduced both on the voltage and current as indicated by the red arrows after installation of EP filtration.

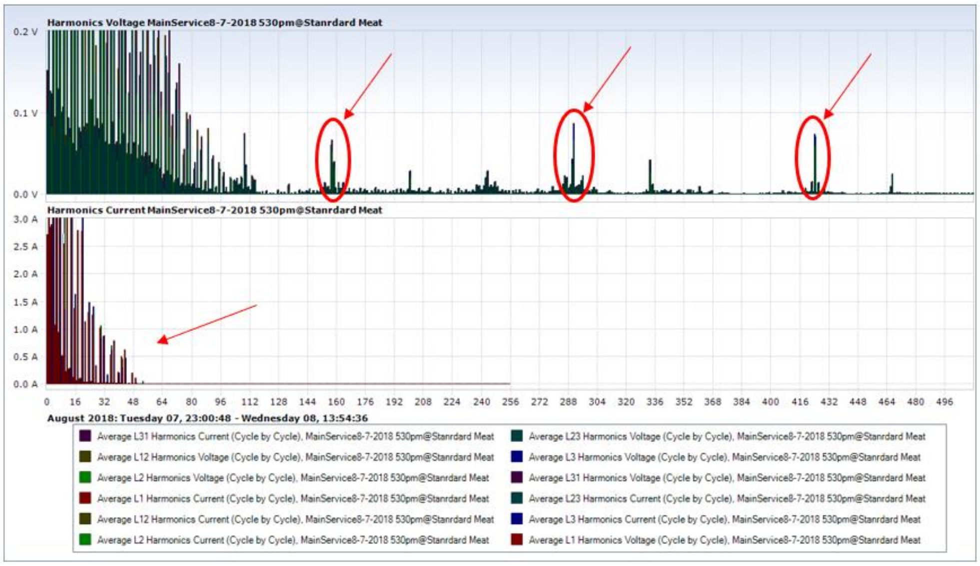


Figure 13
High-Frequency Noise (FFT analysis) of Voltage and Current before installing EP

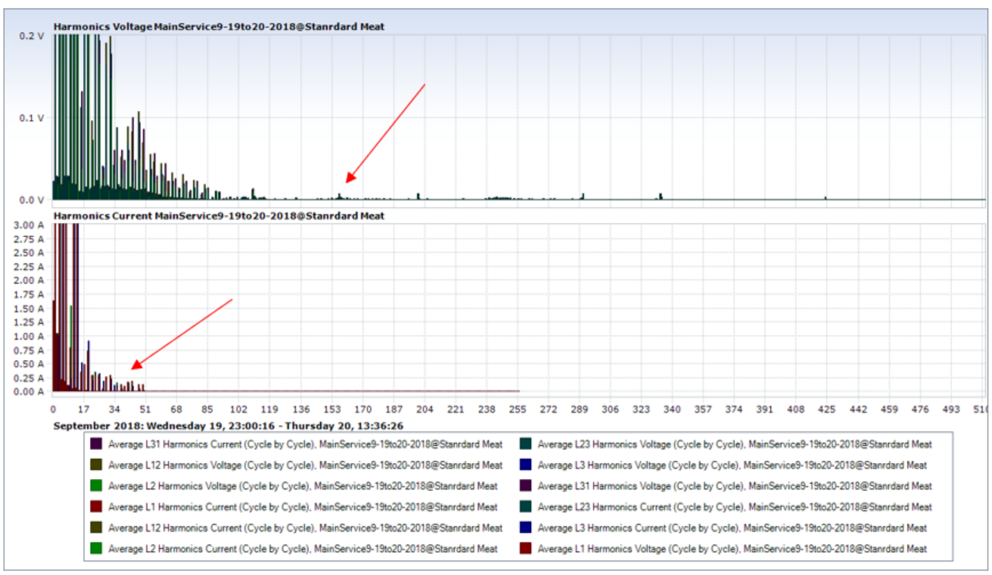


Figure 14
High-Frequency Noise (FFT analysis) of Voltage and Current after installing EP

