POWER SYSTEM STUDY

FOR

DS-1J Heat Trace System, Alaska, USA

September 18th, 2006

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environmental potentials

Initial Problem/Concern:

Client has a heat trace system that runs in the oil pipelines to keep them warm. The input power is fed from a 480v Delta to Wye transformer. The heat trace system is distributed in hundreds of 277/480 wires that also carry information back to the PLI on the voltage lines. The data is transmitted on a sinusoidal 47 to 51 kHz signal. The problem is the high frequency harmonic noise being contributed by the variable frequency drives saturating the electrical distribution system on both sides of the Delta to Wye transformer causing the data signal to be lost.

Measurements:

The measurements in this report were taken with a Power Sight Energy Analyzer with a High Frequency Analysis option. This analyzer has the capability to take simultaneous readings on all phases and the neutral line. This analyzer is capable of reading both voltage and current frequencies ranging from 22 Hz to 100 KHz. Measurements were also taken at the PLI with a Fluke 199B Scopemeter.

Measurement Locations:

Measurements were taken at the variable frequency drive cabinets labeled CP-1J15, P-1J06B-M, and SY-1J075

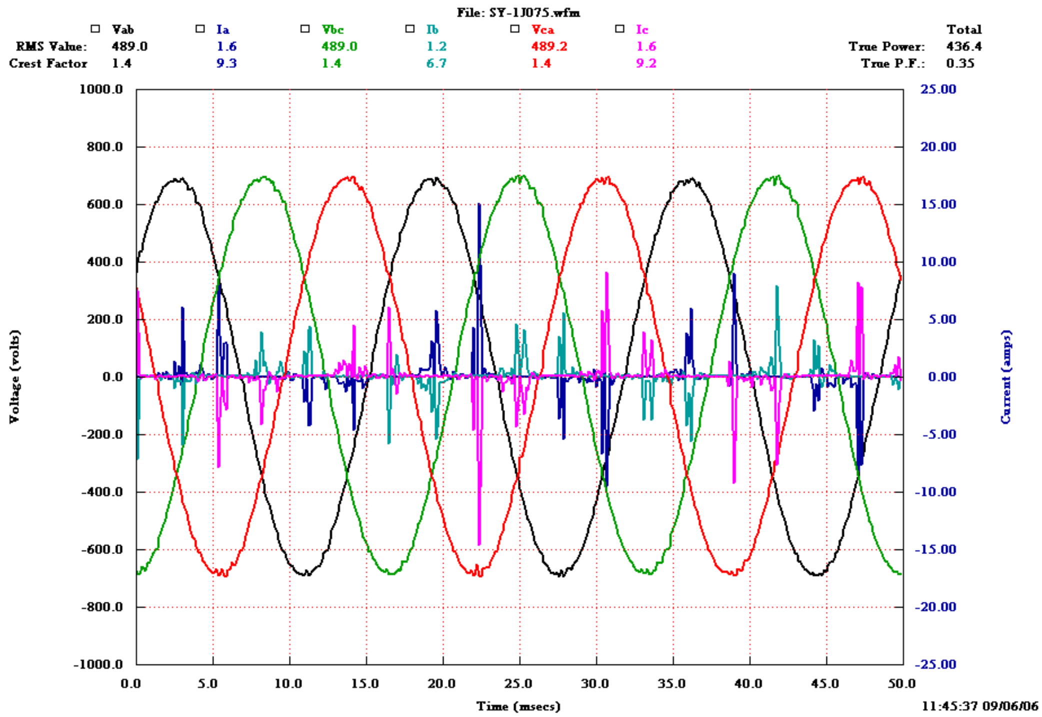
Electrical Configuration:

The electrical configuration of the power distribution system is a 480v Delta at 60 Hz.

Power Sight Energy Analyzer Readings:

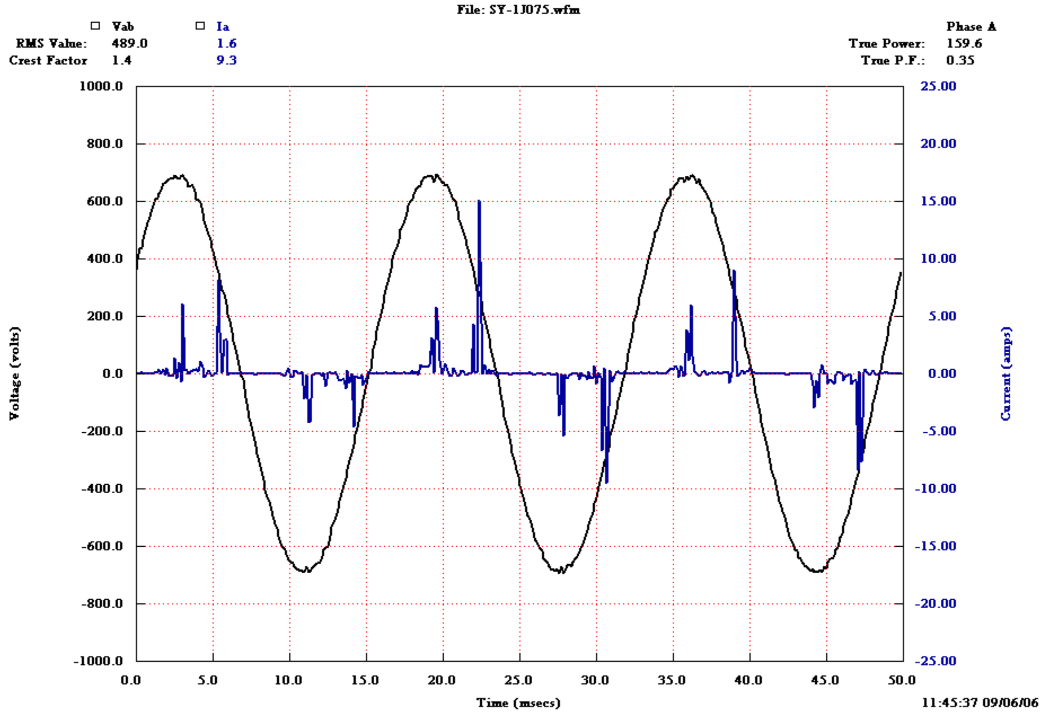
The following readings are real time snapshots of the three phase fundamental power along with high frequency voltage and current readings.

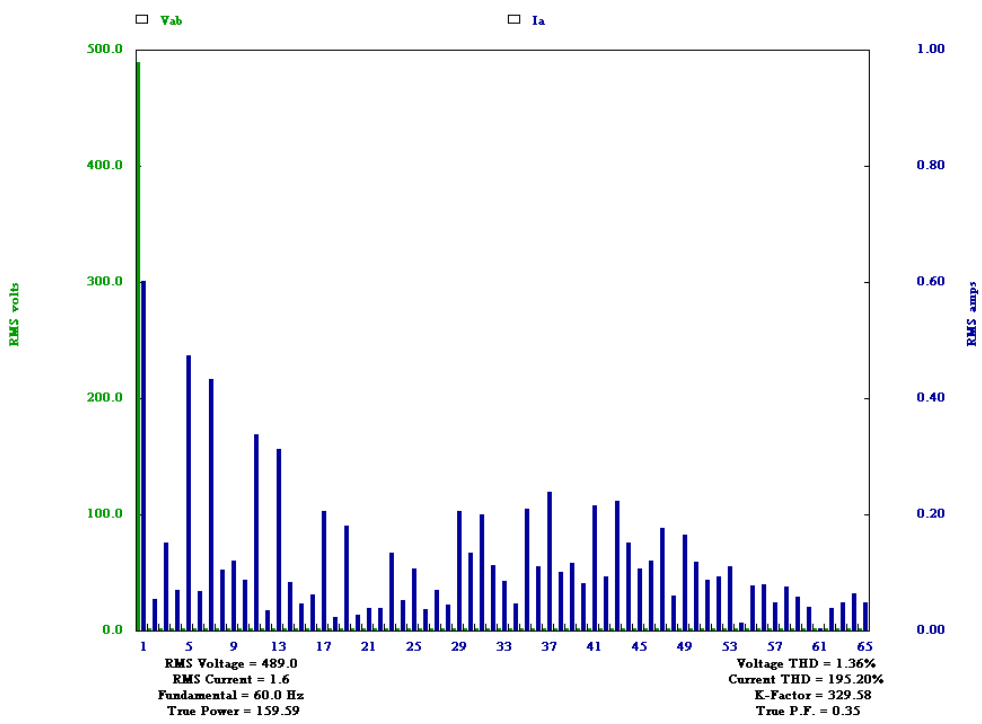
SY-1J075 readings: This cabinet contained 4 PowerFlex4 VFD's with the readings reflecting the contribution from all four drives.



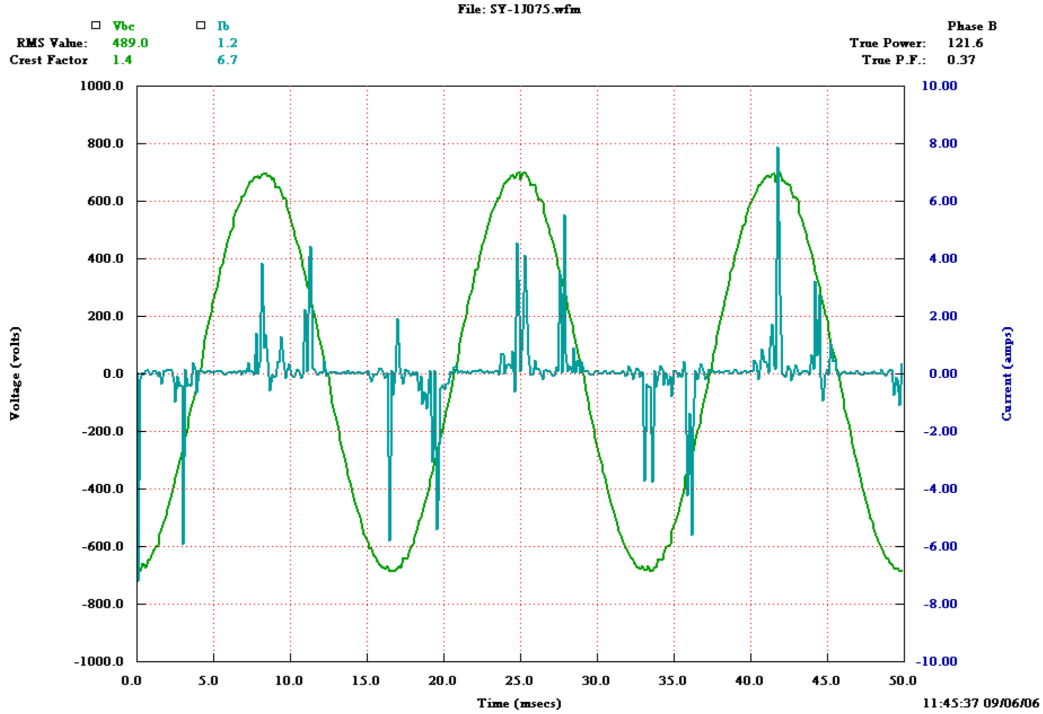
Initial readings show the crest factors of the current sinewave to be above 1.4. Crest factors above 2.0 indicate that there are severe current transients occurring along the sinewave of all three phases. These transient will create resonant frequencies within the distribution system and cause the distribution system to become inefficient.

