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Sample Report

EXECUTIVE SUMMARY
Voltage Distortion & Power Quality Study
for
General Hospital
Somewhere Valley, AK

Background / Introduction

General Hospital has experience a series of problems associated with the facilities electrical distribution when operating on emergency generator. The most troublesome condition is associated with UPS equipment located in equipment rooms on multiple floors of the facility. The specific condition is the apparent inability of the UPS equipment to recognize the voltage as a viable source when operating on emergency generators resulting in a gradual discharge of the battery back-up and eventual failure of the connected electronic equipment if the utility power source is not restored before the depletion of the battery supply.

The problems experienced during generator testing are not limited to the above mentioned UPS equipment as there are reports of motor drives tripping-out as well.

In an effort to identify the route cause and develop a mitigation strategy to correct the situation PowerCET Corporation was retained to conduct a thorough monitoring of the electrical distribution during a the periodic (monthly) generator test.

The hospital's electrical environment consisting of a total of four (4) automatic transfer switches (ATS) serving a variety of loads as well as two (2) active harmonic (filter) mitigation devices. Previous testing attempts, while providing some insight to the problem, were insufficient to provide a complete picture of this dynamic environment.

The objective of the *Voltage Distortion & Power Quality Study* is to document the circuit conditions (specifically voltage distortion) during both normal and emergency generator operation. The information gathered can then be used to determine the appropriate mitigation of unsatisfactory conditions to allow for reliable operation of electrical/electronic equipment under all conditions.

Methodology / Technical Approach

Bruce Lonie (PowerCET Corporation) developed a comprehensive monitoring plan to document conditions across the facility before, during and after a typical generator test.

Figure 1 is a simplified diagram of the normal and emergency electrical distribution associated with the facility. A total of ten (10) Dranetz power monitors were used and set to record both periodic (timed) readings as well as transient conditions. More detailed information on testing configuration is available in the full study report.

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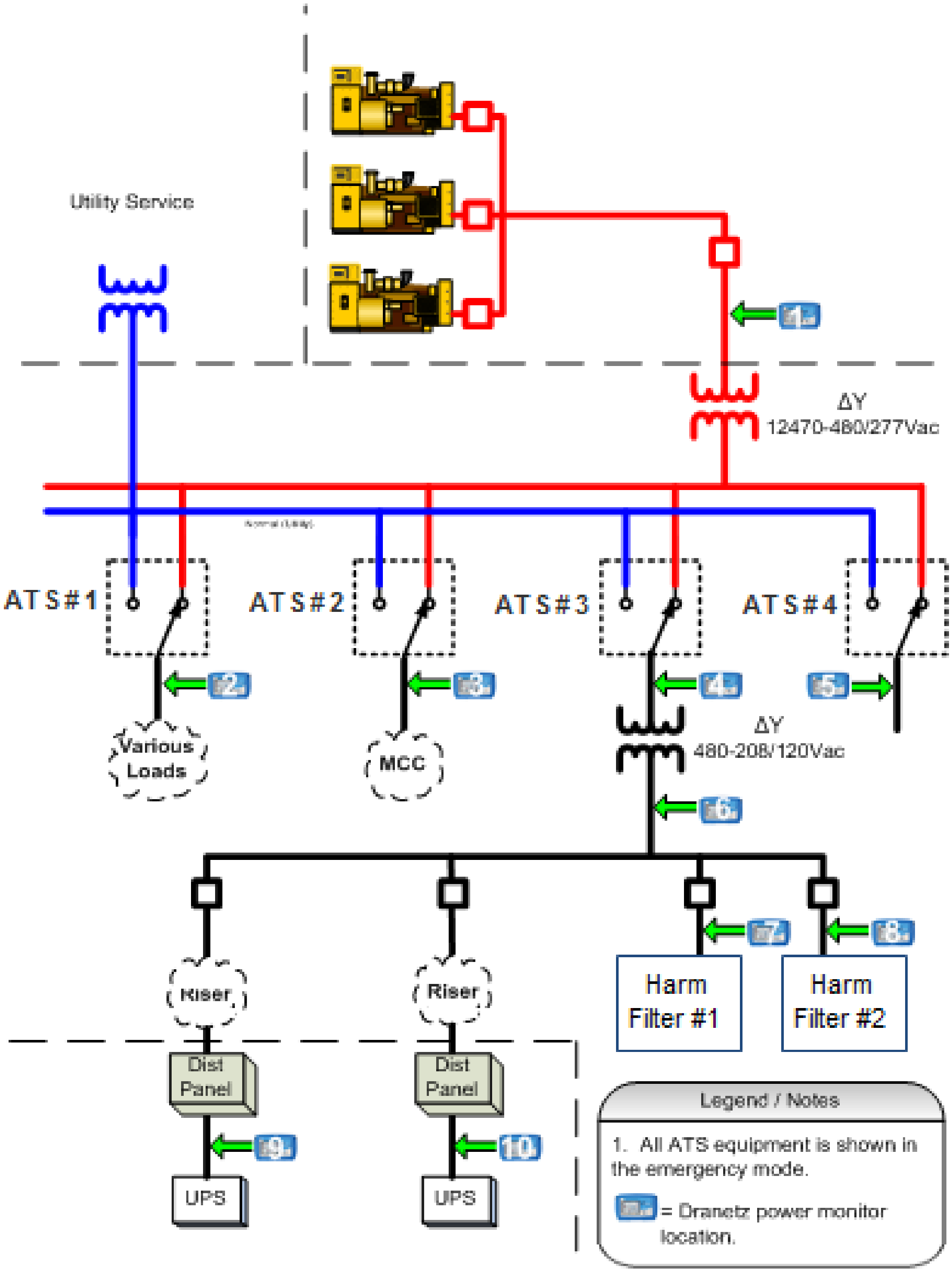