NEUTRAL HARMONICS

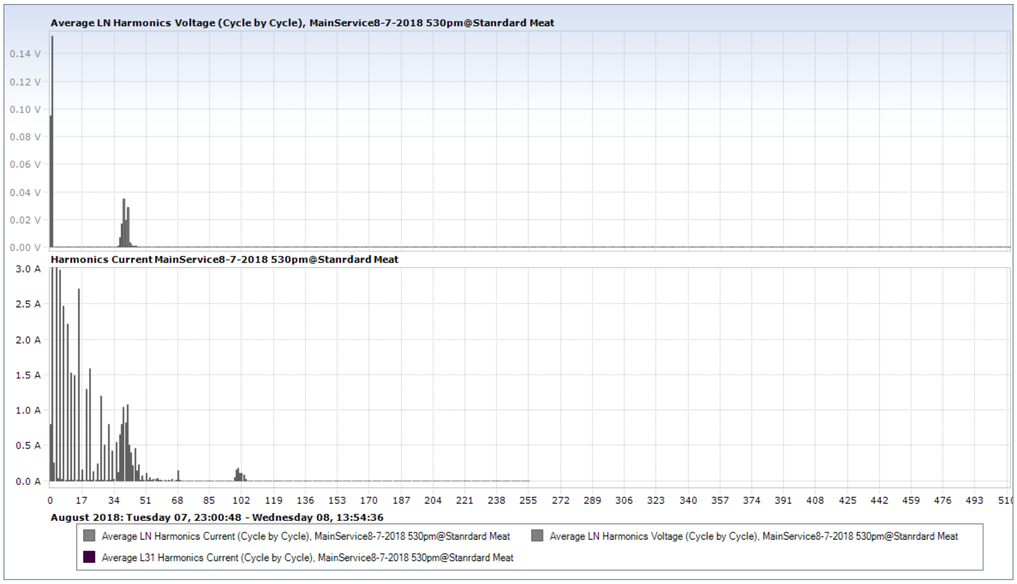


Figure 15
Neutral Harmonics before installation of EP Units

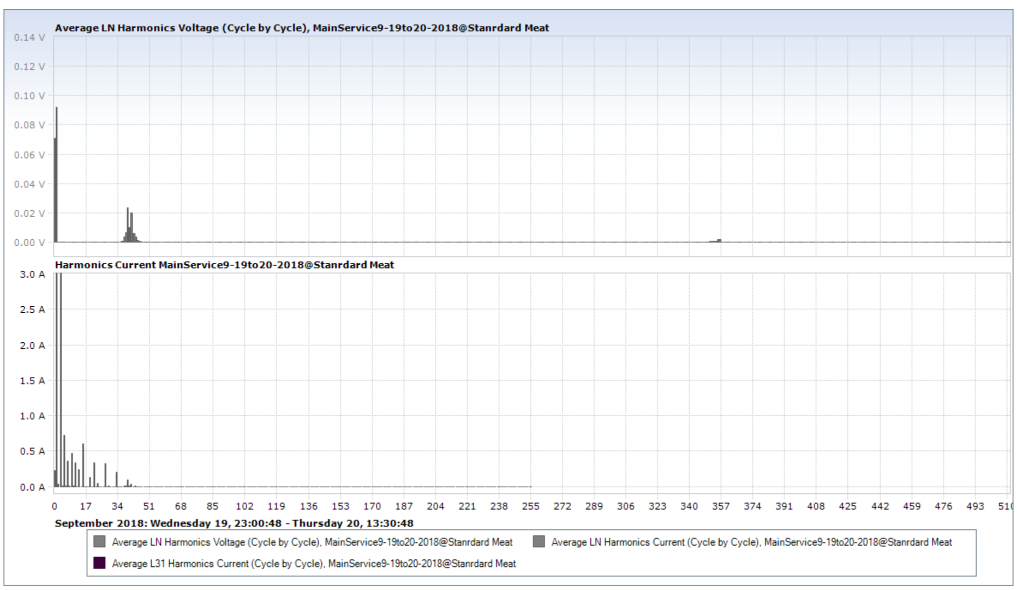


Figure 16
Neutral Harmonics after installation of EP Units

TEMPERATURE MEASUREMENTS AT MAIN SERVICE PHASE B WIRE

Figure 17
8-7-2018 8:16pm load on B Phase 1175 Amps Temp=45.7°C
(Before installatin of EP Units)

Figure 18
9-20-2018 4:38pm load on B Phase 1250 Amps Temp=39.4°C
(After installation of EP Units)

Note:" The temperature on the B phase wire was reduced by 6.3°C while the load increased by 75 amps.

READINGS AND OBSERVATIONS – PANEL CL – MULTI-VAC

VOLTAGE HIGH FREQUENCY NOISE

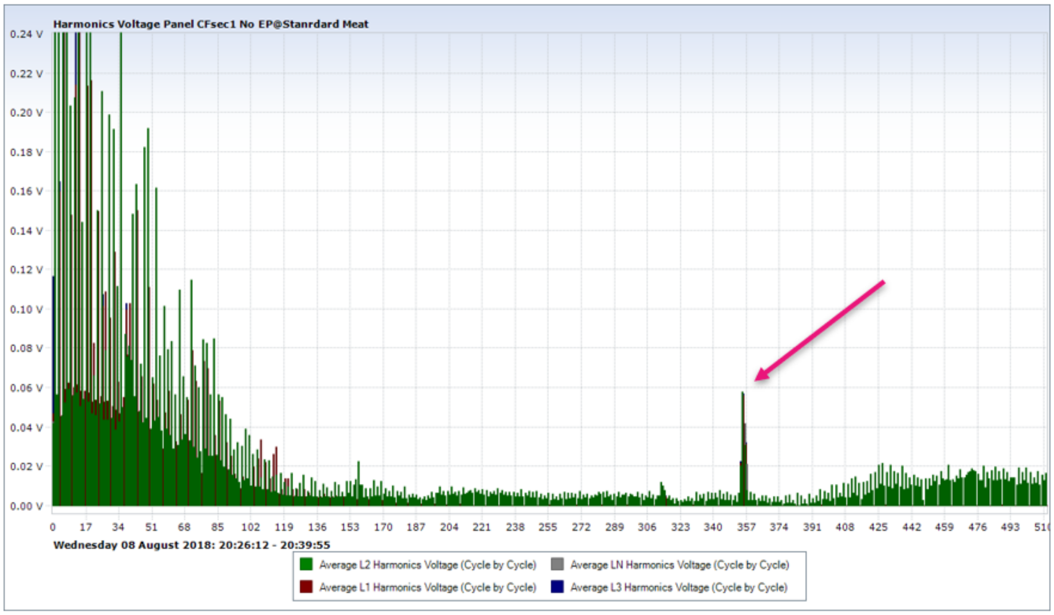


Figure 19
High Frequency Noise on Voltage before installation of EP Units

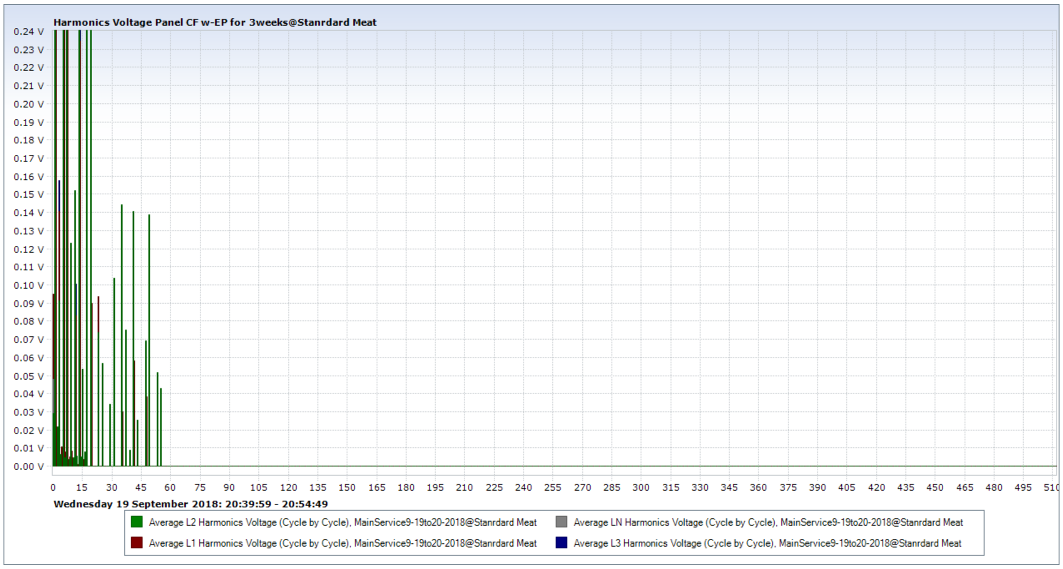


Figure 20
High-Frequency Noise on the Voltage after installation of EP units.