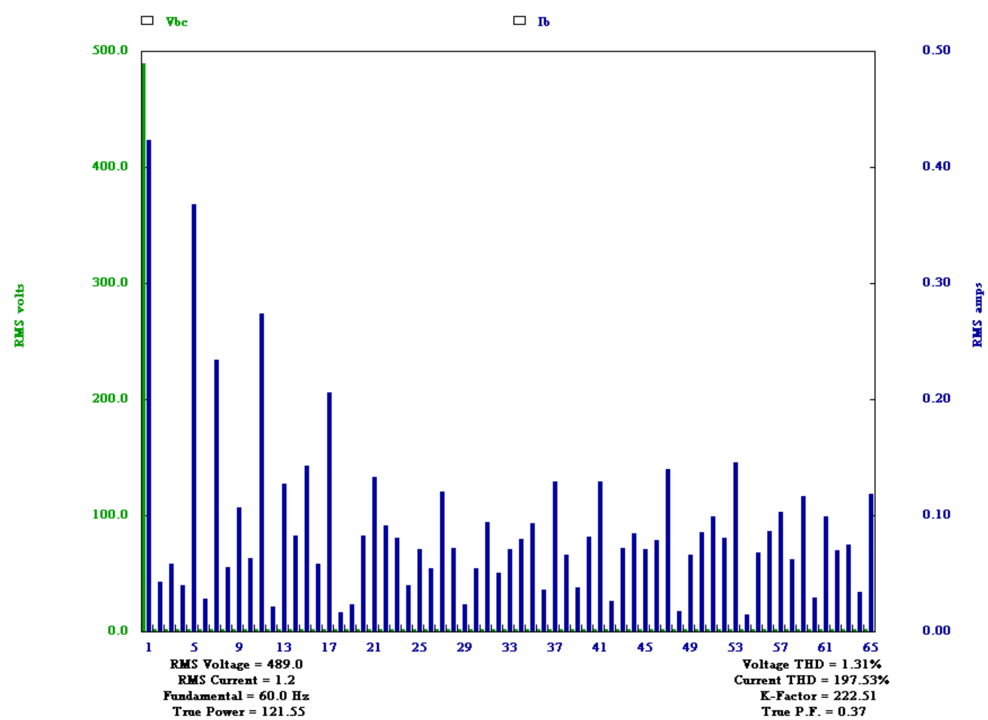
PHASE A WAVEFORM AND HARMONIC CONTENT



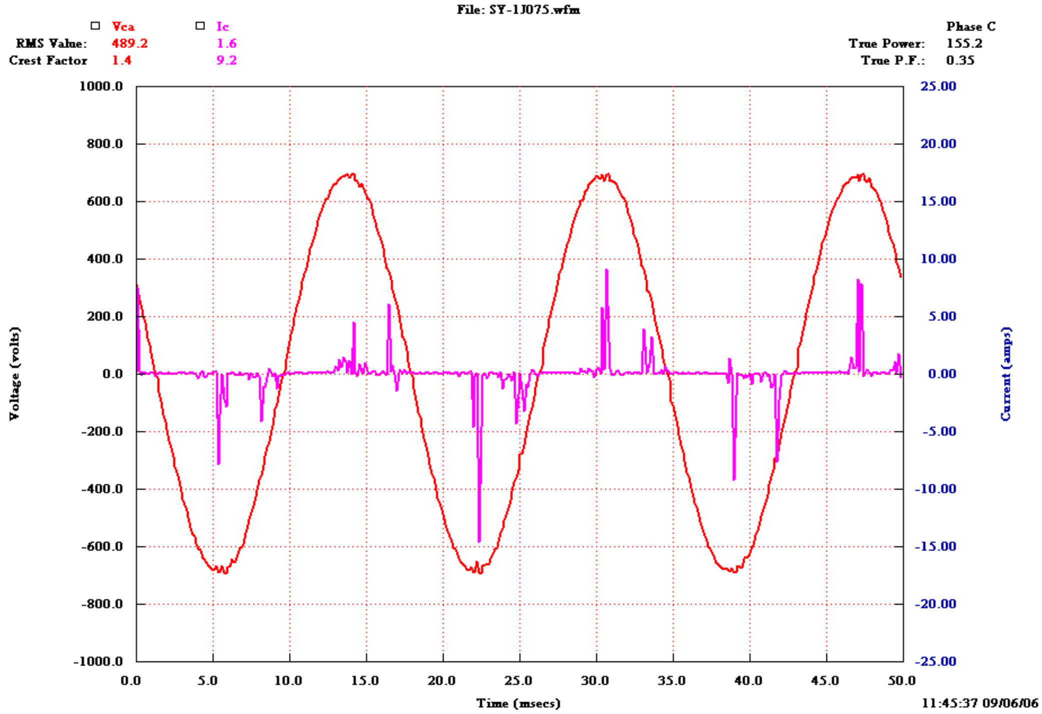


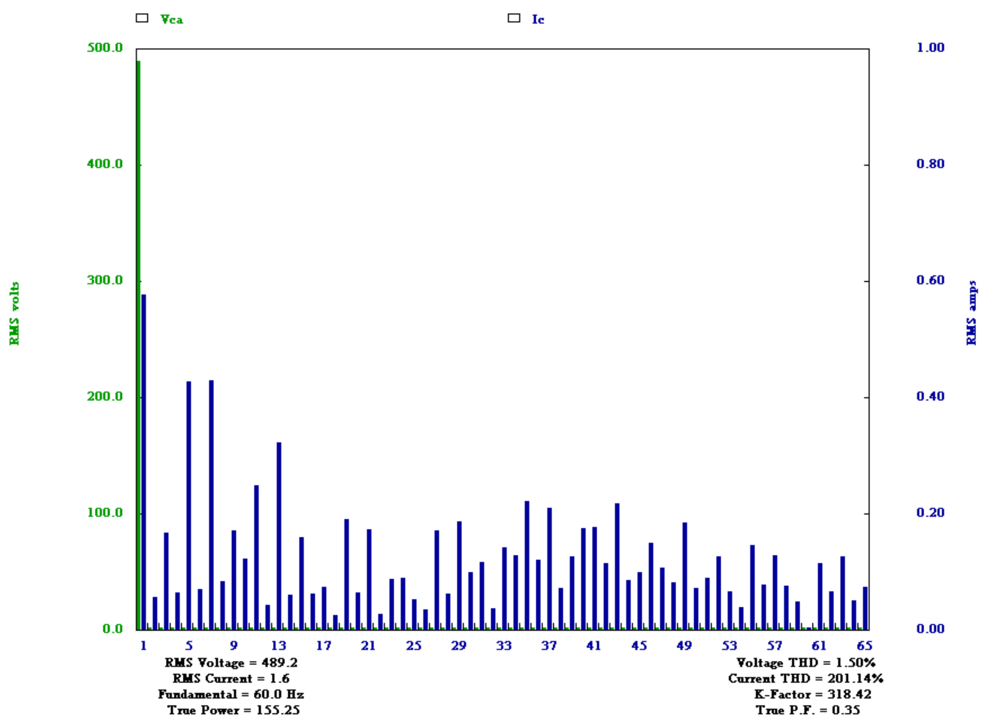
PHASE B WAVEFORM AND HARMONIC CONTENT





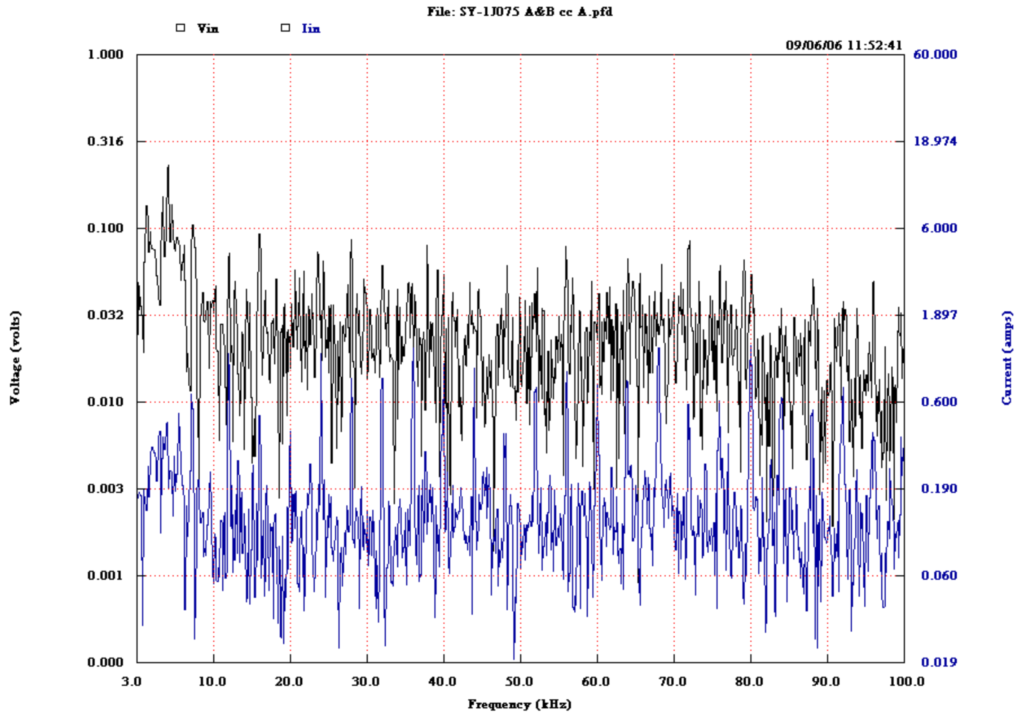
PHASE A WAVEFORM AND HARMONIC CONTENT



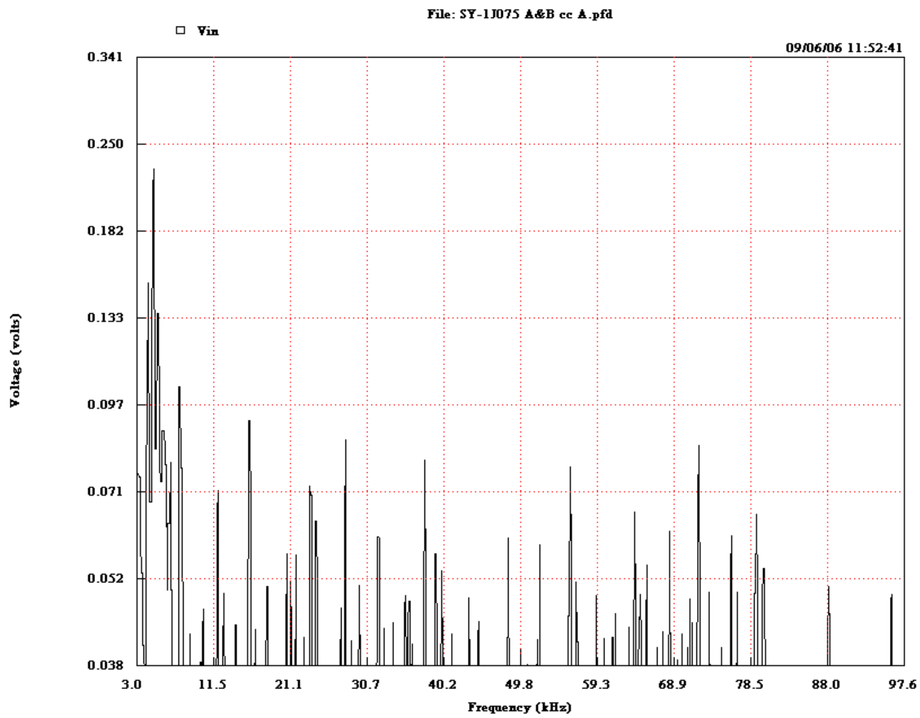


These are high frequency readings taken at SY-1J05'S input power. As we can see there is a tremendous amount of high frequency voltage and current being created by the transient activity from the A/C to D/C rectification process. These high frequency voltages cut across the rectifier and transformer cores and create eddy voltages which will induce eddy currents. The eddy currents will flow in a direction that oppose the flux change and inhibit the flow of 60 cycle current.

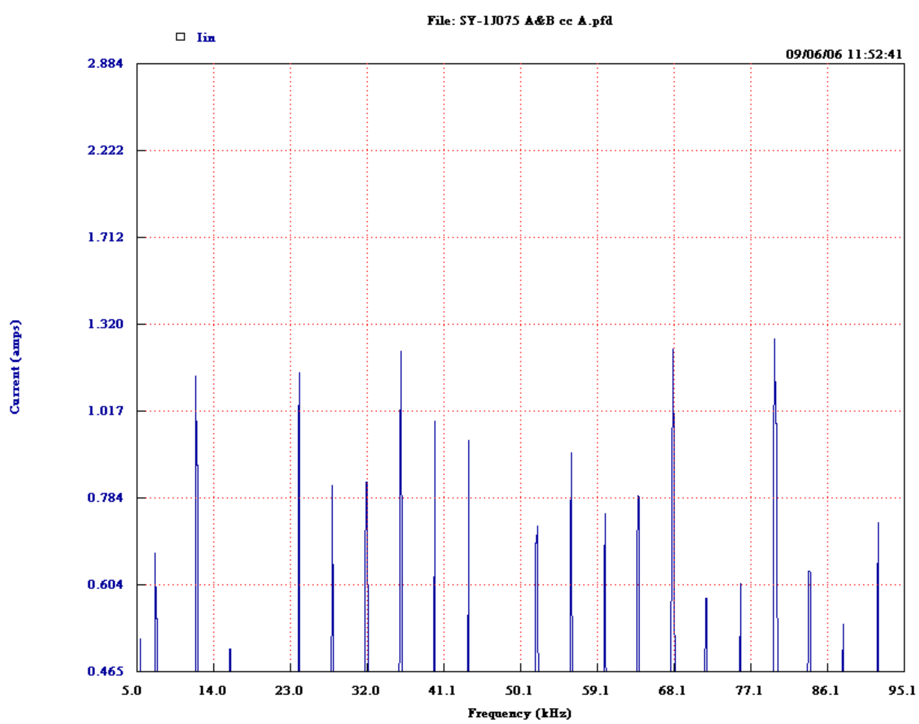
Voltage and Current noise between phases A&B with the current readings on A



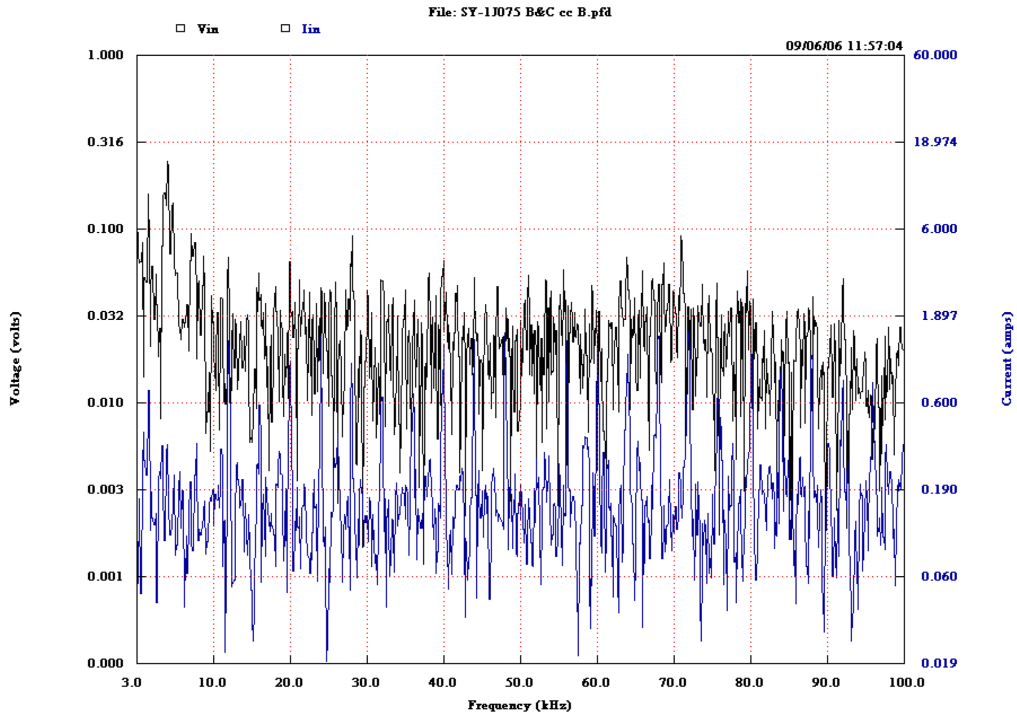
Zoomed view of the voltage noise peaks between phases A&B



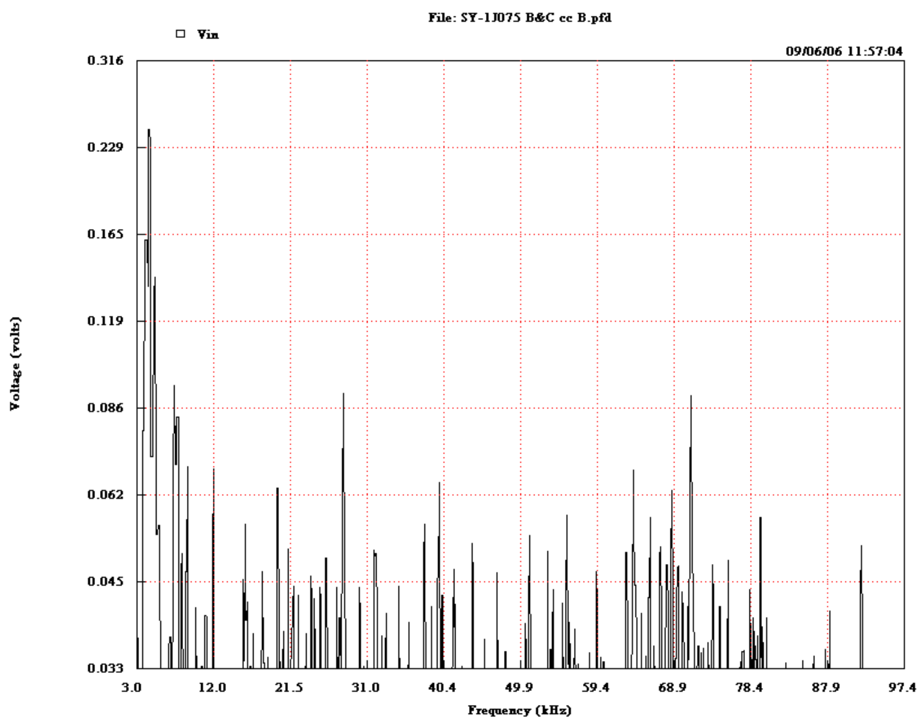
Zoomed view of the Current noise peaks on phase A



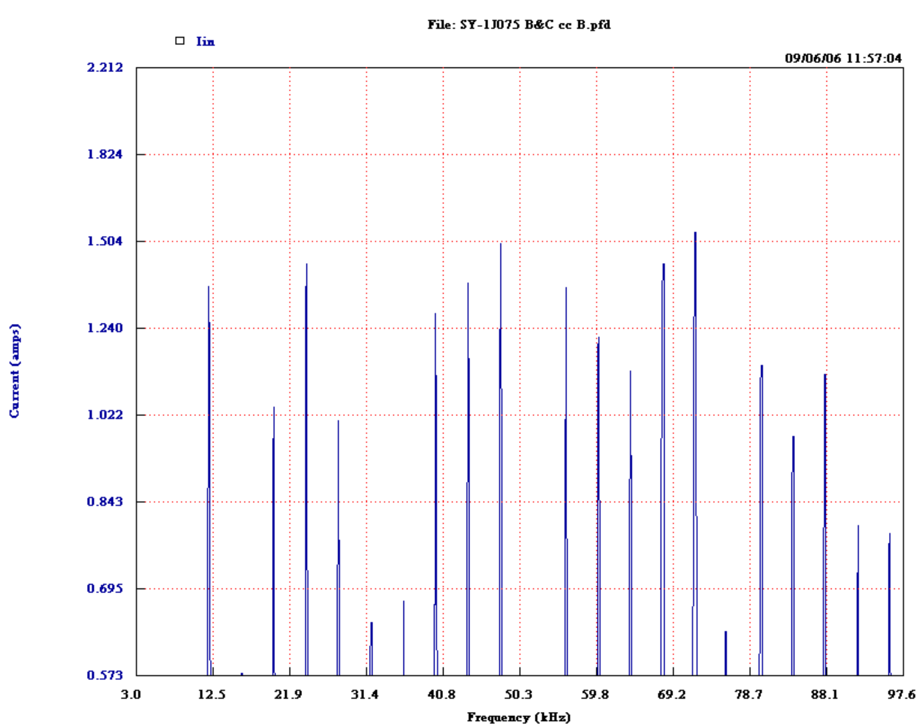
Voltage and Current noise between phases B&C with the current readings on B