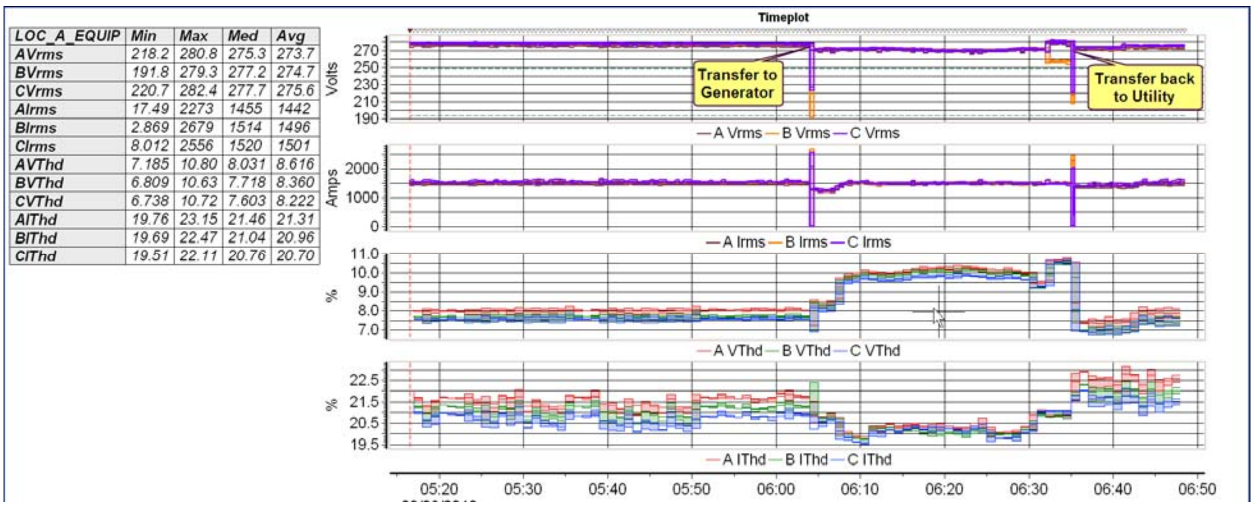
Figure 1 – Simplified single-line of Building A's electrical distribution system.

Key Findings and Recommendations

The testing conducted on Wednesday, October 15, 2010 revealed that while the voltage distortion is elevated when operating on emergency generators the level of voltage distortion (Vthd) under normal utility operation ranges from 3% to 8% and is contributing to equipment misoperation and stability issues.

Normal Utility Power Source Discussion

Figure 2 (below) shows the voltage, current and distortion plots for monitoring Location #3, ATS #2 which is the dominant source of the voltage distortion for the electrical distribution system



LOC_A_EQUIP	Min	Max	Med	Avg
AVrms	218.2	280.8	275.3	273.7
BVrms	191.8	279.3	277.2	274.7
CVrms	220.7	282.4	277.7	275.6
AIrms	17.49	2273	1455	1442
BIrms	2.869	2679	1514	1496
CIrms	8.012	2556	1520	1501
AVThd	7.185	10.80	8.031	8.616
BVThd	6.809	10.63	7.718	8.360
CVThd	6.738	10.72	7.603	8.222
AIThd	19.76	23.15	21.46	21.31
BIThd	19.69	22.47	21.04	20.96
CIThd	19.51	22.11	20.76	20.70

Figure 2 – Vthd and Ithd time plots of ATS (Monitor #3).