Note: There was a significant reduction of high-frequency noise which resulted after the installing the EP units.

CURRENT HIGH FREQUENCY NOISE

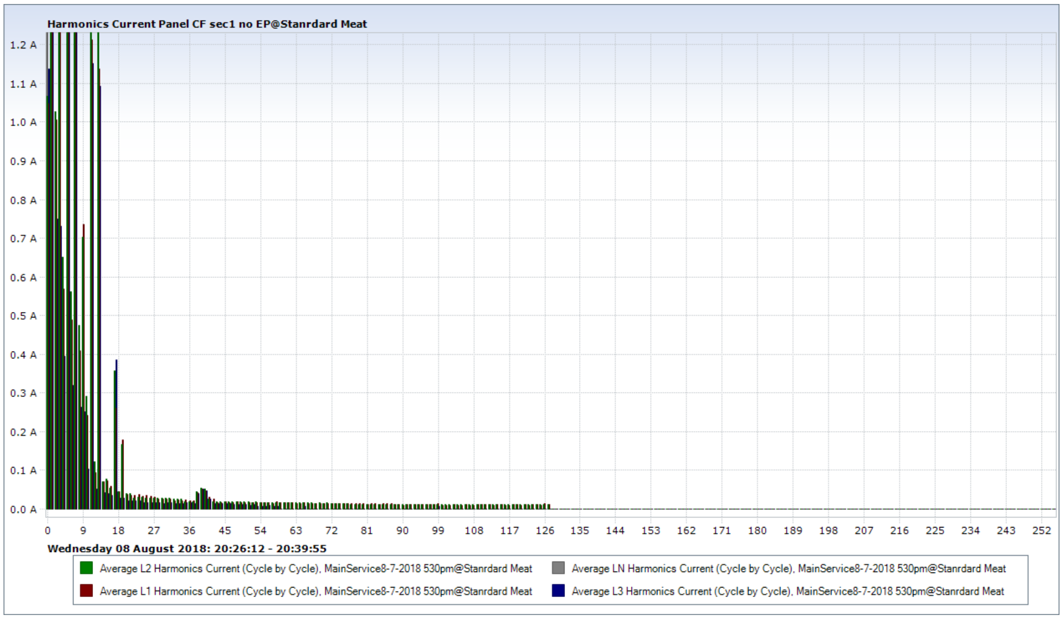


Figure 21
High Frequency Noise on the Current before installation of EP units.