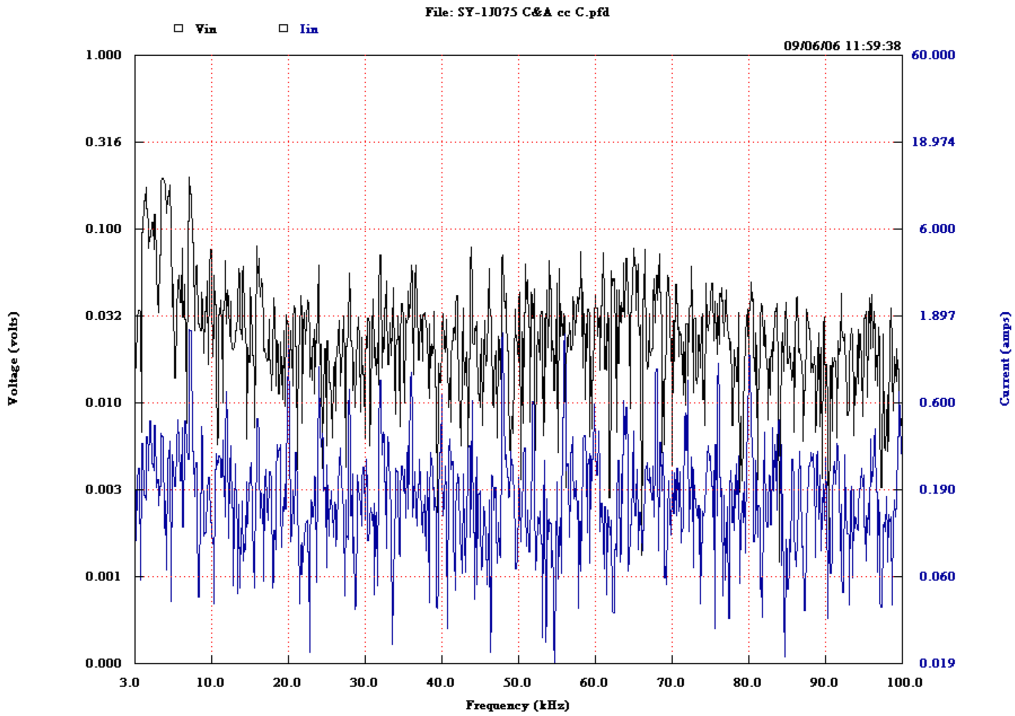
Zoomed view of the voltage noise peaks between phases B&C



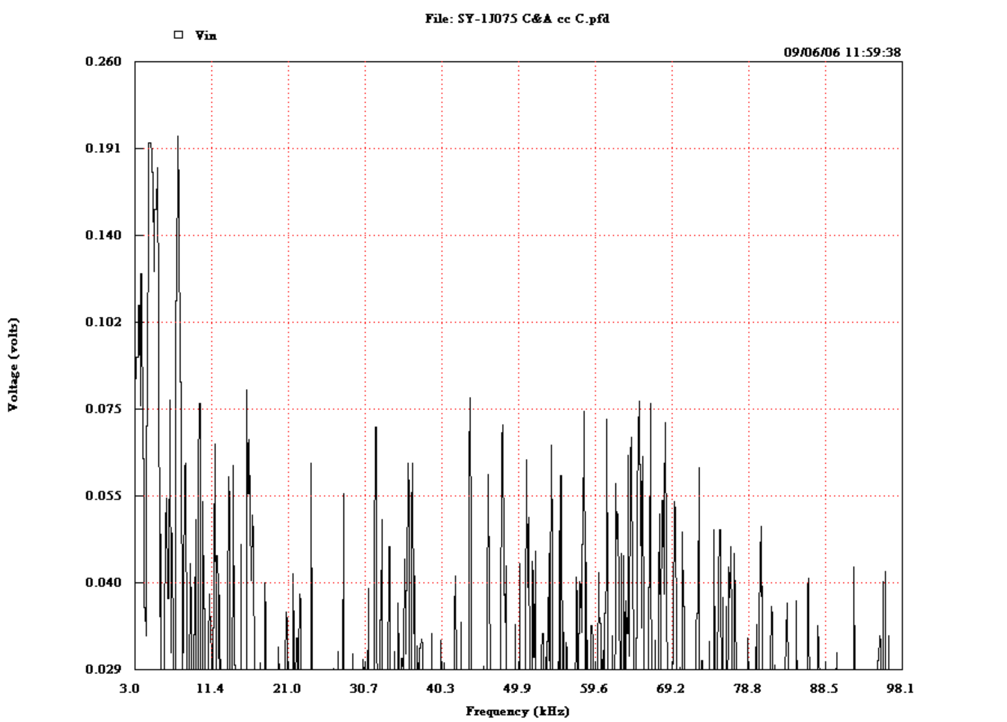
Zoomed view of the Current noise peaks on phase A



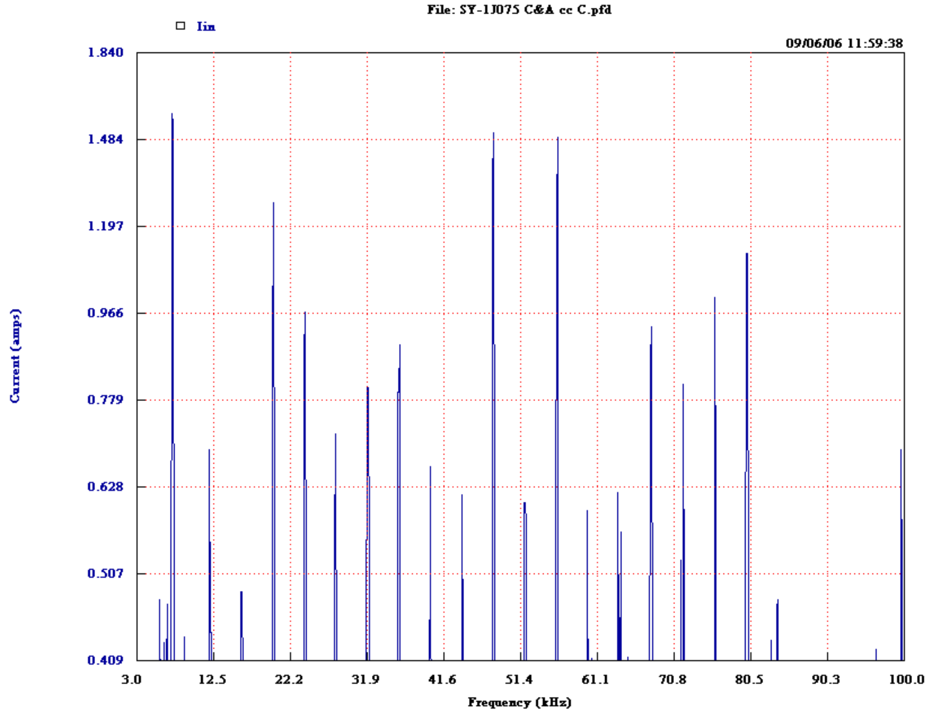
Voltage and Current noise between phases C&A with the current readings on C



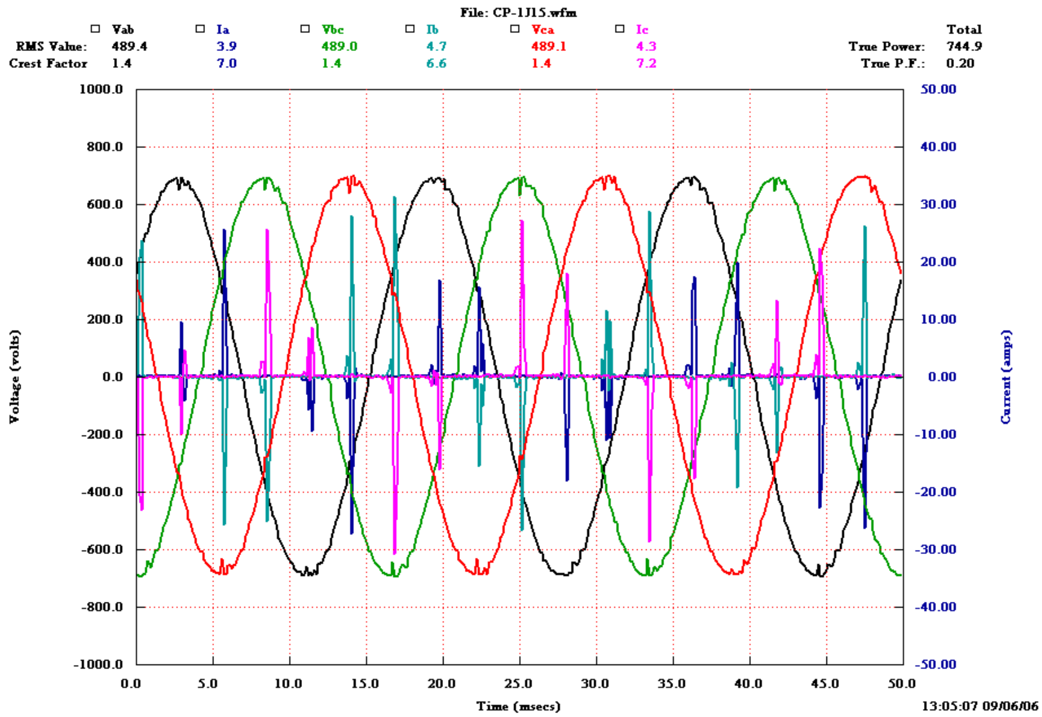
Zoomed view of the voltage noise peaks between phases C&A



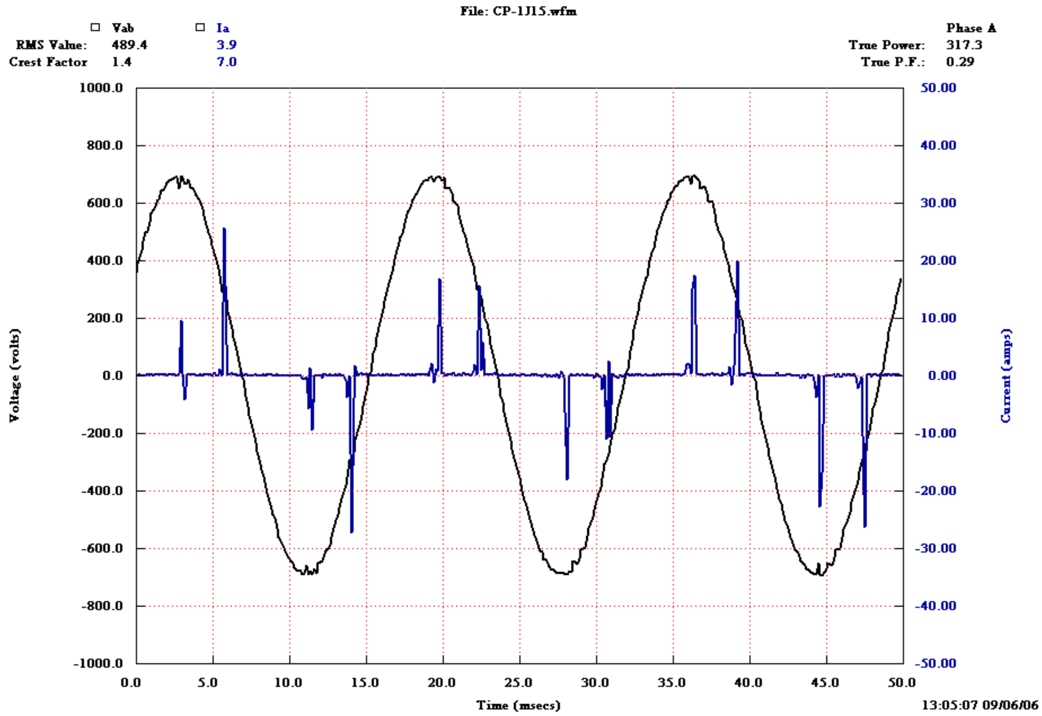
Zoomed view of the Current noise peaks on phase C

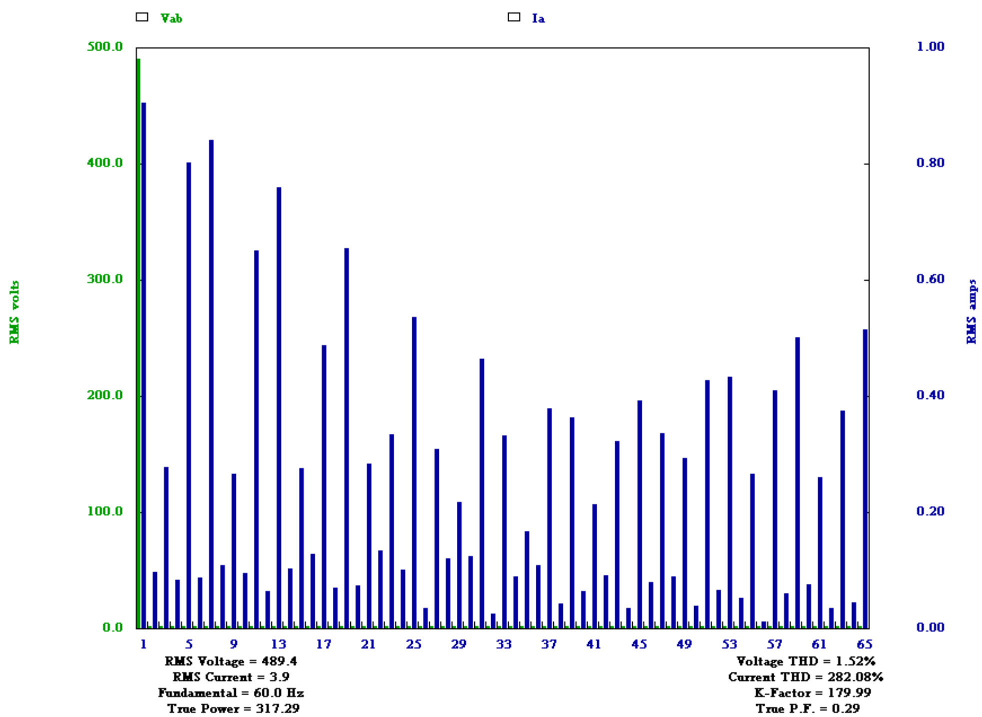


CP-1J15 readings: This cabinet contained 6 PowerFlex4 VFD's with the readings reflecting the contribution from all 6 drives.