Under normal, utility operation the Vthd is in the 7% to 8% range and increase to between 9% and 10% when operating on the generator supply. This increase in Vthd is the result of the higher (about 3%) source impedance presented by the generators to the distribution system. Industry practices attempt to operate facilities in the 3% to 5% Vthd range for Utility operation and expect an increase when switching to the emergency generator supply.

Figure 3 (below) shows the voltage and current waveforms during normal utility source operation just prior to the generator test conducted on October 15th. The current waveforms are typical of 6-pulse rectified loads with line-reactors installed.

The loading on the ATS #2 (Monitor #3) was approximately 1500A/phase at 480Vac phase-to-phase and consists of the larger environmental loads, HVAC, for the facility. Analysis of the voltage and current waveforms indicates that the distortion is dominantly the balanced doublets 5th - 7th and 11th - 13th harmonics from the 6-pulse drives associated with the motor loads.

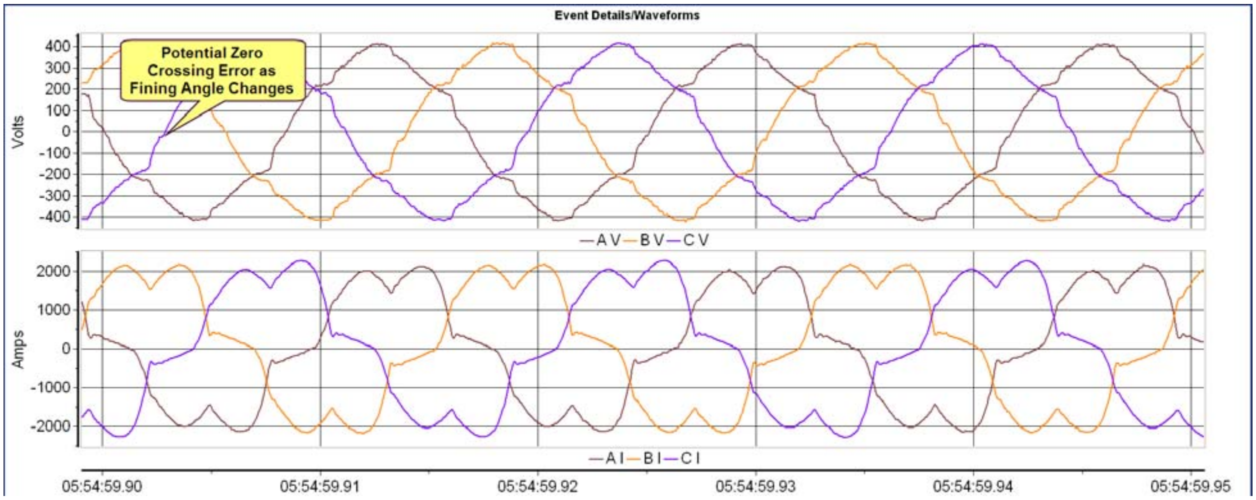


Figure 3 – Monitor #3 (ATS #2), utility source, voltage (phase-to-neutral) and current waveforms showing typical 6-pulse current waveforms.

Emergency Generator Power Source Operation

Figure 4 (below) shows the voltage (line-to-neutral) and current waveforms for the ATS #2 (Monitor #3) operating on the generator supply. Note the increase in voltage distortion and the prominent multiple zero-crossings which typically cause drives to "trip-off" as they can not synchronize properly. [Note: It was reported that a number of drives had "trip-off" during the early morning testing on October 15th.]