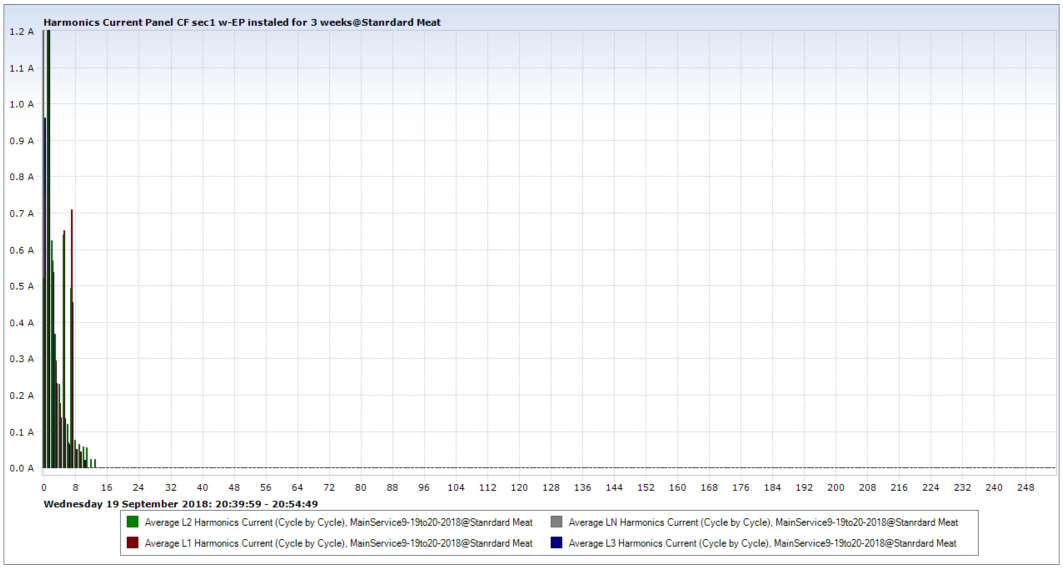


Figure 22
High-Frequency Noise on the Voltage after installation of EP Units

TEMERATURE MEASUREMENTS AT PANEL CL – MULTI-VAC

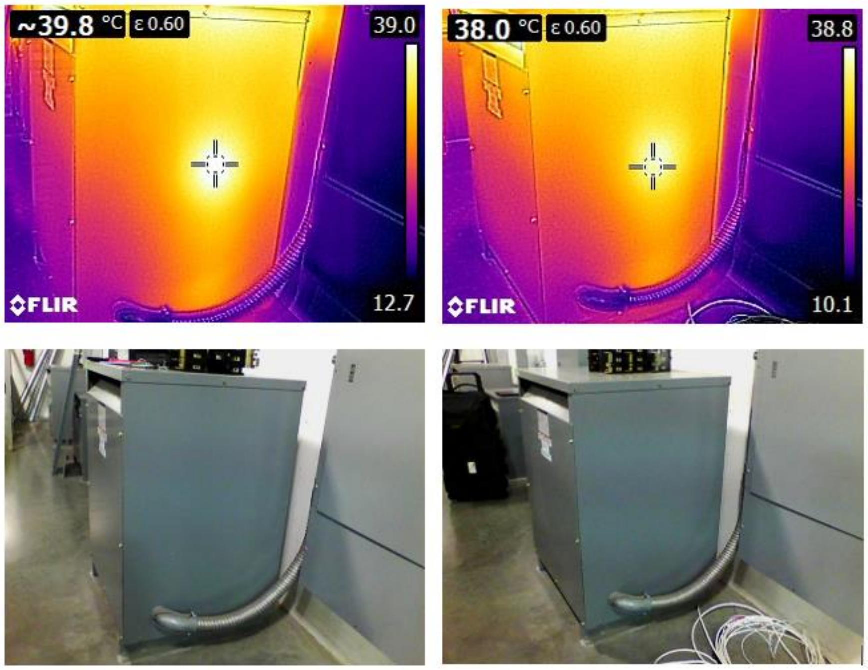


Figure 23:
The temperature of the transformer reduced by 1.8 degrees after installing EP units.

Figure 24:
Temperature on the breaker at Panel CL is reduced by 1.6°C.

READINGS AND OBSERVATIONS – PANEL HF – CHICKEN AREA

HARMONICS WAVEFORM VOLTAGE

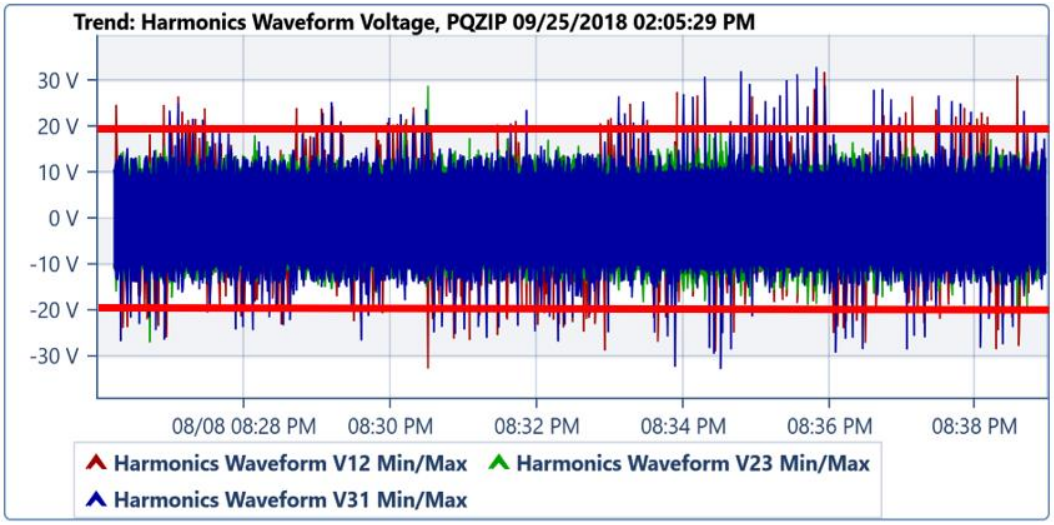


Figure 25:
Harmonics Waveform Voltage before installing EP units.

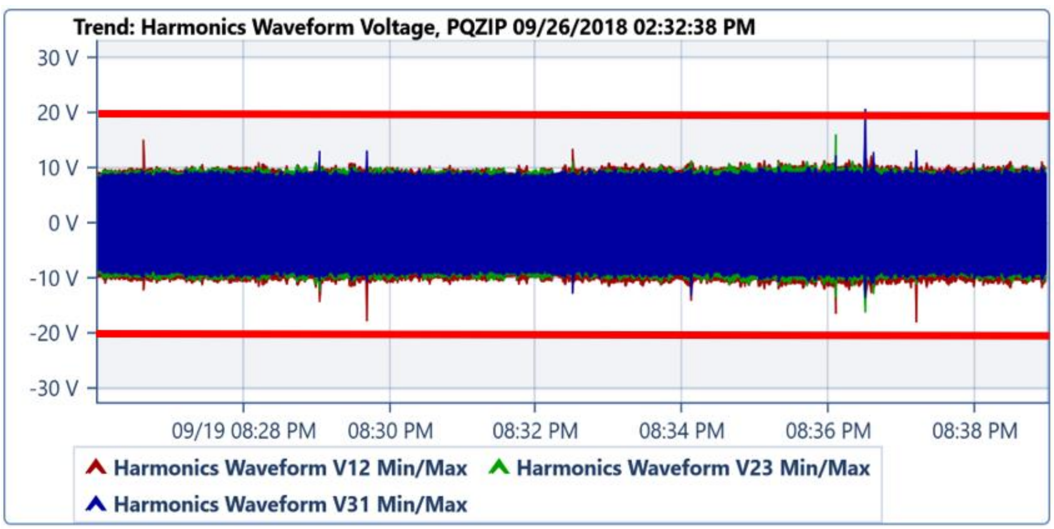


Figure 26:
Harmonics Waveform Voltage after installing EP units.

