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A DATA PROCESSING POTPOURRI OF POWER QUALITY PROBLEMS

by

Patrick J. Lynch, P.Eng.

Power Line Systems Engineering Inc.

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ABSTRACT

A major bank data processing centre decided that a totally redundant standby "hot" centre was required. This redundant data centre would be geographically located at least 100 miles away from the main centre to reduce the chances of any local disturbances (ie. electrical disturbances, as well as bomb threats, etc.) from causing disruptions with this banking operation.

Various electrical power safeguards were installed at this new site, including 2.4 MVA of U.P.S. (6 modules each of 400 KVA.) and corresponding back-up diesel systems. After this site had been commissioned, major power quality issues began to surface. Recently transferred cheque encoding machines, that had worked flawlessly at the other data processing site would continually fail within 5 to 10 minutes after being "plugged in" to standard utility power at this new site. Regular testing of the diesel / U.P.S. high speed transfer switch system would also cause, the intermittent tripping of the main U.P.S. input breakers. Also, at various times of the day, the text on the computer monitors would severely waver back and forth, and lead to incorrect data entries by the operators.

The results of these investigations, revealed a serious harmonic resonance situation had been set up between the U.P.S. and some of the other non-U.P.S. loads, as well as with the U.P.S. input harmonic filters during transfer switch operations. Chiller power cables were also found to be located above the ceiling tiles, within 10 to 15 feet of the computer screens, causing a low frequency magnetic field interaction to occur with the computer monitors.

Prior to building a priority data centre site of this magnitude, it would be strongly recommended to first perform a detailed electrical system analysis and computer modelling investigation in an attempt to circumvent some of these pitfalls. Investigating and solving these types of electrical problems afterwards, as demonstrated, can be very costly and extremely disruptive in nature to a facility designed to be an ultra-reliable 24 hour-7 day continuous operation.

1. INTRODUCTION

PROBLEM 1: FAILURE OF CHEQUE ENCODING MACHINES

Each cheque that is collected at a bank branch, throughout the country, is forwarded by express courier to their centralized data processing facilities. Each cheque's dollar value is first read by an operator and then coded on the bottom of the cheque, using a cheque encoding machine. The cheque is then sent to a high speed cheque debit / credit processing machine. Each banking institution associated with the cheque receives either the appropriate credit or

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debit recorded against their bank. The banking association has collectively agreed that they will allow "x" number of hours for the "cheque floats" to be processed. Failure to process the cheques in this pre-determined amount of time, will result in very large financial penalties, automatically being assessed against the offending banking institution. All of the approximately 20 cheque encoding machines, powered with utility power at this new data processing facility (Site 2), were automatically turning themselves off within 5 to 10 minutes after being turned on.
As a result, very few cheques were being processed and approximately $50,000 to $100,000 per day of banking penalties were regularly being assessed against this major banking institution.

The cheque encoding operators were attempting to cope with the situation by moving from a failed machine to another working machine, as the failures occurred (somewhat like musical chairs - without the music). If they could have heard the music, it would have sounded like the "death march" for the senior executives at this site.

Initially, the facility's engineering staff thought that the machines all must have been damaged in shipment from the other data processing site (Site 1). NOTE: These machines had worked flawlessly at the other site (Site 1) for approximately 5 to 7 years. The staff shipped 5 failing units back to the original data site. Guess what? All these machines worked perfectly when plugged into the standard utility power 120 Volt wall outlets at the original site.

The machine manufacturer's representative was then frantically contacted. He suggested these machines required dedicated "orange" isolated plug ground receptacles to work at optimum performance at the new site. The new site was quickly rewired with this grounding

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system, however, the machines continued to "turn off" after 5 to 10 minutes of operation. The machine manufacturer's representative then said each machine needed it's own neutral wiring and could not be a shared neutral system with the other machines. The new site was then rewired once again with this dedicated neutral and ground system. The machines still continued to "turn off" after 5 to 10 minutes of operation

Approximately 3 weeks had now elapsed. All these trial and error or "knee jerk" approaches to the problem produced no solution. The dreaded "death march" (prepare the resumé time) music was now ringing quite loudly into the ears of all the executives at this site.

With the music, now at a very high pitch crescendo, it was decided by the executives to hire an outside electrical engineering power quality systems specialist to either: A) solve this problem or B) absorb all the blame for not solving the problem quickly enough. Our company happily accepted this challenge. We picked up the fallen relay baton and used it to orchestrate a systematic problem solving approach.