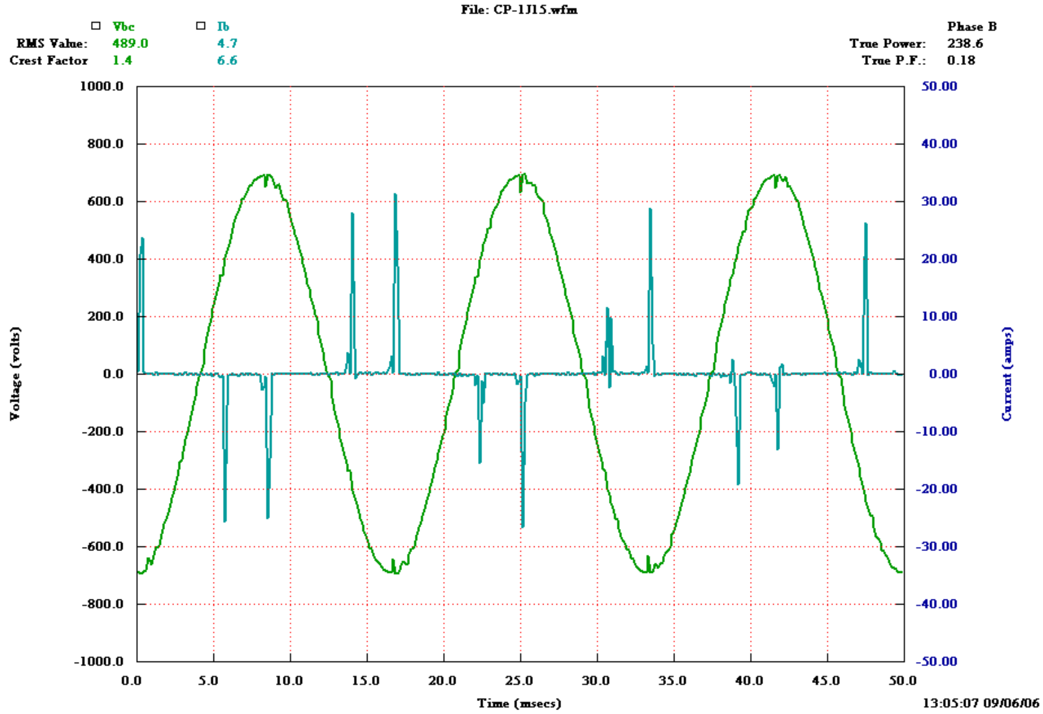


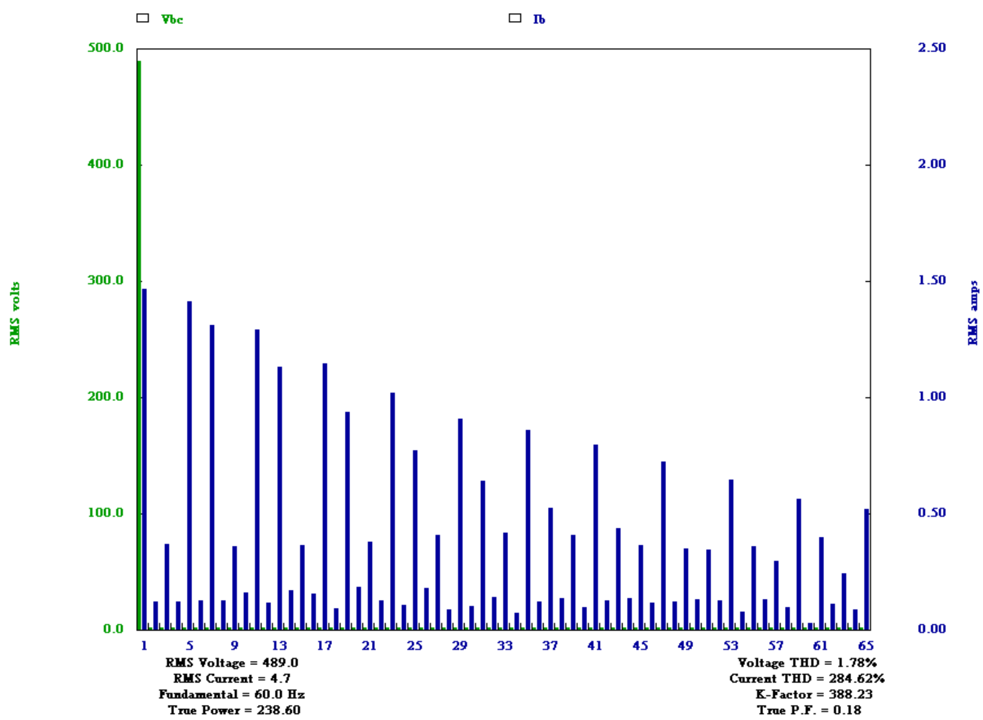
PHASE A WAVEFORM AND HARMONIC CONTENT



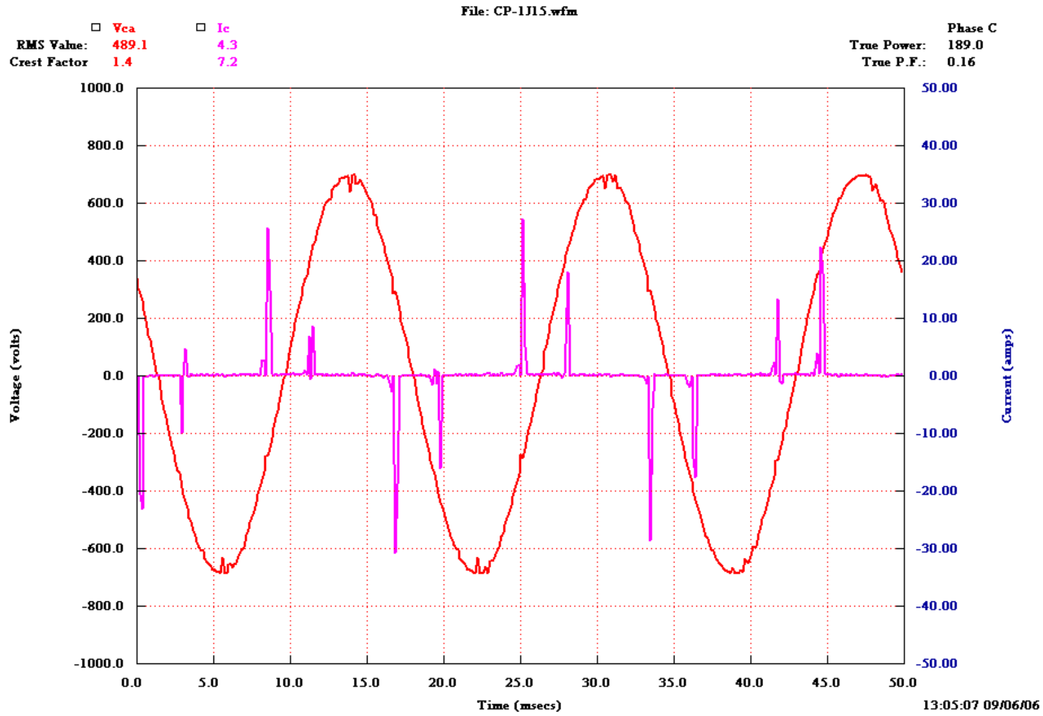


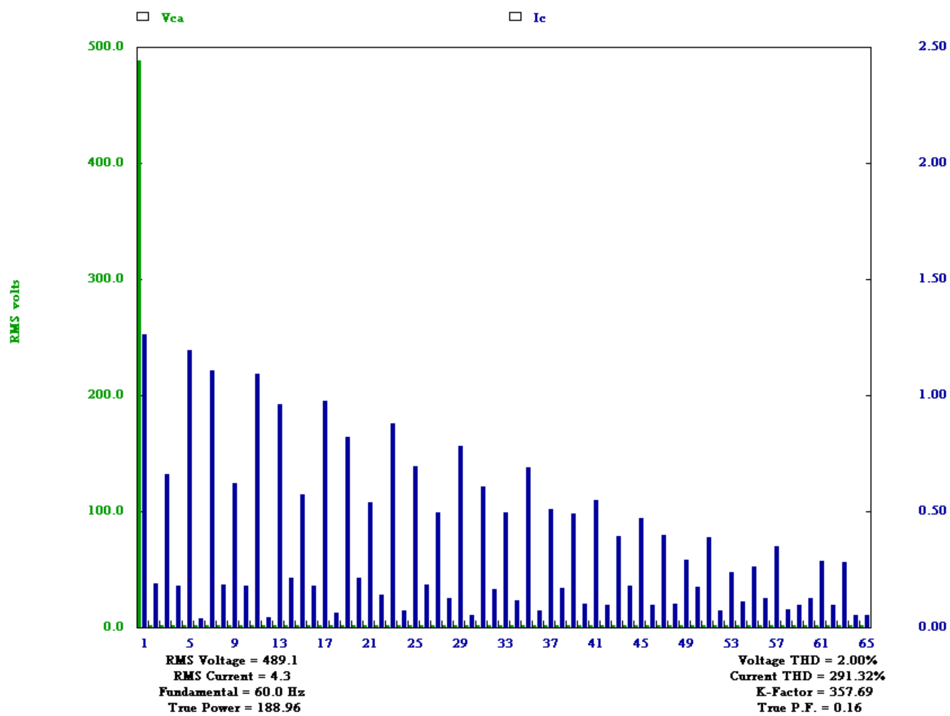
PHASE B WAVEFORM AND HARMONIC CONTENT



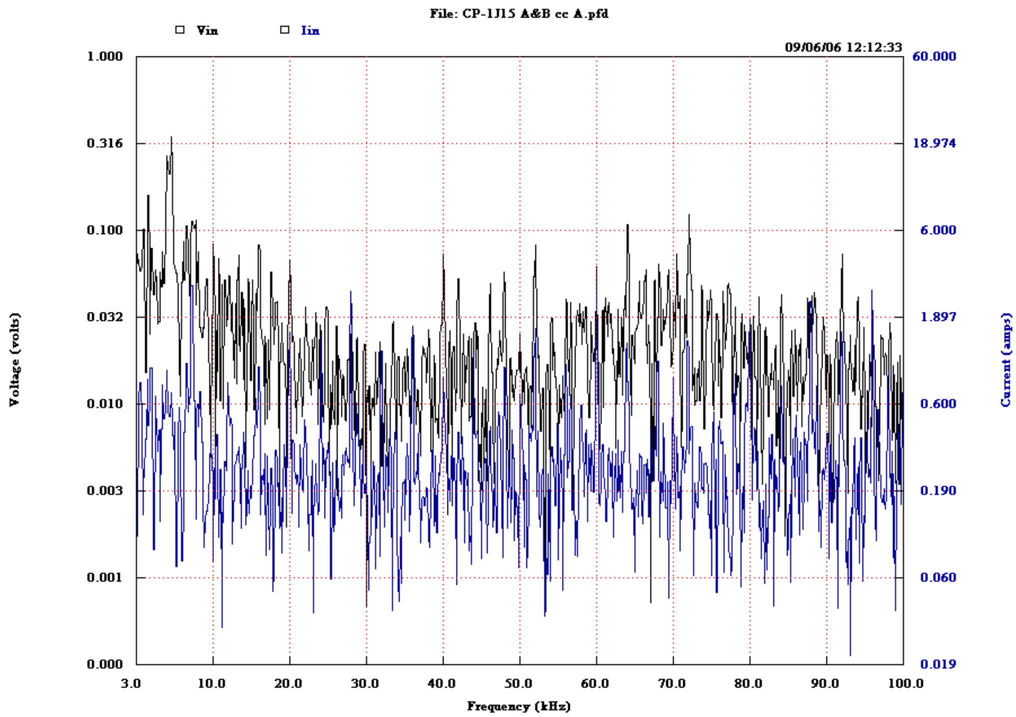


PHASE C WAVEFORM AND HARMONIC CONTENT

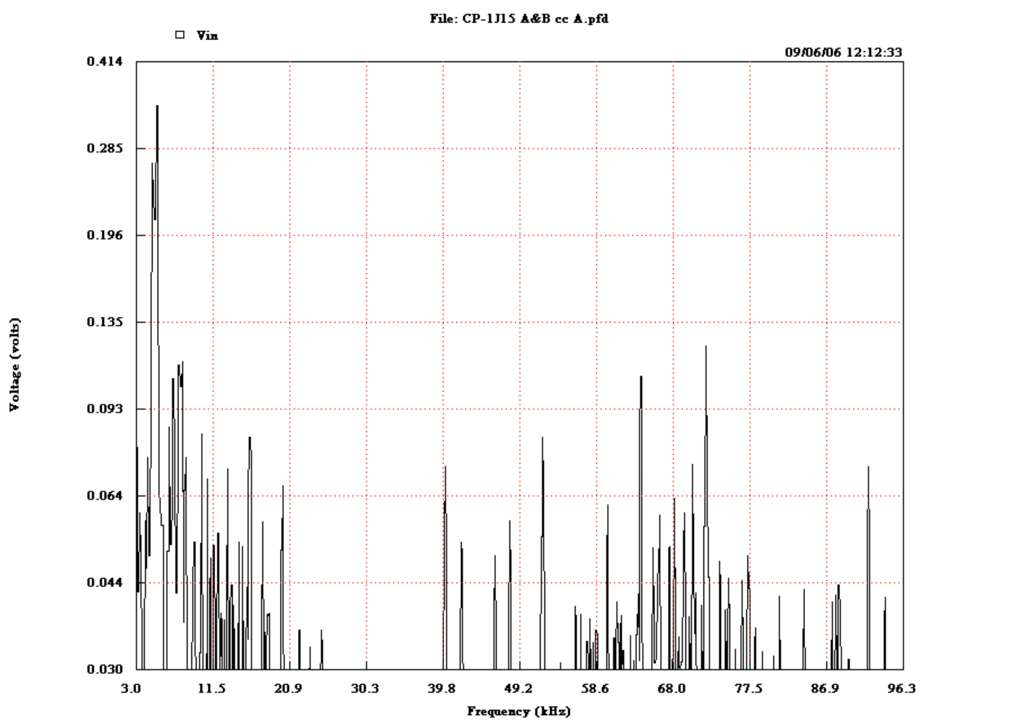




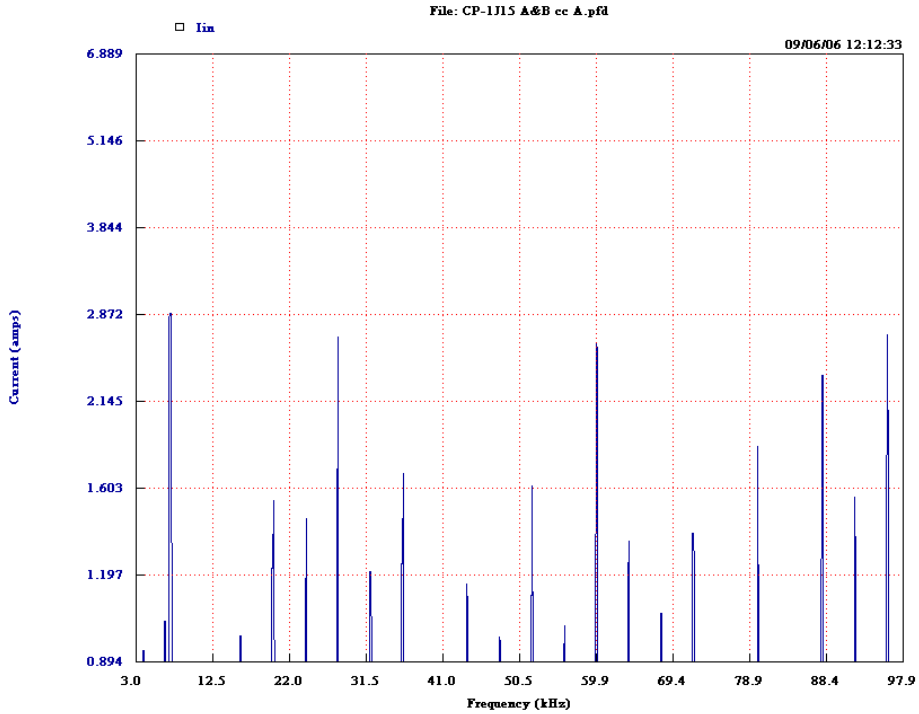
Voltage and Current noise between phases A&B with the current readings on A