HARMONICS WAVEFORM CURRENT

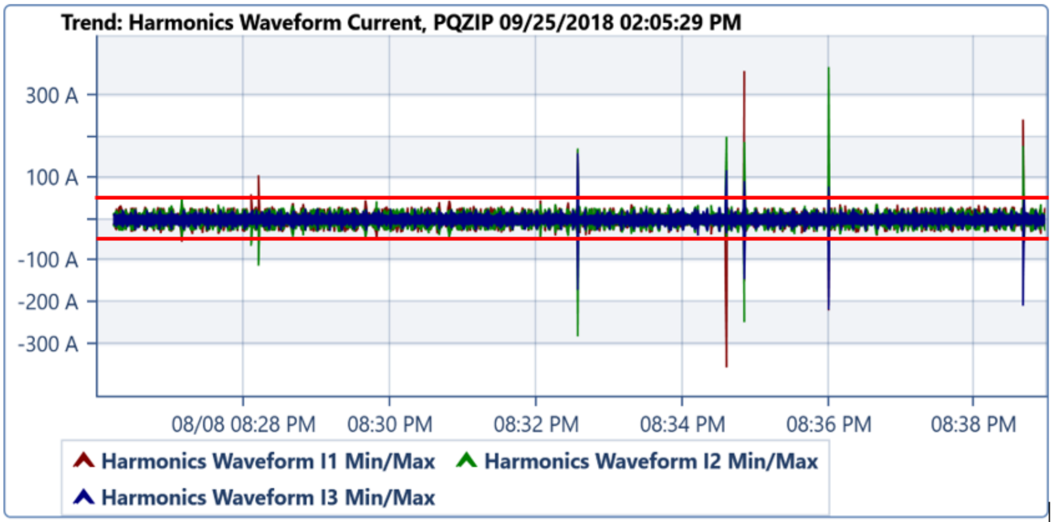


Figure 27
Harmonics Waveform Current before installing EP unit.

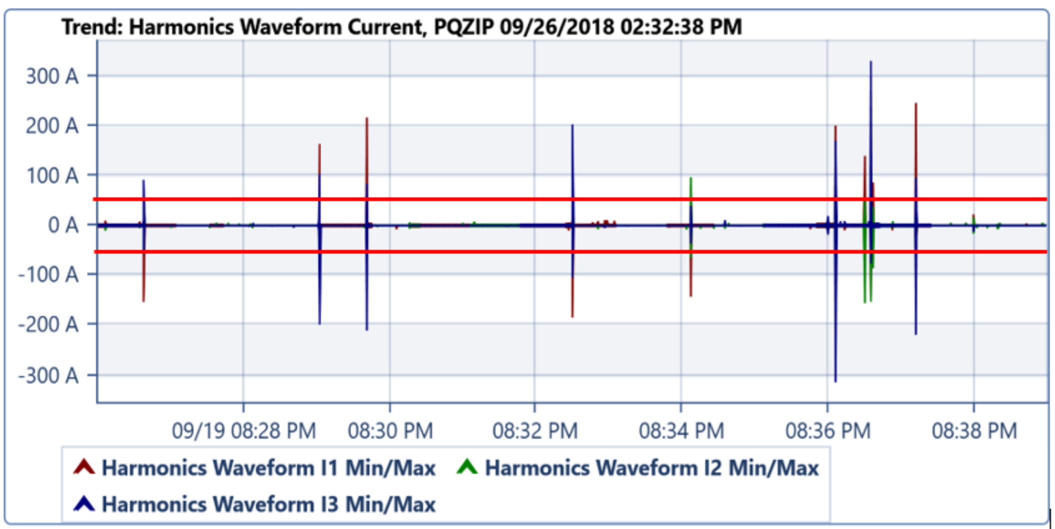


Figure 28
Harmonics Waveform Current after installing EP units.

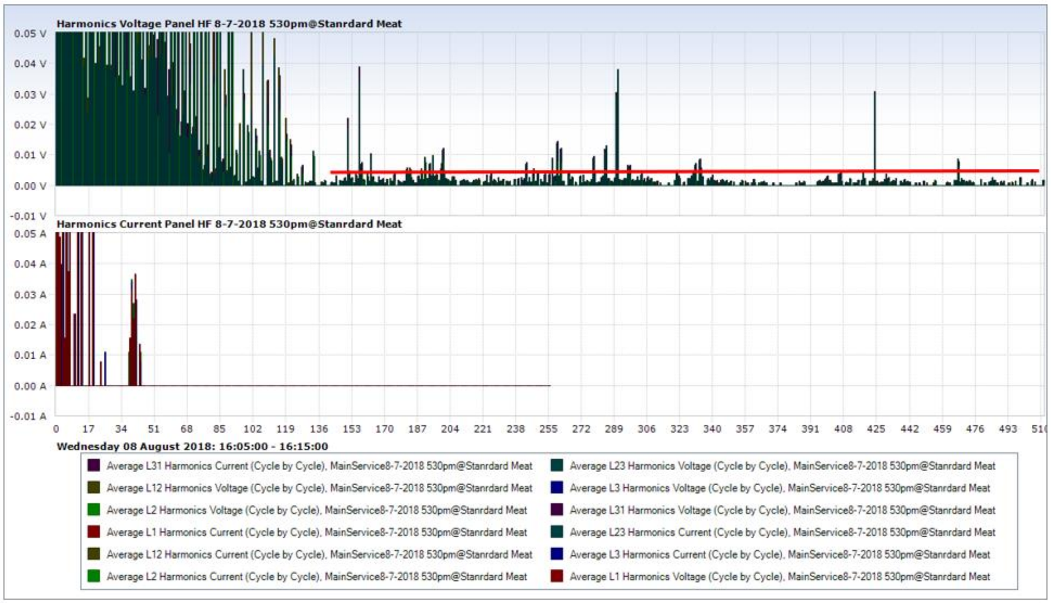


Figure 29
High-Frequency Noise on the Voltage and Current before installing the EP 2500 unit.