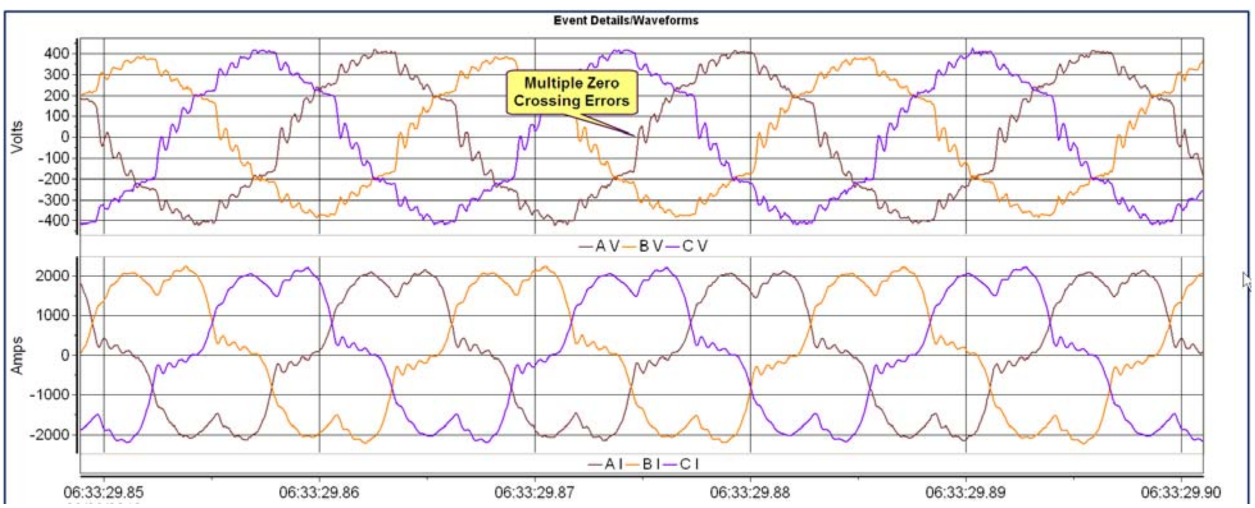


Figure 4 – Monitor #3 (ATS #2), generator source, voltage (phase-to-neutral) and current waveforms showing distortion and multiple zero-crossing errors.

In summary the primary driver of the distortion on the electrical distribution are the large environmental loads and their associated 6-pulse drives. Unacceptable levels of distortion are present regardless of the power source—utility or emergency generator. Figure 5 (below) graphically illustrates the problem and the flow of harmonic energy in the distribution system.

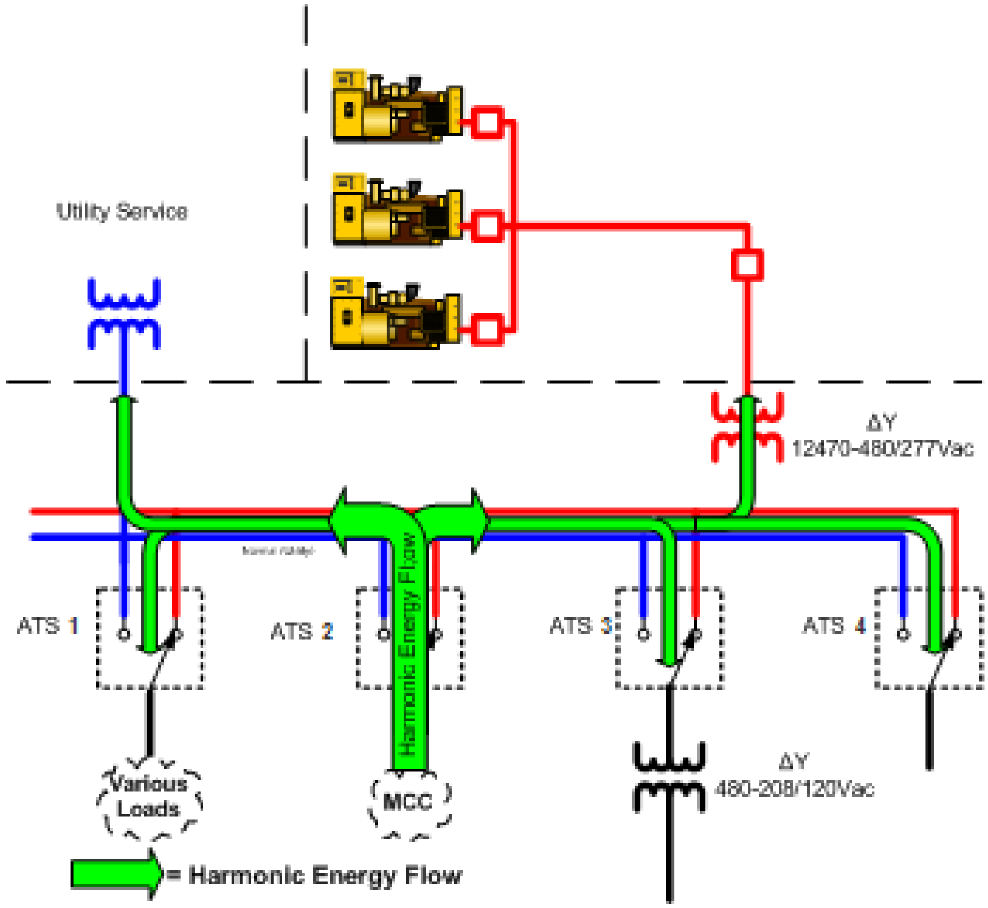


Figure 5 – Simplified single-line showing direction of harmonic energy flow [GREEN].