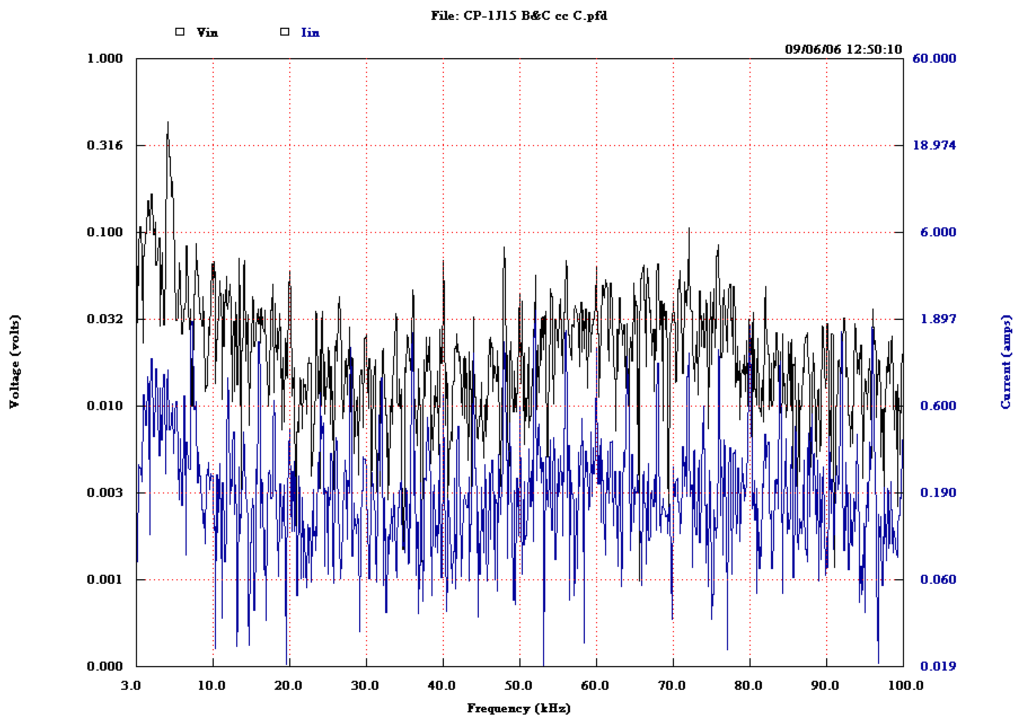
Zoomed view of the voltage noise peaks between phases A&B



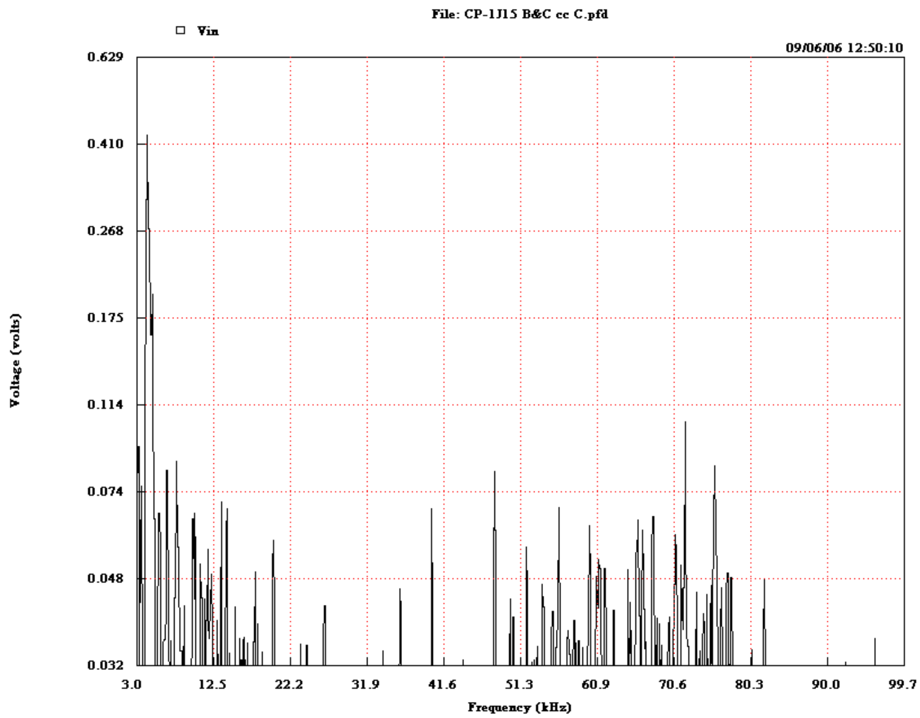
Zoomed view of the current noise on phase A



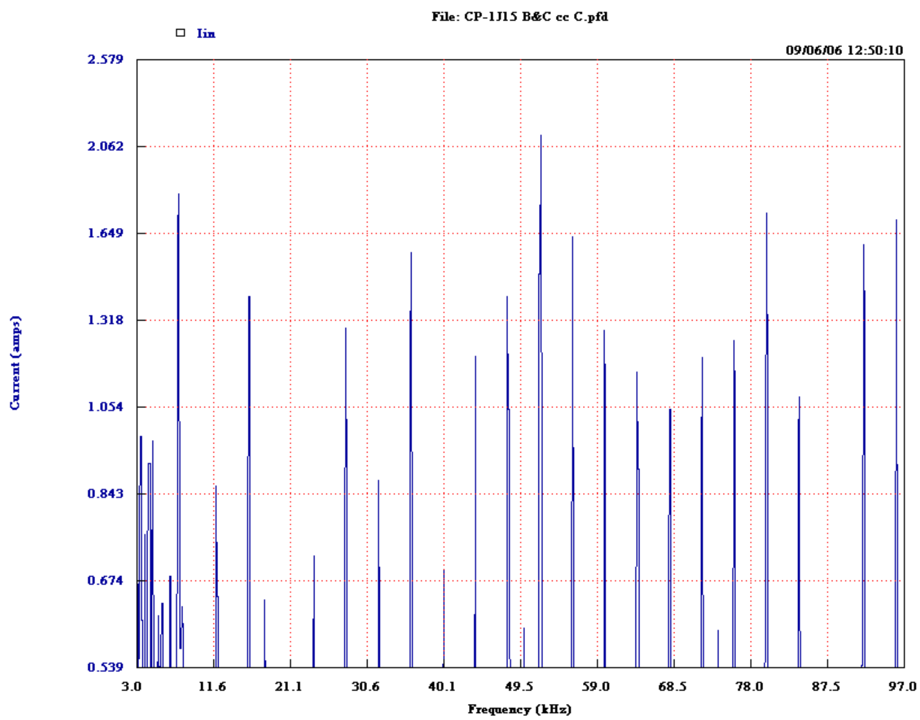
Voltage and Current noise between phases B&C with the current readings on B



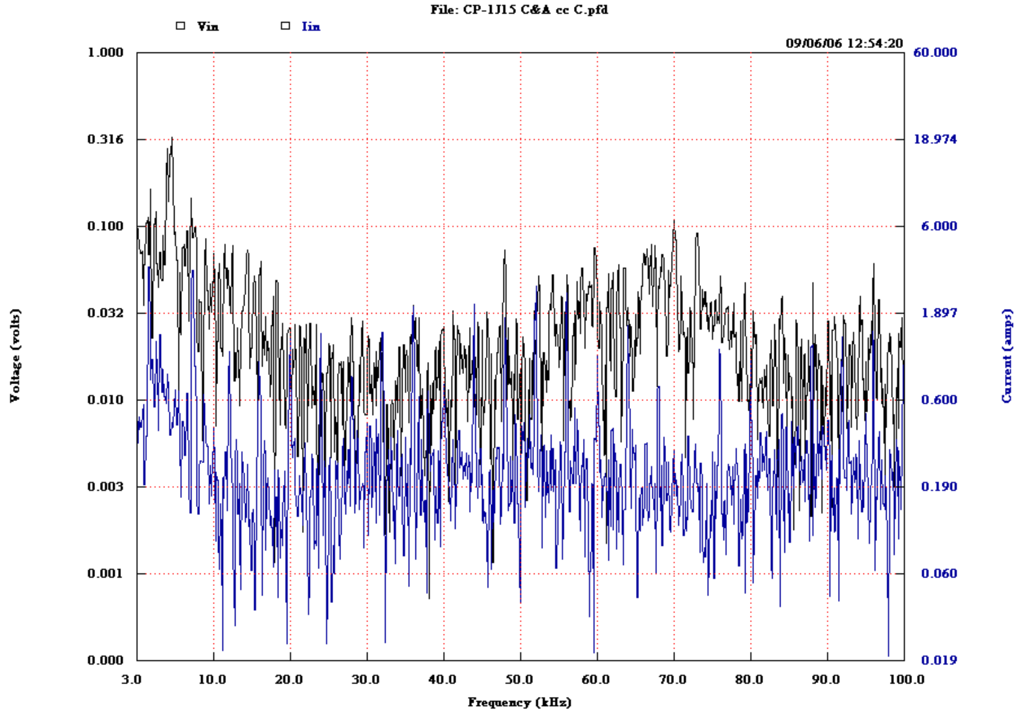
Zoomed view of the voltage noise peaks between phases B&C



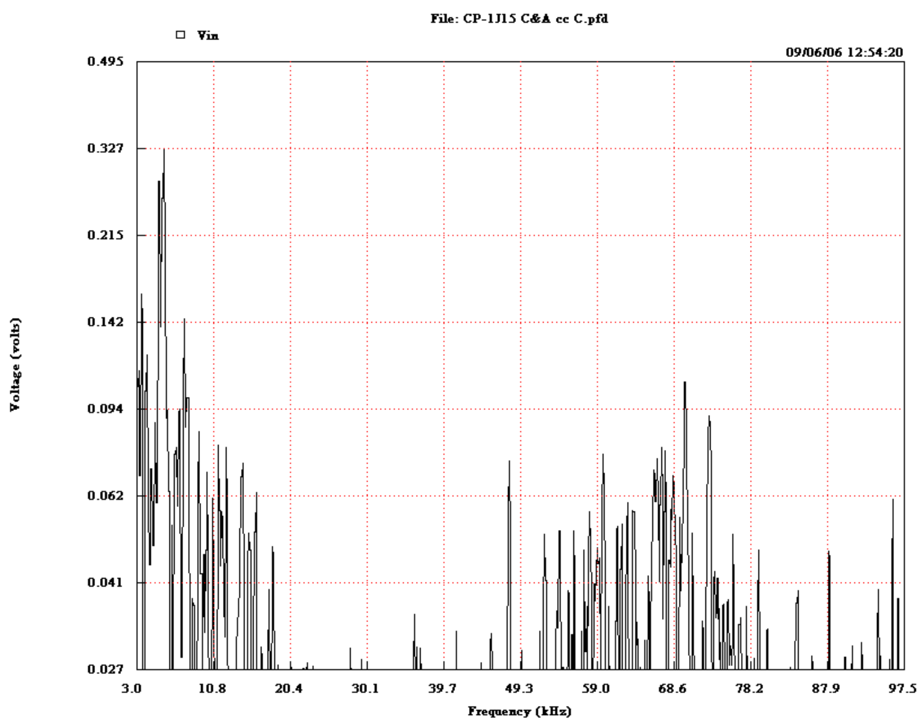
Zoomed view of the current noise on phase B



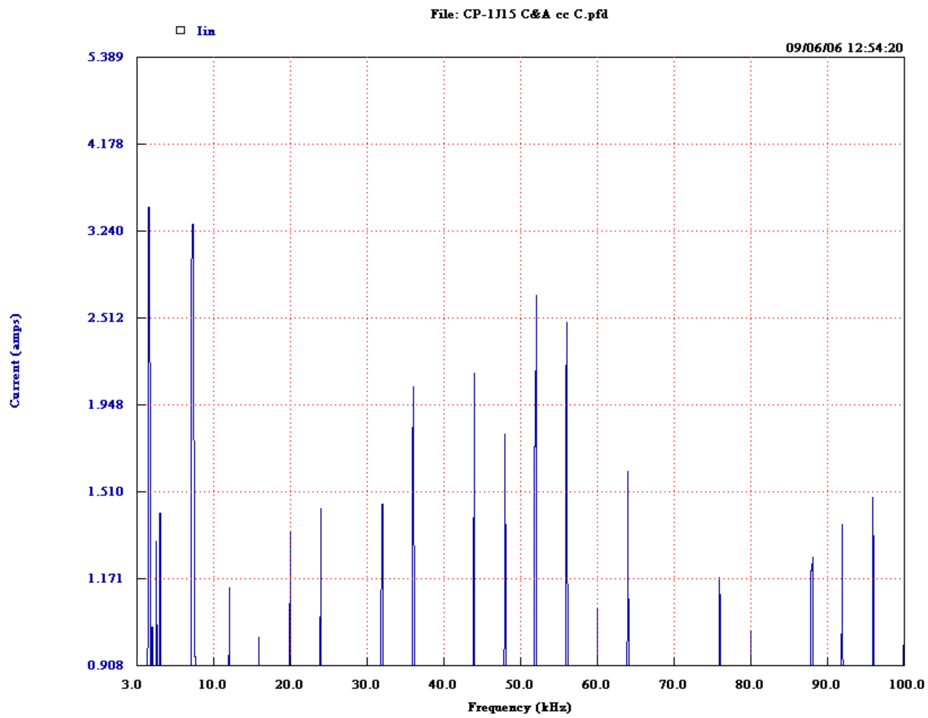
Voltage and Current noise between phases C&A with the current readings on C



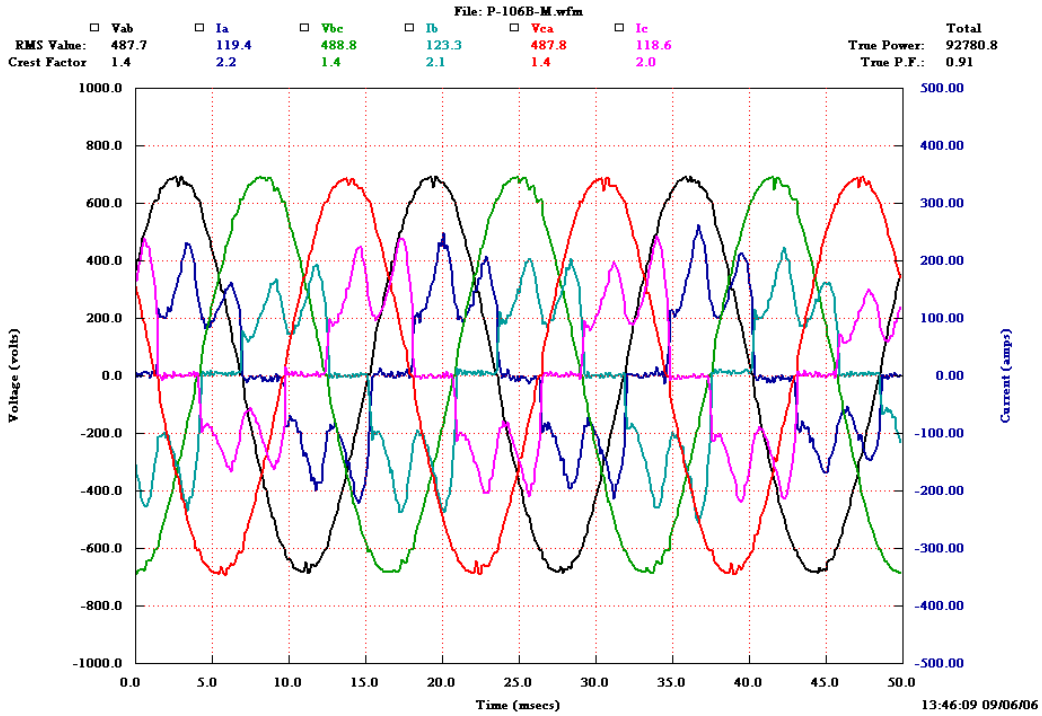
Zoomed view of the voltage noise peaks between phases C&A