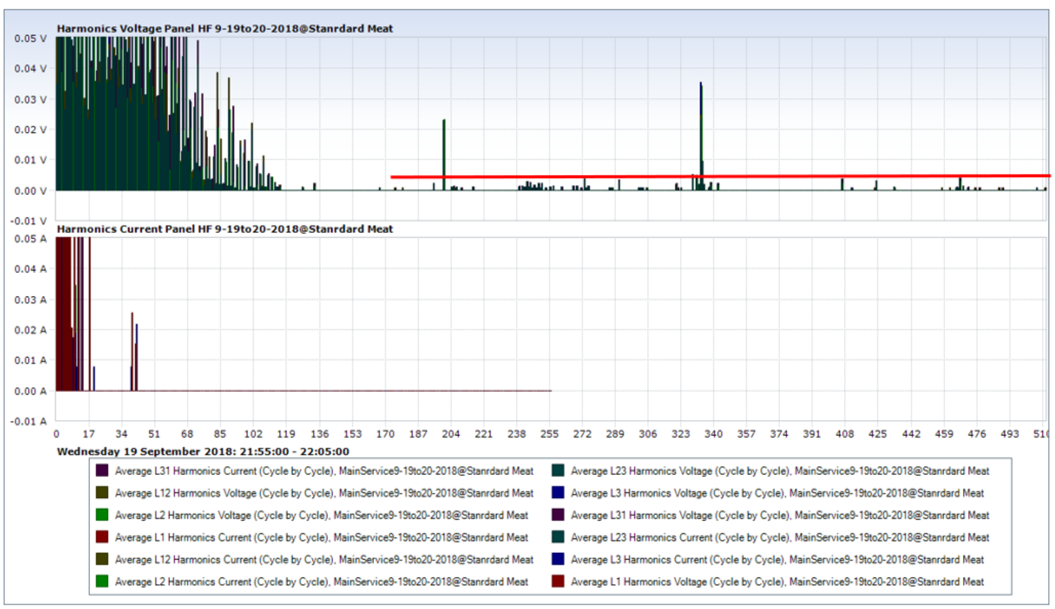


Figure 30
High-Frequency Noise on the Voltage and Current after installing the EP 2500 unit.

READINGS AND OBSERVATIONS - PANEL HA – CHICKEN AREA

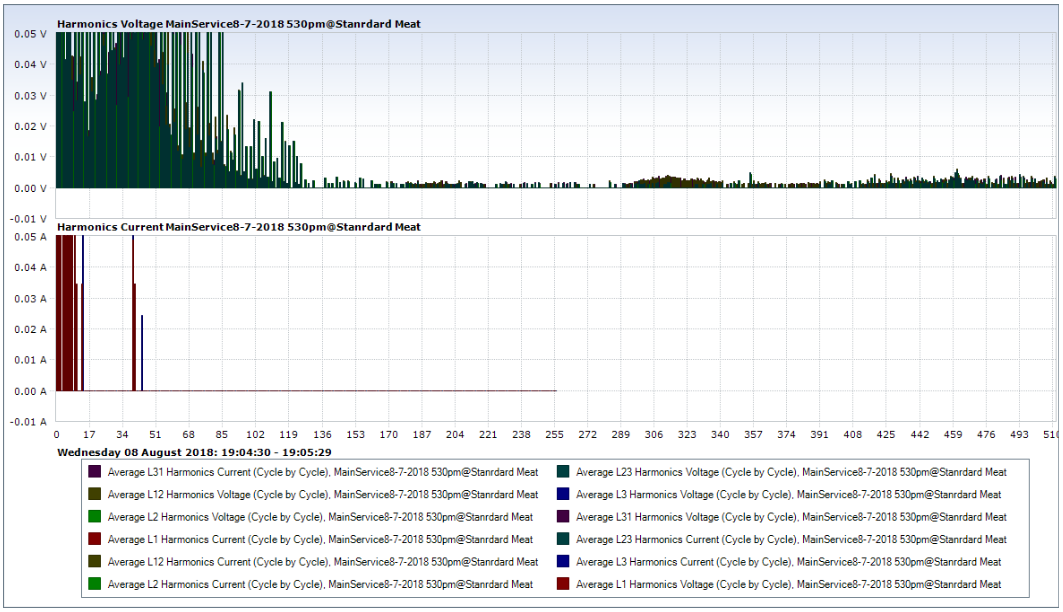


Figure 31
High-frequency noise on Voltage and Current before installing the EP 2000 unit.

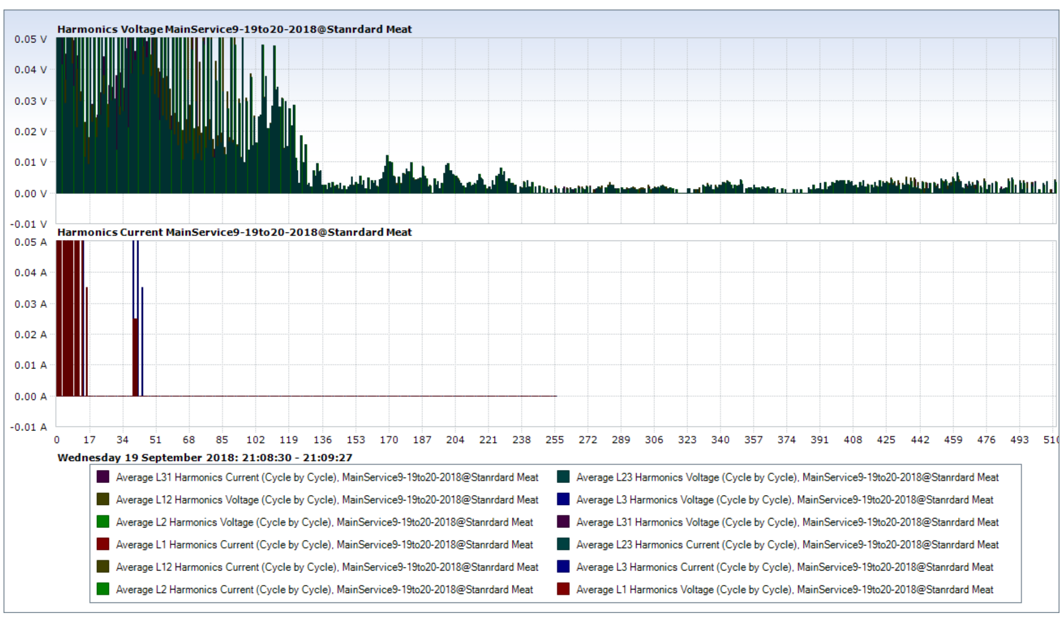


Figure 32
Figure 26: High-frequency noise on the Voltage and Current after installing the EP 2000 unit.

APPENDIX A: IEEE STANDARDS / PUBLICATIONS

TOTAL HARMONICS DISTORTION ON FACILITY
(REFERENCE: IEEE 519 SECTION 11)

Table 11.1
Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV through 161 kV	1.5	2.5
161.001 kV and above	1.0	1.5

Excerpt from IEEE 519 – 1992 Section 11 -"The system must be measured at the point of common coupling (PCC) or at the Main power entrance supplying the building to assess overall total harmonic distortion on the voltage of the whole system as prescribed limits by the guidelines."