RECOMMENDATION: The Vthd$_{fnd}$ associated with the 1500A/phase ATS #2 (Monitor #3) should be reduced to less than 4% under normal utility power source operation. This can be accomplished through:

1. **Change out of existing 3% impedance line reactors for 5% impedance reactors, and**
2. **Installation of phase shifting, zigzag transformers on some of the drives to cancel out 5th and 7th harmonic currents. The advantage of the phase shifting is that it is a passive harmonic filter and does not present the problem of cross-talk or interaction between other system distribution components that conventional harmonic filter might.**

ATS #3 (Monitors #4, #6-10) – UPS Charging Problem On Generator Source

The load side of the ATS #3 (see Figure 1) connects to a 480-208/120Vac step-down distribution transformer that distributes 208/120Vac power to a series of equipment rooms on each floor. Part of the load in each of the rooms is a UPS, 4.2kW (5.2kVA). The UPS is connected as a 208Vac single-phase device and has input power factor correction.

Several of the USP installations have experienced problems during the periodic generator testing in that the rectifier (input power supply) will not recognize the emergency generator as a valid power source.

In an apparent effort to mitigate the USP situation two active harmonic filters were installed on the 208Vac distribution bus associated with the secondary of the step-down transformer discussed above.

Figures 6 and 7 (below) are current and voltage waveforms for the UPS equipment when powered from utility source and generator source respectively. The UPS power supply is *power factor corrected* which means it tries to follow the voltage waveform. If the voltage is distorted then the corresponding current waveform will be distorted.

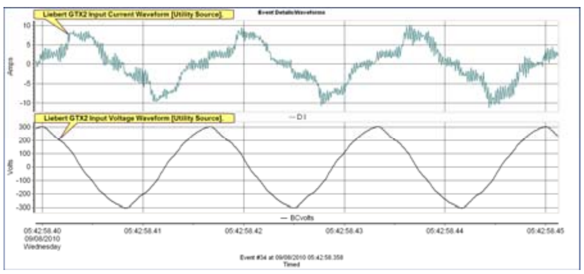


Figure 6 –UPS input voltage and current waveforms—utility source

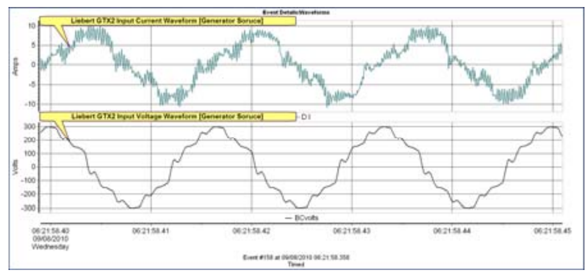


Figure 7 UPS input voltage and current waveforms—generator source

The active harmonic filter is also a voltage following device which means there are two devices in series trying to compensate for the distortion. The result is generally and unsatisfactory condition.

During the testing activities on October 15th several of the UPS's failed to come on-line when transferred to generator. As an experiment the active harmonic filters were turned off, Figure 8 (below), and the current hunting from the UPS equipment stopped and the UPS equipment came on-line and started charging the batteries. It appears from this experiment that the increase in voltage distortion when operating with the generators as the power source results in an unstable condition in which, at least some of the UPS's, can not accept the voltage signal. Disabling the active harmonic filter equipment allows the UPS equipment to return to normal operation.

Observations of the active harmonic filter equipment under normal operating conditions do not reveal any significant benefit from operation of the equipment in this application.

RECOMMENDATION: Install 5kVA transformers on the input power to the UPS equipment. This will buffer the power factor corrected supply from the source and result in improved performance. Do NOT install any type of active regulating device in series with this type of application.

RECOMMENDATION: From the testing results the active harmonic filter equipment is not improving the operating environment for the UPS equipment and should be removed from this application. During emergency generator operation the equipment actually appears interfere with the reliable operation of the UPS equipment.