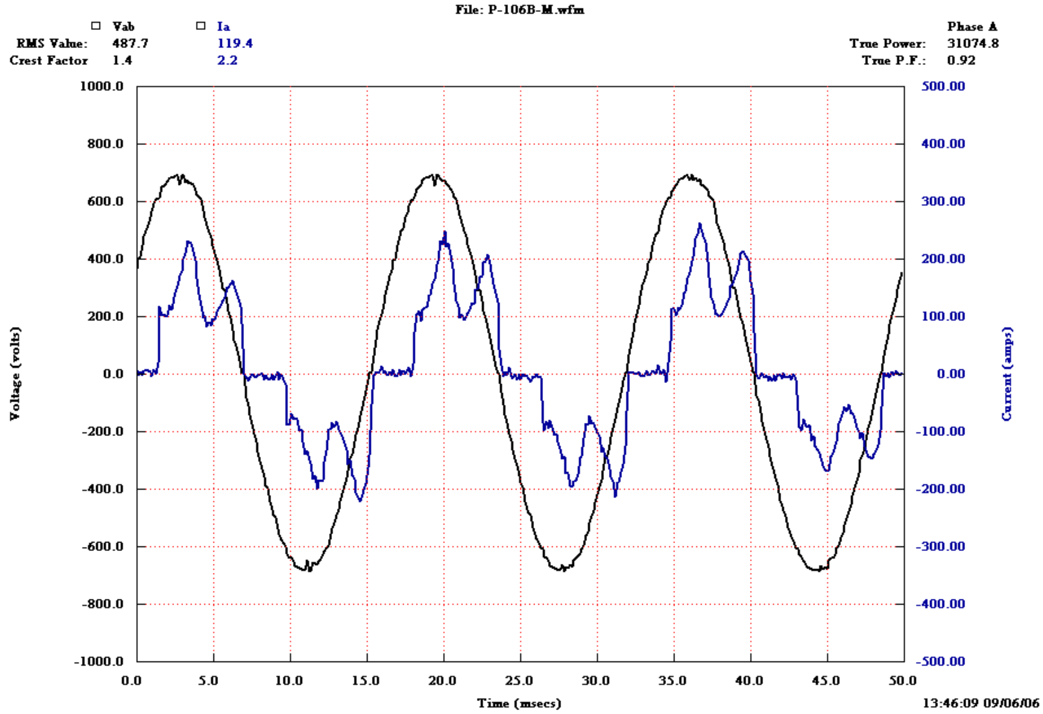
Zoomed view of the current noise on phase C

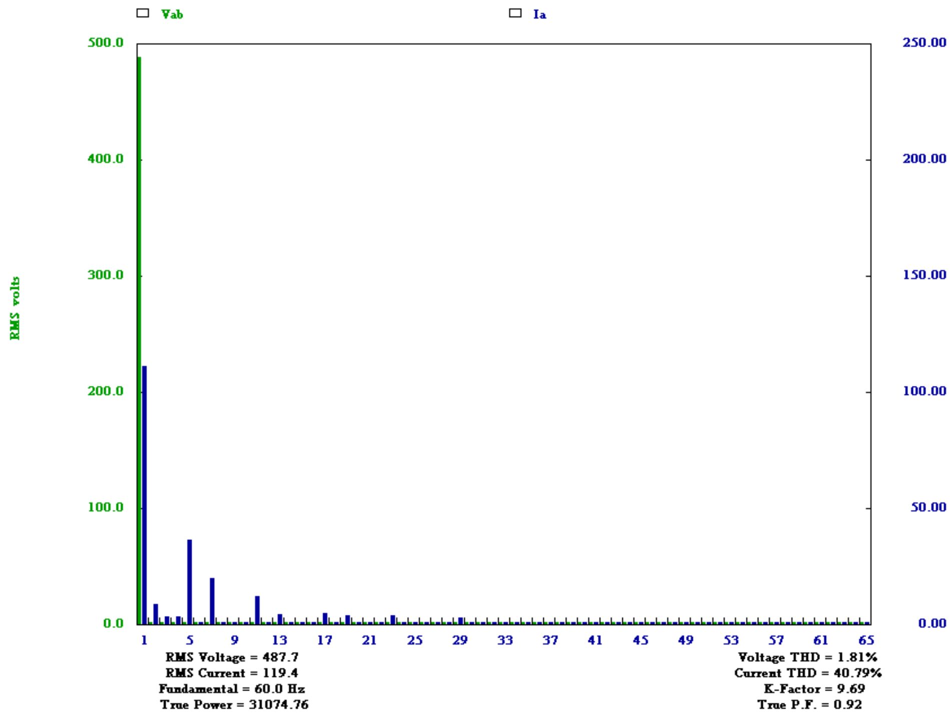


P-106B-M readings: This cabinet contained 2 150 HP VFD's the readings reflect the contribution from all drives.