HIGH-FREQUENCY HARMONICS / NOISE
(REFERENCE: IEEE 1100 SECTION 1999 AND IEEE 519-1992 SECTION 6.6)

4.2.1.2 Performance range

The term *performance range* is defined here to be in the frequency range between tens of kHz and tens of MHz. It is within this range that conducted, coupled, and radiated electromagnetic energy in the conducted mode and both the near- and far-field modes can significantly impact the operational performance of most forms of electronic equipment.

Excerpt from IEEE 519 – 1992 Section 6.6 - "Higher levels of harmonics result in erratic, sometimes subtle, malfunctions of the equipment that can, in some cases, have serious consequences. Instruments can be affected similarly, giving erroneous data or otherwise performing unpredictably. Perhaps the most serious of these are malfunctions in medical instruments."

TRANSIENT VOLTAGE AND SURGES
(REFERENCE: IEEE 1159 SECTION 2009)

1.0 Transients			
1.1 Impulsive			
1.1.1 Nanosecond	5 ns rise	< 50 ns	
1.1.2 Microsecond	1 µs rise	50 ns – 1 ms	
1.1.3 Millisecond	0.1 ms rise	> 1 ms	
1.2 Oscillatory			
1.2.1 Low frequency	< 5 kHz	0.3–50 ms	0–4 pu[a]
1.2.2 Medium frequency	5–500 kHz	20 µs	0–8 pu
1.2.3 High frequency	0.5–5 MHz	5 µs	0–4 pu

Technical References:

1. Unger, C.; Krueger, K.; Sonnenschein, M.; and Zurowski, R.; " Disturbances due to voltage distortion in the kHz range - Experiences and mitigation measures" , presented at the 18th International Conference on Electricity Distribution Turin, 6-9 June 2005, Paper No. 52.
2. Maki-Ontto, P.; " Modeling and reduction of shaft voltages in ac motors fed by ¨ frequency converters" , Doctoral thesis Helsinki University of Technology, 21 April, 2006
3. Voss, G.; Mattatia, S.; and Bajog, G.; " Interaction between power electronic components and distribution transformers - Risk evaluation and mitigation techniques" presented at the 18th International Conference on Electricity Distribution Turin, 6-9 June 2005, Paper No. 477.
4. Hoff, C.M.; and Mulukutla, S.; " Analysis of the instability of PFC power supplies with various AC sources" , Proc. APEC ' 94, Feb. 1994 pp. 696 - 702 vol.2

APPENDIX B: POWER QUALITY

NEGATIVE CONSEQUENCES OF HIGH FREQUENCY NOISE

Higher order harmonics noise often called High-Frequency noise is an unwanted electrical signal on the fundamental frequency. While the negative consequences of the High-frequency noise in the system are enormous, its damaging effect to the electronics loads is what is seen in this facility. The generated high-frequency noise along with transients could cause detrimental effects on the facility. Frequency noise in the higher kHz range leads to malfunction of electronic office equipment, blown power supply units, and malfunction of electronic controls or unacceptable noise. The noise could puncture holes on the capacitors, increase junction temperature of semiconductor devices, increase ohmic losses (increased power bills), cause improper triggering of FET's and thyristors, and data corruption. Thus, the noise causes erratic behavior of the load and a reduction in meantime between failures (MTBF), resulting in premature failure of the equipment.

High-frequency noise resulting from the transients and high energy spikes causes permanent damage to the electrical loads. High-frequency noise results in damage to lighting ballasts and drivers, motor bearings, transformers, power supply units, and other sensitive electronic equipment. The damage to the load starts from the breakdown of the dielectric in the capacitors. The majority of nonlinear loads have active PFC (power factor correction) circuits added to its front in the form of numerous electrolytic capacitors. The addition of PFC to every AC power source cause instability, leading to resonance noise in the system. The resonance (Ferro electromagnetic resonance) occurs when the capacitive reactance of the non-linear loads is matching the inductive reactance of the system. The resonance amplifies the unwanted electrical noise to a significant level that could cause permanent damage.

TECHNICAL EXPLANATION OF POWER QUALITY

Power electronics and power quality are synonymously linked together. Power Electronics is a field in electrical engineering that deals with electrical energy conversion, applications, and electrical devices. Electrical energy conversion can be AC to DC, DC to DC and DC to AC. Power electronics includes dealing with magnetic devices for energy storage, control methods, semiconductor devices, integrated circuits, and communication networks. An example of power electronics engineering would be a Switch Mode Power Supply, also known as SMPS or simply a "power supply".

Power Quality, on the other hand, measures the electrical power's characteristics. Good power quality indicates the load is running efficiently with longer life while poor power quality indicates the distorted waveforms, poor efficiency, excessive electrical losses, and shorter lifespan of the equipment. Due to the nature of their operating principle (i.e. energy conversion), the power electronics load will draw non-sinusoidal current waveforms from the main supply. And thus, power electronics-based loads are also called "non-linear loads". According to an IBM and IEEE study, more than 85% of the electrical loads in any facility are non-linear (which are primarily power electronics-based load).

NONLINEAR LOADS CAUSING POOR POWER QUALITY

SMPS (Non-linear loads aka power electronics) convert AC to DC, DC to DC, and DC to AC. Multiple design topologies can be used to convert the power. All the design topologies require AC signals to switch at a much faster frequency to achieve the required unity power factor. The frequency at which the converter switches is called "switching frequency" and is usually within the 35kHz to 200kHz range which is outside of the fundamental 50Hz to 60Hz frequency range. The poor quality of the magnetic material used in the SMPS and its ferromagnetic electrical resonance with the parasitic capacitance in the system causes the switching frequency to "resonate" within the system with the ringing noise. The ringing noise, often called "switching transients or noise", is the byproduct of every non-linear load within the system. The switching noise is unwanted electrical signal overlapping the fundamental waveform and resulting in poor power quality. The fundamentals of electricity dictate that everything must have a return path. The noise on a converter must take the neutral or ground to complete the circuit, therefore the "switching noise" must take a return path to the main supply if it is not properly removed.