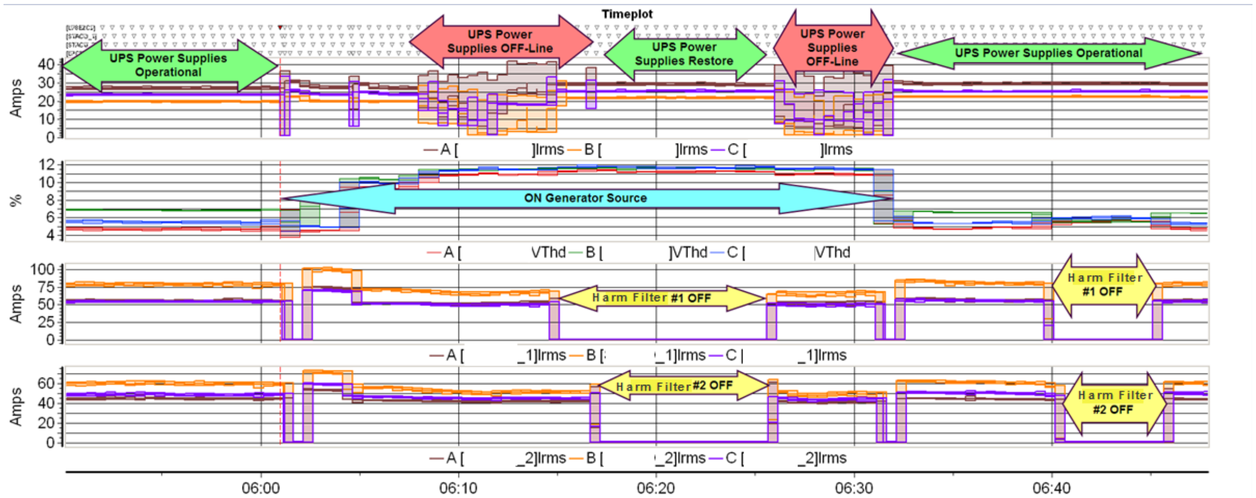


Figure 8 – Active harmonic filter current time plots versus UPS current plot documenting UPS power supply stability when active harmonic filters are OFF.

Summary

It is surprising how well things operate in view of the level of distortion under normal operating conditions.

As a general rule the facility should be operated with a Vthd level of less than 5% and expect some increase when switching to generator operations with the corresponding higher source impedance. In the case of this facility the nominal Vthd on the 480V bus is about 8% and increases, as expected, during operation on the emergency generator power source.

The major contributor to the distortion levels is the ATS #2 loads that typically appear to run about 1500A/phase at 480Vac. All drives were verified to have either 3% or 5% line reactors installed which appears to be insufficient to control the 5^{th} and 7^{th} harmonics associated with 6-pulse loads. There may be additional load issues, but they will be difficult to identify as they would be masked by the size of the ATS #2 load and associated harmonics.

The mitigation of the harmonics, especially the 5^{th} (300Hz) harmonic, associated with the ATS #2 loads should be the first priority. A number of possible solutions are available to address these issues which are discussed in more detail in the full study report. The more significant recommendations include…

- Replace 3% line reactors with 5% (assuming the drives can tolerate the higher losses)
- Install phase-shifting transformers on selected drives to cancel harmonic currents.

Reducing the Vthd from 8% to 4% will probably resolve most, if not all, of this type of problem and improve equipment performance and reliability.

The other issue investigated in the activity is the performance of the UPS equipment. The problem has been the unreliable operation of the equipment when on the emergency generator power source. Specifically the UPS input power module does not always recognize the generator as a viable power source and under extended runtime the back-up battery supply is depleted.

In a previous effort to resolve the UPS performance problem a set of active harmonic filters were installed. Unfortunately, these are not an appropriate solution for this type of problem. The UPS equipment has a power factor corrected input power supply which is a voltage following device…the current tracks the input voltage signal. The active harmonic filter is also a voltage following device…two similar devices in series seldom works.

During the testing, while operating on the generator supply, the active harmonic filter equipment was turned-off…the UPS equipment returned to normal operation with the active harmonic filter off.

Recommend discontinuing use of the active harmonic filter equipment for this application.

General Hospital is a large complex facility and some type of on-going monitoring capability should be implemented on the key distribution locations. This will allow for tracking of conditions over time and with the proper analysis can result in identifying unsatisfactory conditions before they become catastrophic. In addition with permanent monitoring should a problem occur much better information is available to facilities personnel to help them determine the source of the problem and the appropriate course of action.

Prepared by:

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