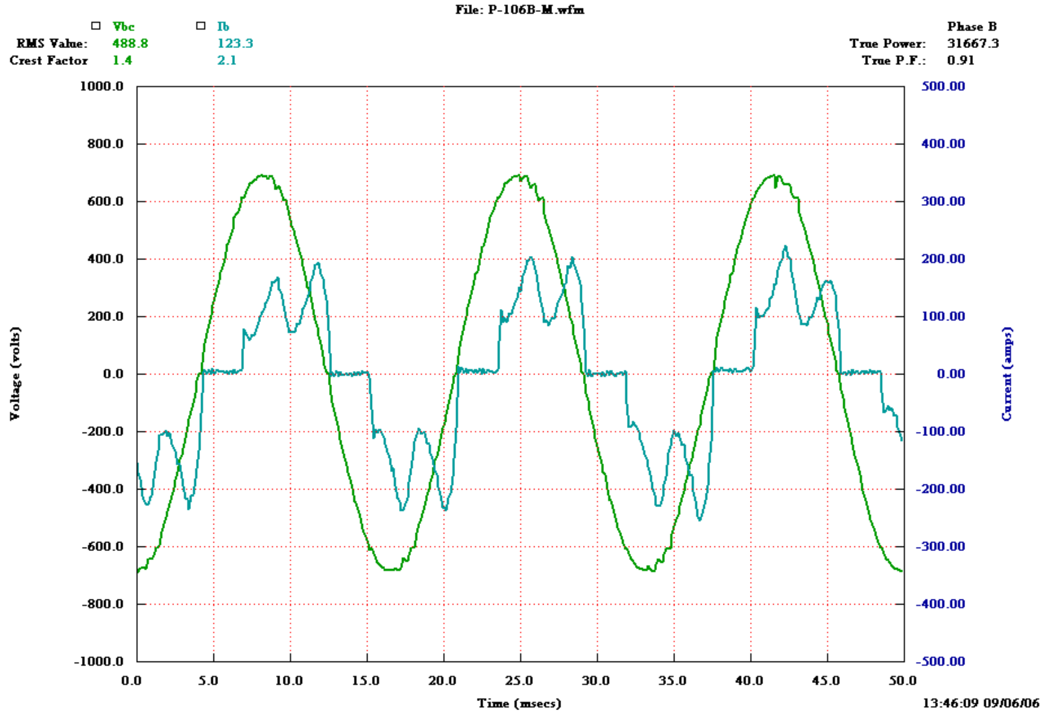


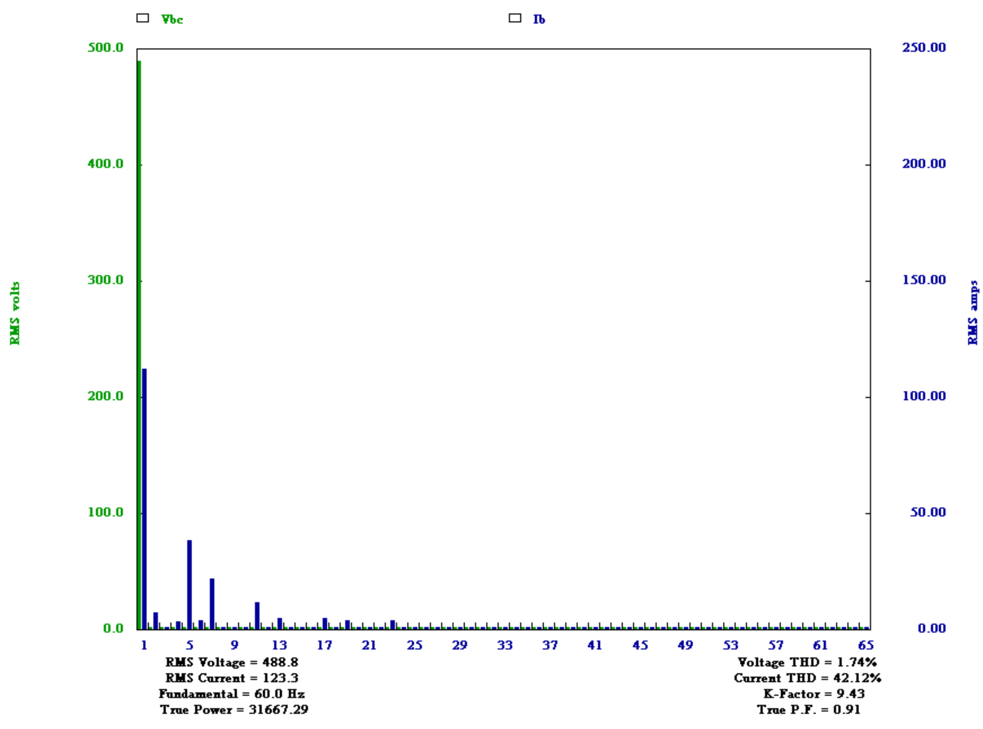
PHASE A WAVEFORM AND HARMONIC CONTENT



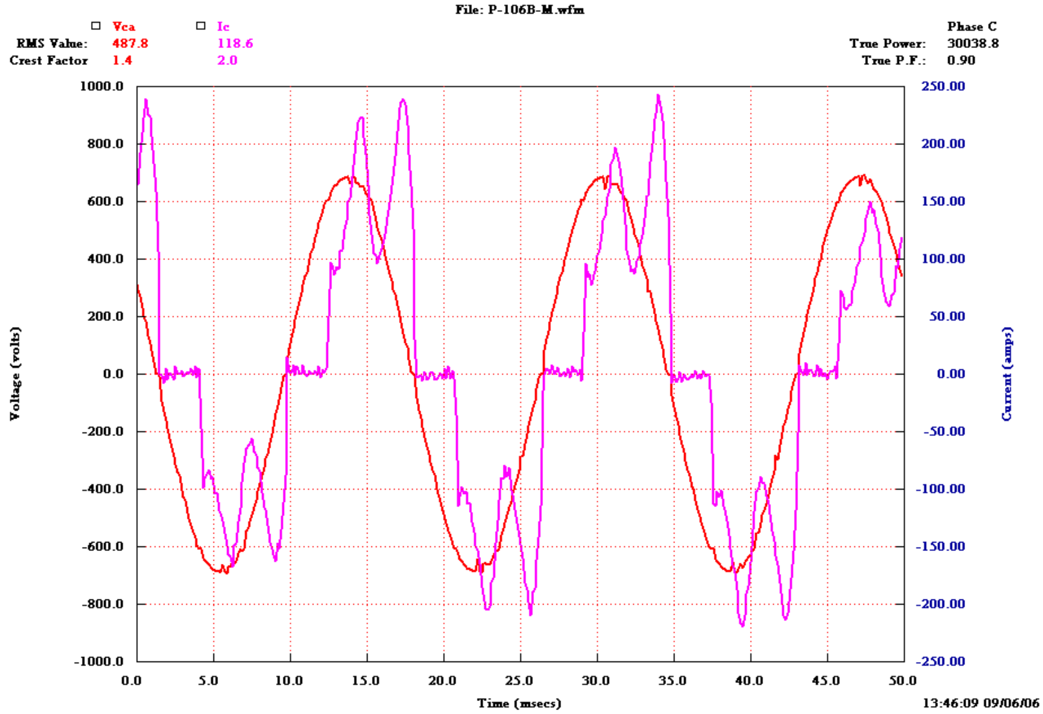


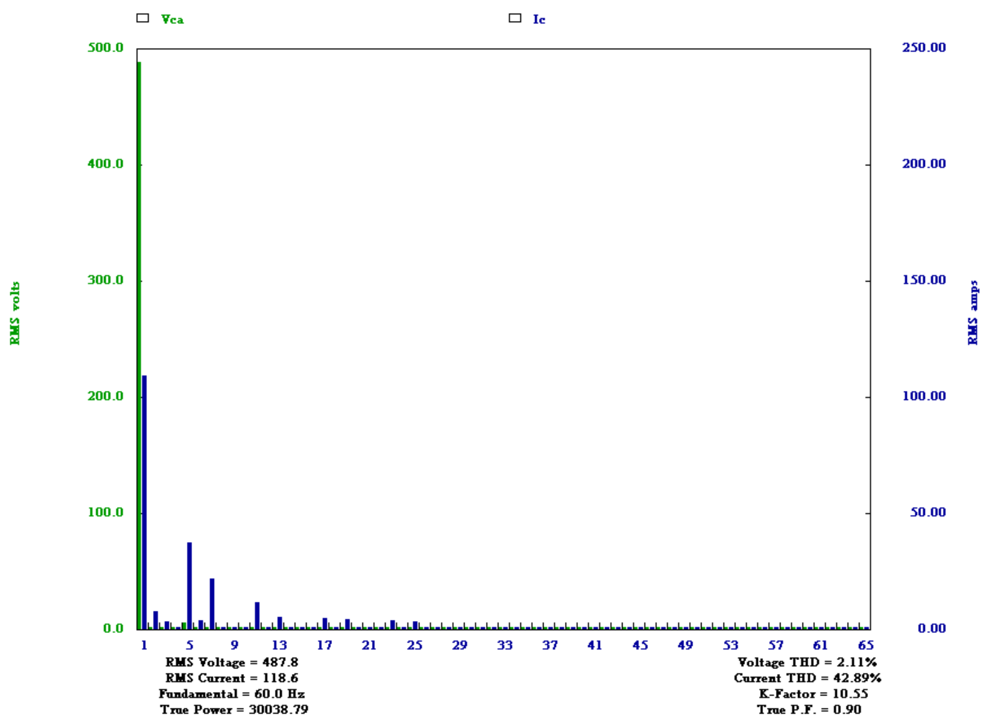
PHASE B WAVEFORM AND HARMONIC CONTENT



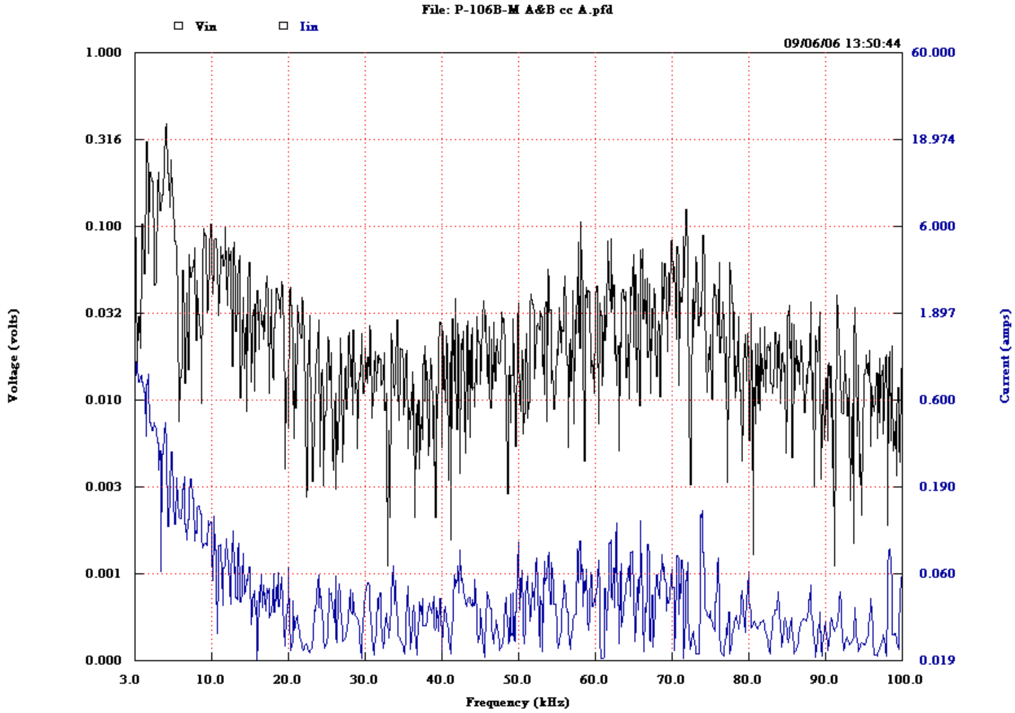


PHASE C WAVEFORM AND HARMONIC CONTENT

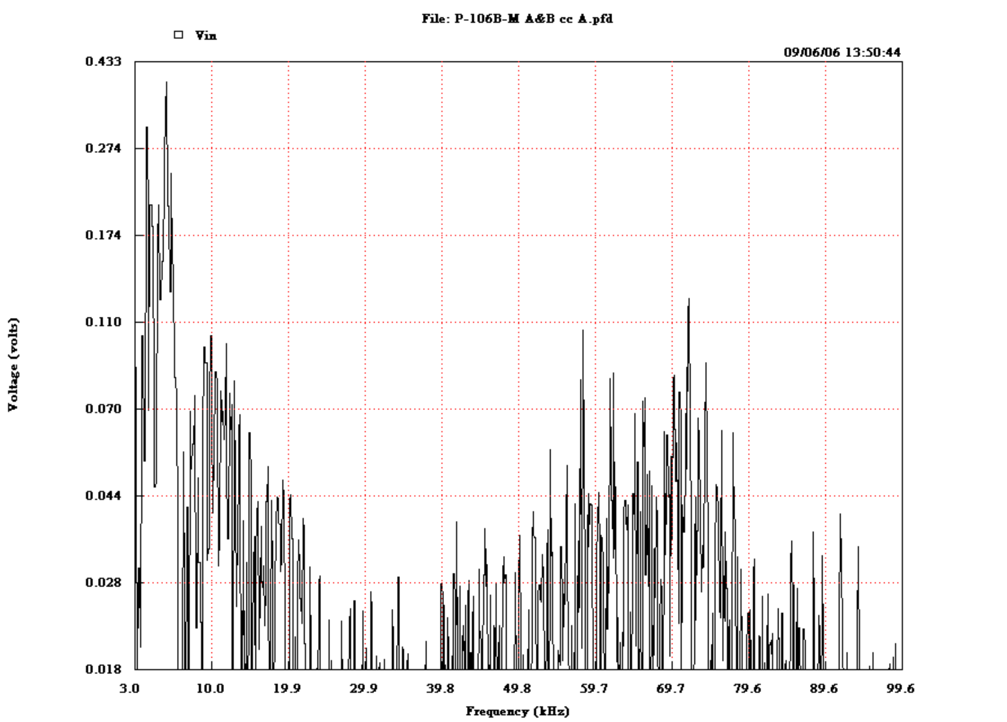




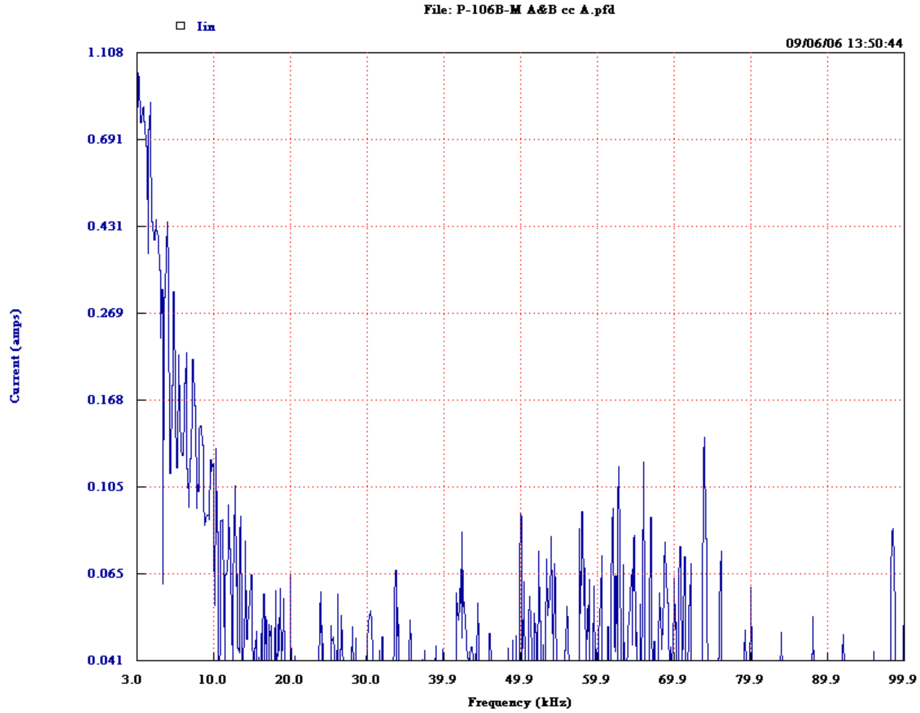
Voltage and Current noise between phases A&B with the current readings on A



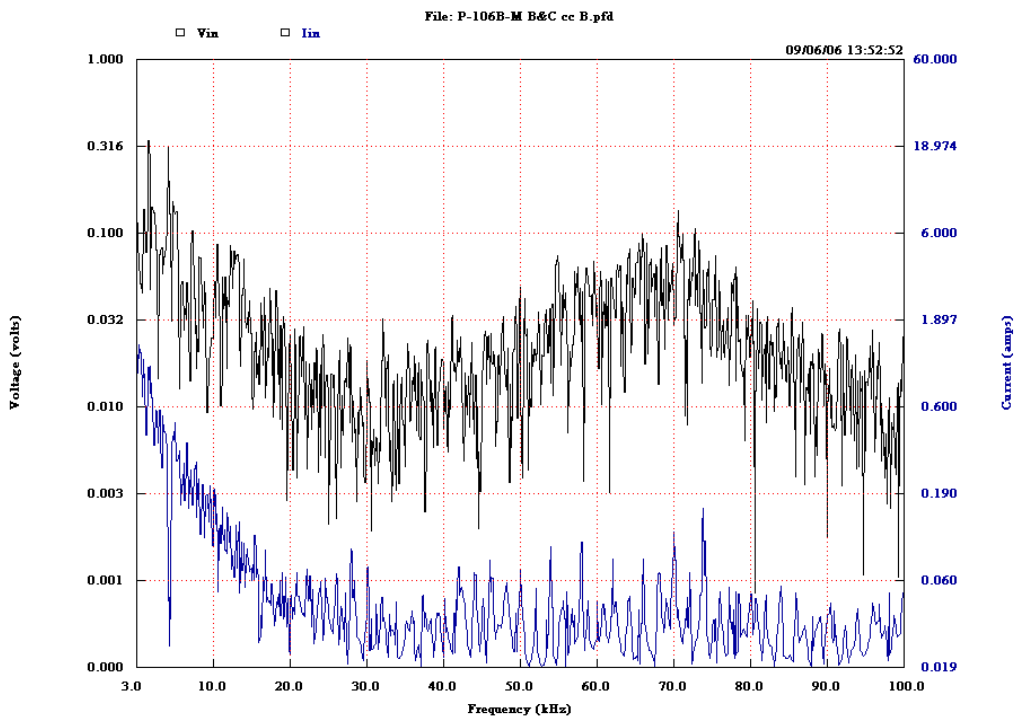
Zoomed view of voltage noise peaks between phases A&B



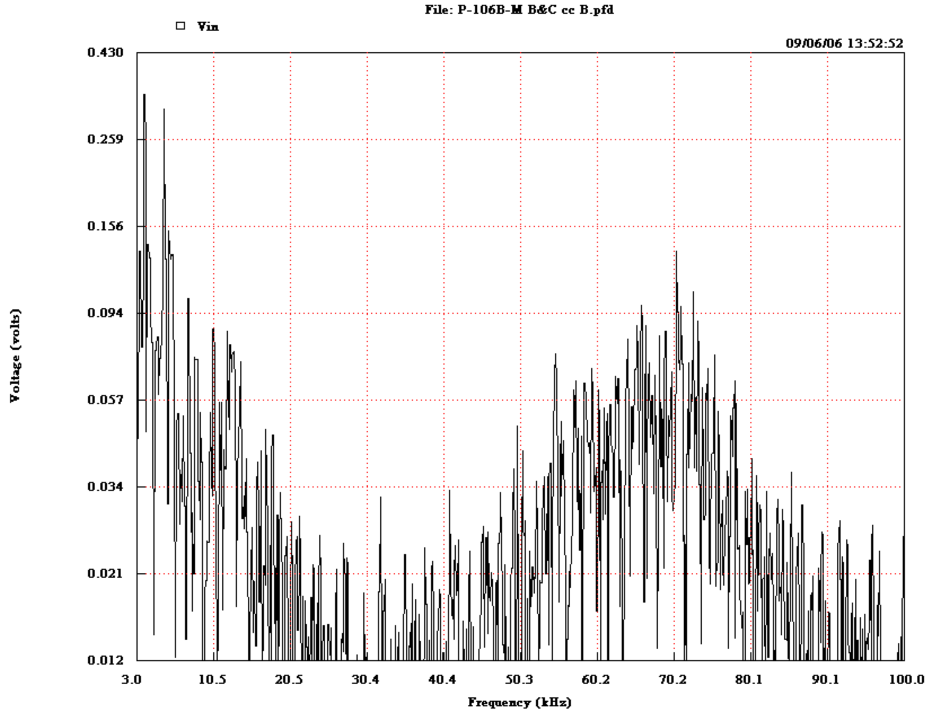
Zoomed view of current noise peaks on phase A



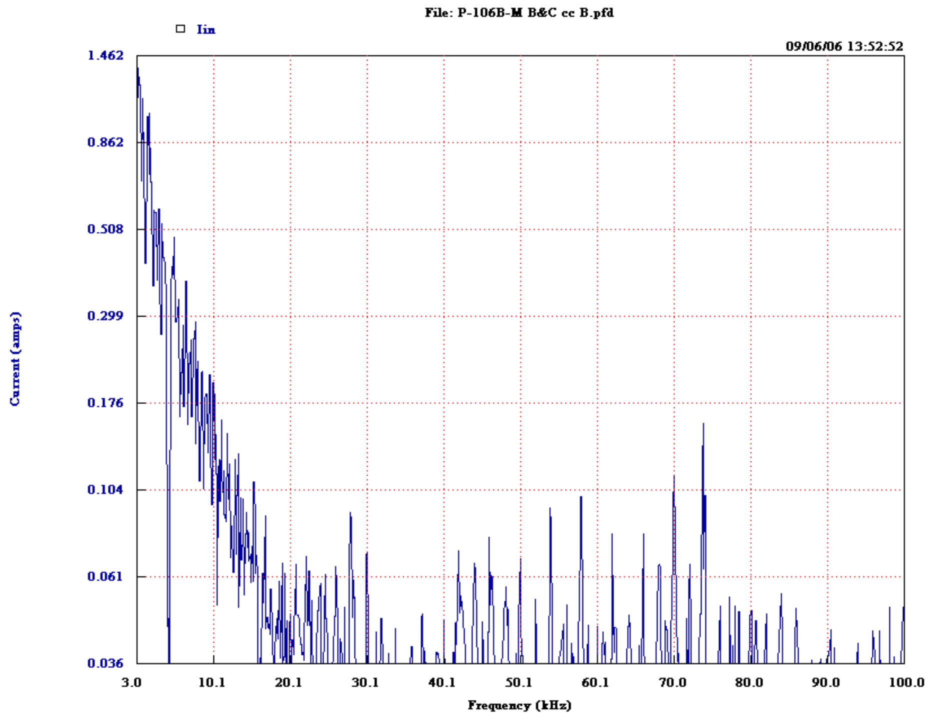
Voltage and Current noise between phases B&C with the current readings on B



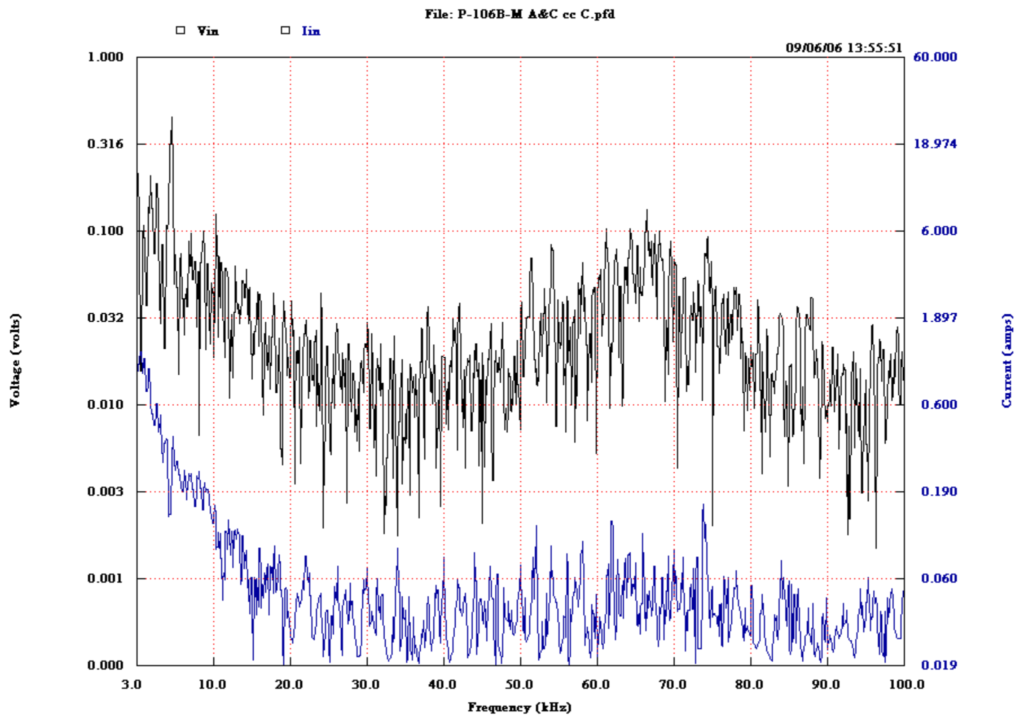
Zoomed view of voltage noise peaks between phases B&C



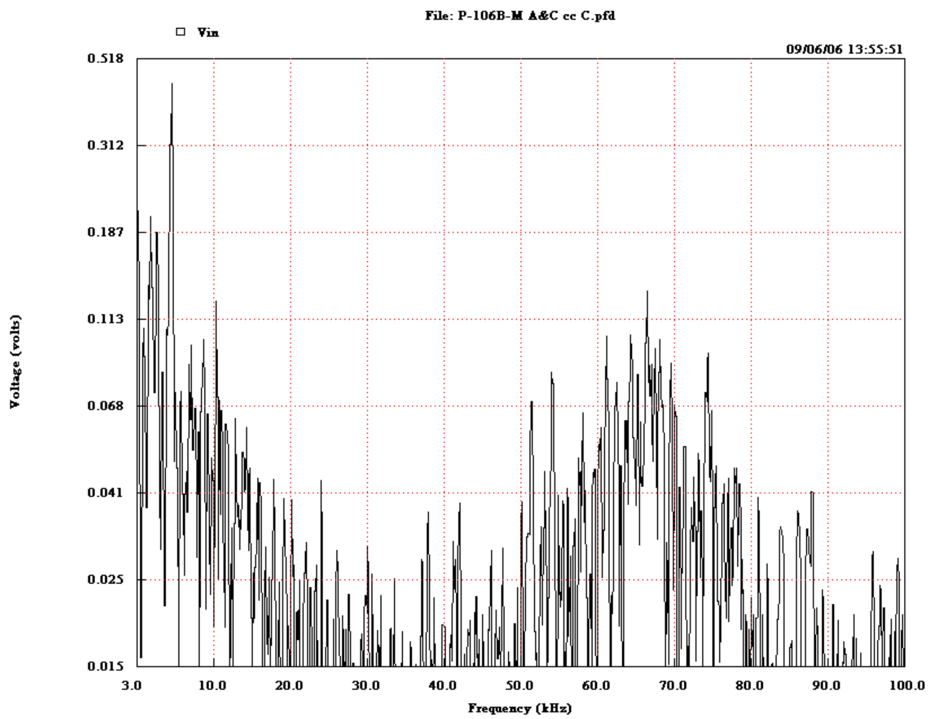
Zoomed view of current noise peaks on phase B