POOR POWER QUALITY AFFECTING SENSITIVE EQUIPMENT

Sensitive equipment (SMPS) uses Integrated Circuits (ICs) for its operation. The operating voltage of these ICs are usually under 12volts DC, and they can only operate with clean (noise-free) DC. The switching phenomenon in the system and its poor power quality adds noise onto the converter DC line, thus altering the DC voltage from its 12v range. This could falsely trigger the IC and therefore its IGBT or MOSFET (fast switching semiconductors in the load). In simple terms, the noise forces MOSFETs and IGBTs to turn on, when they are supposed to be in the OFF condition. This would cause the load to be permanently damaged or cause erratic behavior of the load with the false signal. This is the most common phenomenon that is observed in any modern facility.

OTHER FORMS OF ELECTRICAL NOISE

Apart from nonlinear loads, there are other forms of electrical noise sources such as an Electro Magnetic Pulse (aka lightning) discharge or power grid switching. These sources of noise are external to the facility and only account for 15% of the total noise within an electrical system. Although it is only 15% compared to the noise generated by nonlinear loads, the magnitude of external noise is significantly large compared to any other noise. The indirect lighting could take as large as 8/20uS 5kA 10kV shape and could instantly incinerate wires and loads in the facility.

POOR POWER QUALITY AFFECTS YOUR ENTIRE POWER SYSTEM

All the electrical loads are connected to the mains at the transformer and the breaker panels. The neutral and phases are the return path of current for wye and delta respectively. So, the switching noise that is created at the load must need to "see" the transformer either through a phase or the neutral. And from that transformer, all the noise splits to different breaker panels, the least path of resistance being the first one to reach. Therefore, the noise generated by an electrical load always circulates within the power system, which never leaves the system.

We learned that poor power quality exists when the facility has nonlinear loads generating switching noise and the existence of external transient resources. Poor power quality could have numerous detrimental effects on your facility. Some of the major effects are:

1. An increase in heat within an electrical system: Poor power quality is wasted energy. Power quality is analogous to having mud in drinking water. The more mud the water has, the more energy that is needed to clean the water suitable for drinking.
2. Similarly, noise within an electrical system consumes more energy to operate the electrical loads. The excess energy takes the form of heat in the system. Increased heat in the system not only causes the wires to burn out, but also decreases the life of the load. The rule of thumb is: For every 10 degrees rise in operating temperature, the life of load is decreased by half.
3. Malfunction/Erratic behavior of the load: The frequency noise in the system alters the signal that the precise semiconductor devices need. This would cause false triggering of the components and therefore erratic behavior of the load.
4. Damage and longevity of the load: Just as a person's health deteriorates from drinking polluted water; the life of electrical load decreases at the much faster rate when fed from a noisy electrical signal. The damage could be instantaneous in the form of smoke and heat, or it could be as slow as puncturing the capacitor walls over a period.
5. Increased electrical losses in the system: The excess heat adds up to more electrical consumption in the system causing the facilities electrical bill to skyrocket.

APPENDIX C: EP FILTERS – WAVE FORM CORRECTION AND SURGE PROTECTION

OPERATING PRINCIPLE OF EP FILTERS

Environmental Potential devices are the combination of a patented low pass filter and a surge protection device (SPD). The filter will remove the high-frequency noise within the 1.5kHz to 2MHz range, and the SPD portion of the filter will suppress the UL1449 std surges to admissible levels. Unlike other SPDs in the market, the EP unit will not divert a surge to the grounding system and therefor will never create a possible "ground loop" on the electrical system. The EP filter has a patented tank circuit that dissipates the surge within the unit in the form of minor heat. The EP unit may run slightly warm to the touch when filtering the noise and removing surges.

COMPARISON WITH OTHER POWER QUALITY DEVICES IN THE INDUSTRY:

EP filters are unique in design and operate completely different from other power quality devices. Current industry practice requires a combination of multiple devices to address harmonics, transients, and surges. EP filters on the other hand will address and replace the following power quality devices:

- **Harmonic filters:** Traditional harmonics filters only focus on the lower order harmonics. Lower order harmonics will result in heat within the system, however lower order harmonics will typically never resonate nor cause damage to an electrical load. In contrast, EP filters focus on removing the higher order harmonics. High order harmonics are the root cause of resonance and equipment failure or malfunction.
- **Isolation transformers:** Isolation transformers are designed to isolate the primary side from the secondary side. However, the grounds from both sides are connected to a single point. The ground (which is connected to neutral at the main transformer) needs to be isolated as well for good power quality. When they are not properly configured, they cause resonance in the system.
- **Line reactors:** Line reactors are required when additional inductive reactance is needed (i.e. the line side of a VFD). Line reactors do not provide any power quality functions.
- **Capacitor Banks:** Capacitor banks are designed to correct power factor to some extent. Unfortunately, when a capacitor bank is improperly mismatched with the inductive reactance, the capacitor banks will add excessive capacitive reactance into the electrical system resulting in resonance. Capacitor banks are prone to electrical transients causing holes on their capacitor bank dielectric medium. Capacitor banks have the potential and have been known to explode when they are near the point of failure.

HOW EP PROTECTS THE FACILITY FROM POOR POWER QUALITY

Every electrical facility regardless of size or design is prone to power quality issues. Meat Packing is no exception. SMPS is the most commonly used electrical device in the industry. Fan motors, chillers, air cooling system, computers, power supplies, battery charging stations, conveyor belts, elevators, and electric drives all have SMPS units. These need to be protected from harmful electrical noise. The remaining loads such as motors and transformers also need to be protected from the electrical noise. To achieve this, powerful low pass electrical filter with transient suppressing capability is required. Environmental Potentials manufactures a wide variety of transient suppressors along with its patented low pass filtering technology that addresses the noise problem in any facility. Proper installation of EP filters should not only protect SMPS, and other electrical loads in the facility, but also increase the efficiency and longevity of the electrical system.

Efficient running systems equates to a reduction in energy cost, a reduction in equipment replacement cost, and a reduction in labor cost. Energy savings is a known "by-product" of waveform correction.