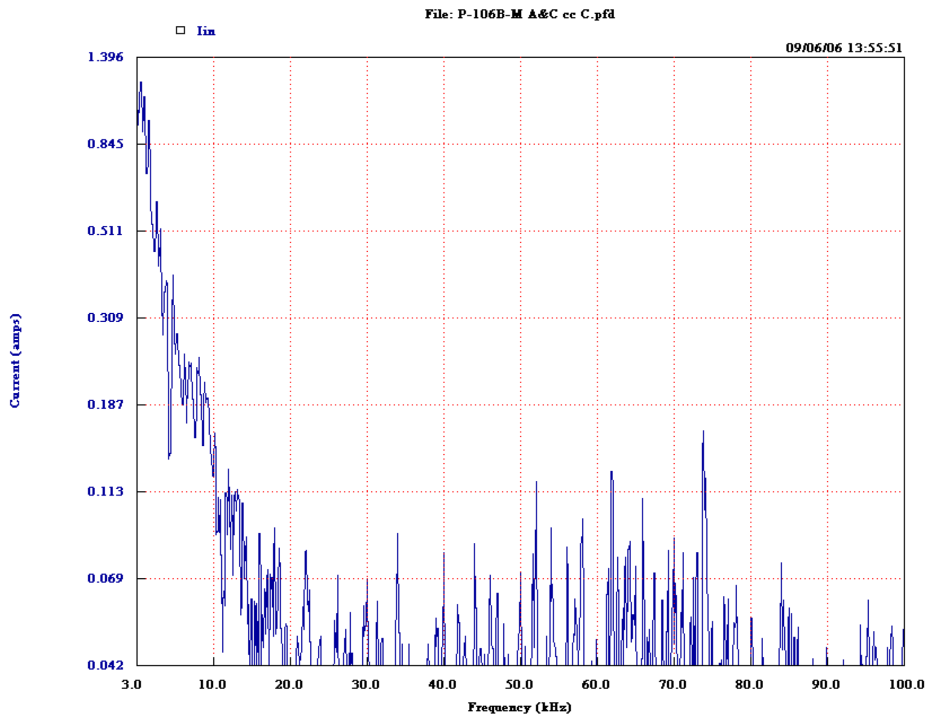
Voltage and Current noise between phases C&A with the current readings on A



Zoomed view of voltage noise peaks between phases C&A



Zoomed view of current noise peaks on phase C



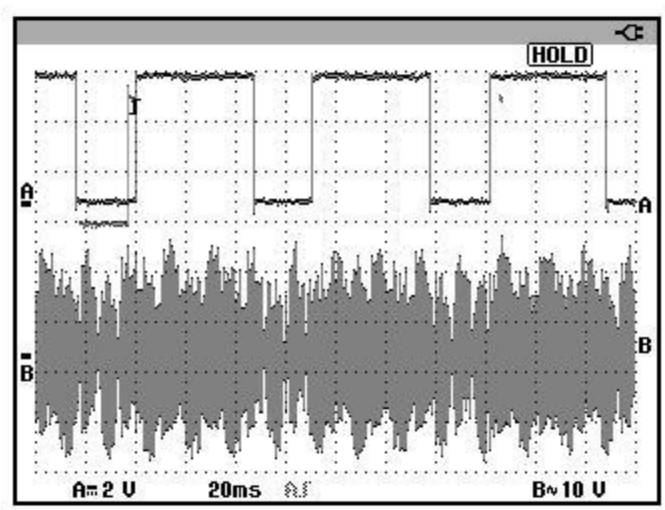
Power Quality Assessment:

The electrical distribution system of DS 1J is exhibiting typical high frequency noise contributions of an environment that contains a multitude of VFD driven loads. The voltage and current noise that is saturating this system is the natural by-product of the AC to DC rectification process that is further exacerbated by the speed of the IGBT's switching speed. The invasive and wide reaching effect of noise in the system was the primary contributor to the malfunction of the Heat Trace system. The noise from the VFD's and UPS system penetrated the delta to wye transformer and caused the transmission signal to the PLI to become unreadable.

The Solution:

The following images were taken with the Fluke 199B Scopemeter as the Environmental Potentials product was applied to the distribution system that feed the Heat Trace system.

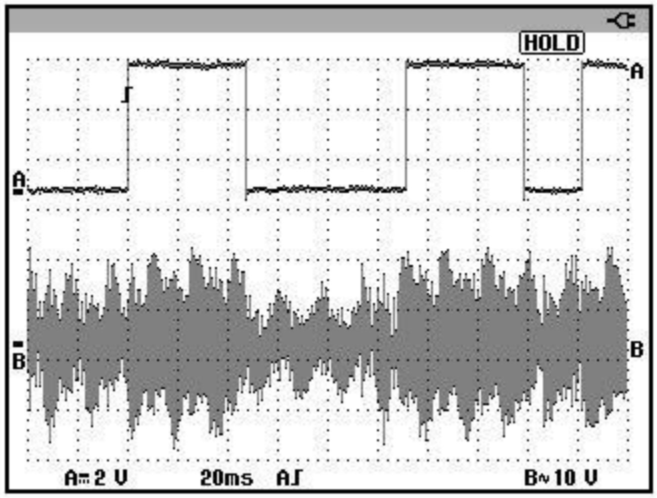
First Unit Installed:



PLI with first filter on Chem Inj

As we can see with one unit installed we still get noise contribution for the rest of the facility through the phase legs and the system ground.

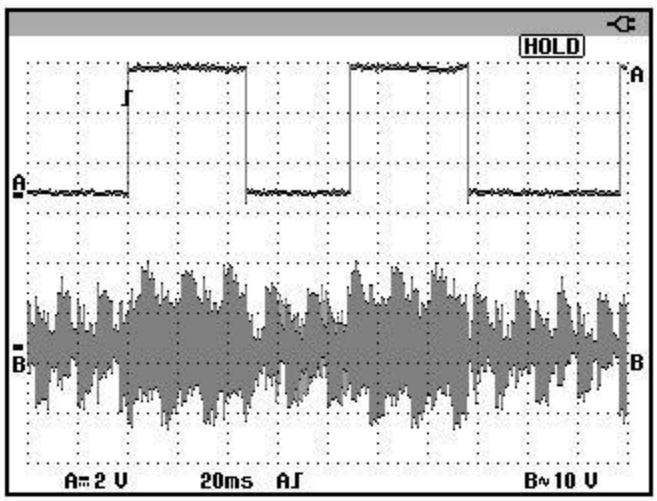
Second Unit Installed:



PLI with second filter at FEF

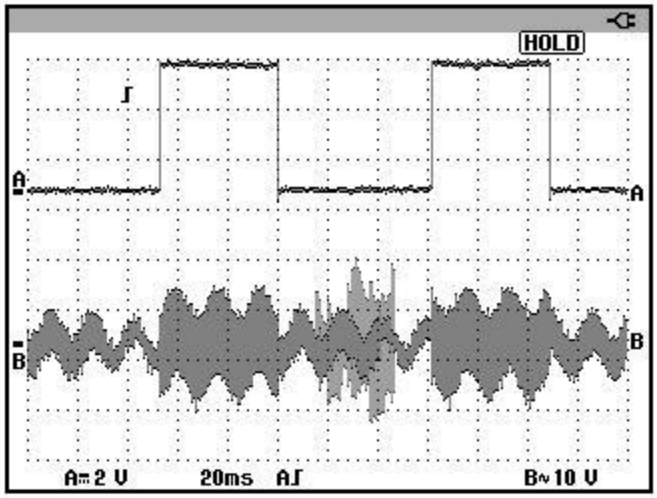
With the second unit installed begin to see some change in the noise level and the 42 to 55 KHz transmission wave begins to appear.

Third Unit Installed:



PLI with third filter on HVAC

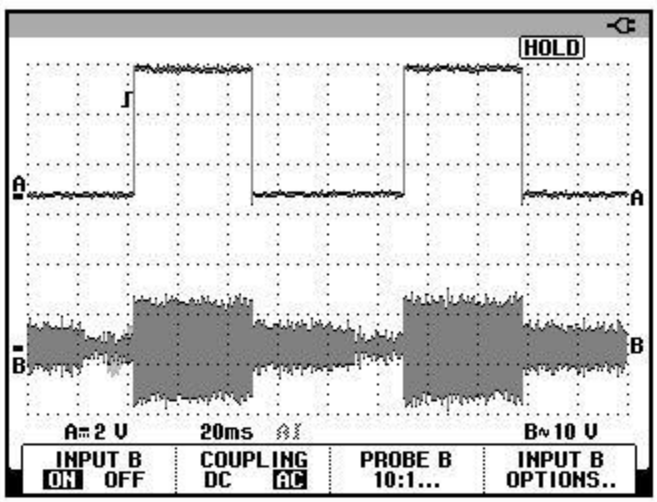
Fourth Unit Installed:



PLI with fourth filter on P-1J06B

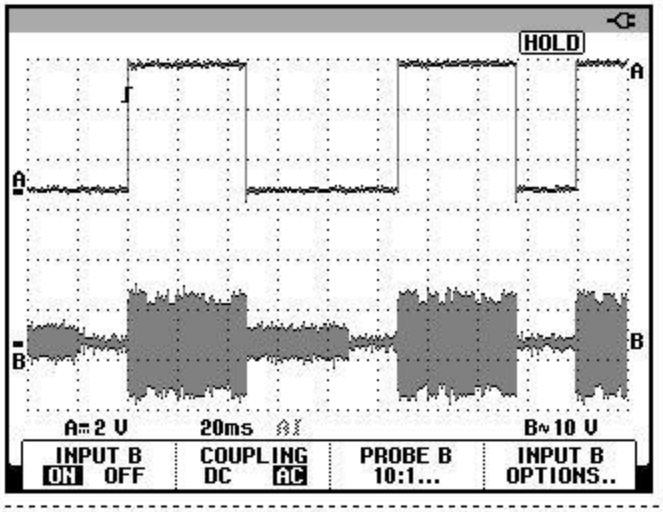
By the installation of the fourth unit we see and emergence of the actual data signal. But we still have enough interference to cause the PLI to not read the data.

Fifth Unit Installed:



PLI with fourth filter and scope input B grounded

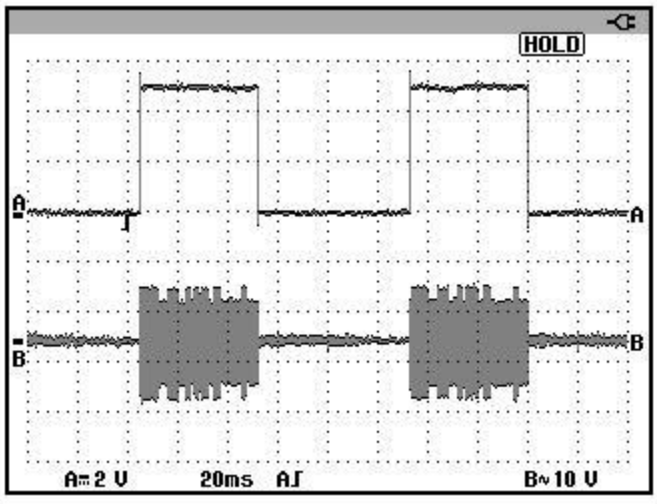
Sixth Unit Installed:



PLI with fifth filter on P-1J06A

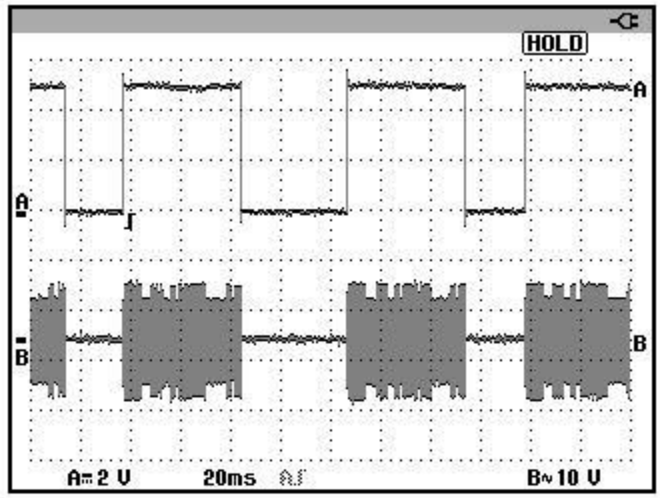
Cleaner signal emerging.

Seventh Unit Installed:



PLI with sixth filter on UPS

Eighth Unit Installed:



PLI with seventh filter on SB-1J01

We now have a clean signal that the PLI of the heat trace can read and interpret. At this point all of the short, medium, and long Heat Trace lines were report at near 100% with on the longest of the lines reporting below 80%. This issue s will be addressed by the manufacturer of the Heat Trace system.

Distributed Power Quality Approach:

In the digital world of today, a distributed approach to power quality must be considered. As the equipment in the facility has changed over the past 20 years, so have the root cause of all power quality problems. It is no longer beneficial to a facility to try to adapt legacy solutions (devices that shunt energy into the ground loop), capacitor banks, etc to address modern day power quality issues. The issue of fast rising low amplitude transients in the system that oscillate into high frequency voltage and current noise can only be addressed by removing them from the electrical distribution system (including the ground wire) from the nearest point of their creation .

More Issues Related to High Frequency Noise:

1. High frequency noise (HFN) can interfere with the transmission of information in digital circuitry. It can cancel out a positive bit with a negative surge, or likewise, a positive surge could be interpreted as a positive bit.
2. If the magnitude of the noise is great enough, it could destroy sensitive transistors in digital circuitry. If a positive surge adds to a positive bit, or a negative surge to a negative bit, it could be more than overwhelm the transistor and destroy it, permanently damaging the circuitry. Damage like this is very difficult to find and repair because there are generally no physical signs of damage.
3. In analog circuitry where sensitive measurements are being taken, removing high frequency noise is very important. For example, consider a system that relies upon a high-performance analog-to-digital converter (ADC) to digitize received analog signals. The energy on the digital outputs of the ADC could easily be 130dB (10,000,000,000,000 times) greater than the energy on the analog input side. Any high frequency noise on the digital side of the ADC could annihilate the low-level analog signal. Therefore, preventing high frequency noise is critical. HFN also comes into play when converting the analog signal into a digital signal. If there is any high frequency noise present on the line, it will greatly reduce the number of effective bits that are available. Finally, a very small voltage spike can end the conversion before it even has a chance to complete by corrupting the microprocessor values.
4. Current surges can score very small traces and destroy sensitive micro-circuitry.
5. High frequency noise can interfere with the functionality of video monitors leaving them with static lines, a wobble, fuzz or burn-in.
6. High frequency current noise takes up space in the core and is viewed as an eddy current. Eddy currents create heat and waste power. As eddy currents create heat, the heat creates corrosion in transformers and inductors which can cause degradation of the conductors and arcing. This cycle creates more high frequency noise and larger eddy currents leading to inductor and transformer malfunctions and eventual failure. The heat created by high frequency noise can lead to ineffective mitigation strategies such as the implementation of larger K-rated transformers. While these strategies may provide temporary relief, the heat will eventually become a factor again if it is not removed.

7. If not filtered properly, high frequency noise on circuit boards can equate to jitter on clocked signals. Supply noise entering a device via power pins produces small momentary shifts in device input switching thresholds and on output signal transitions. Noise produced by on-board switching power supplies has energy, in the approximate frequency range of 100 kHz to 5 MHz. The noise produced by digital switching circuits has energy that dominates in frequencies ranging from 10 MHz to 500 MHz and higher. Both types of noise may contribute to jitter in clock signals on the board.
8. High frequency noise radiates, which can "couple" or flow into any metallic surface or component.

Recommendations:

The issues related to DS 1J are not unique to DS 1J. The application of VFD technology throughout the drilling and pumping processes will benefit greatly from an improved electrical environment. Further readings and sample testing to establish the noise levels with in the facilities should be the next step and a comprehensive power quality plan should be devised and implemented across the facilities.