FACT 1; At both sites, the cheque encoding machines had a nominal 120 Volts and neutral to ground voltages less than .3 Volts.

FACT 2: At the failing site (Site 2), the machine current draw was 3.4 Amps, double the current compared to the original data processing site (Site 1). Each machine had a current limiter that would automatically open and then reset after it had cooled down.

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FACT 3: We then brought in a small portable 1:1 ferroresonant transformer and plugged it into the wall outlets at the failed site. The cheque encoding machine in turn was "plugged into" this ferroresonant transformer. The current draw to this machine immediately dropped to approximately the same value as at the original site (nameplate value). The machine that was plugged into the ferroresonant transformer no longer failed, but all the other machines on each side of it still continued to automatically turn off after 5 to 10 minutes of operation. A typical ferroresonant transformer works on a saturated transformer core principle. Because the core is saturated, it severely attenuates the flow of harmonics between input and output.

Pictures #1, #2 and #3 display the phase current harmonic frequency spectra of the cheque encoding machine at Site 1, Site 2 and Site 2 with the ferroresonant transformer, respectively. NOTE: changes in current draw and harmonic levels for the same machine "plugged into" different 120 Volt power sources.

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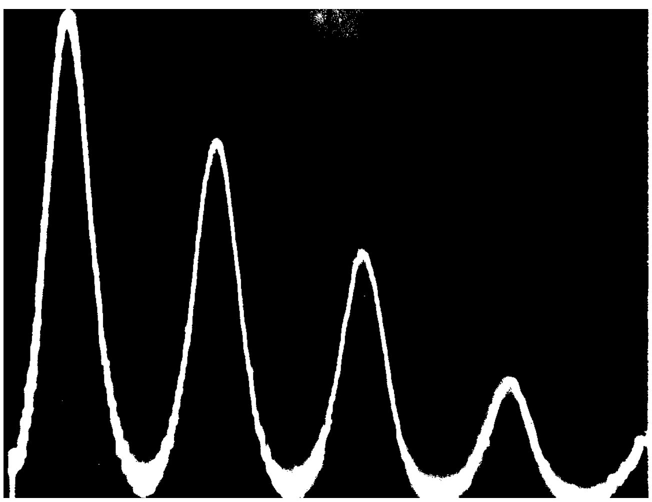
PICTURE #1

CHEQUE ENCODING MACHINE

"FED WITH STANDARD UTILITY POWER" AT SITE 1

PHASE CURRENT - HARMONIC FREQUENCY SPECTRA



Horizontal Scale: 500 HZ. SWEEP

Vertical Scale: LINEAR

TRUE R.M.S. CURRENT: 1.7 AMPS

PREDOMINANT HARMONICS:

3rd Harmonic - 75% compared to the fundamental

5th Harmonic - 50% compared to the fundamental

7th Harmonic - 25% compared to the fundamental

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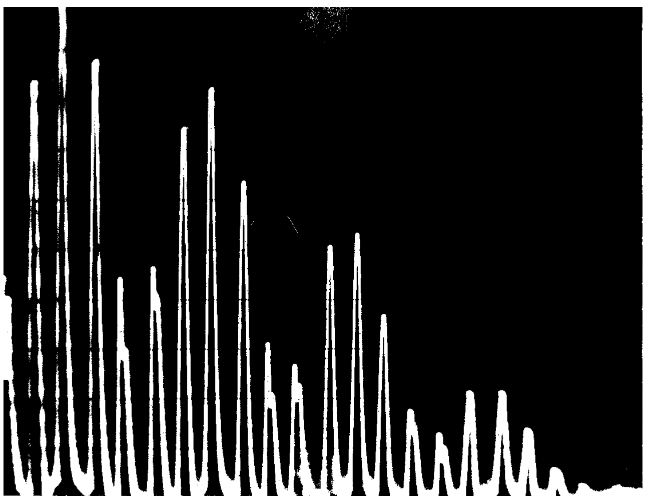
PICTURE #2

CHEQUE ENCODING MACHINE

"FED WITH RAW UTILITY POWER" (ON COMMON U.P.S. FEED) - SITE 2

PHASE CURRENT - HARMONIC FREQUENCY SPECTRA



Horizontal Scale: 500 HZ. SWEEP

Vertical Scale: LINEAR

TRUE R.M.S. CURRENT: 1.7 AMPS

NOTE: Harmonics approximately every 30 Hz. Several frequency components 50% to 100% Larger than the fundamental. Machine automatically shuts down every 5 to 10 mins.

NOTE: With the same machine, the current doubles at Site 2

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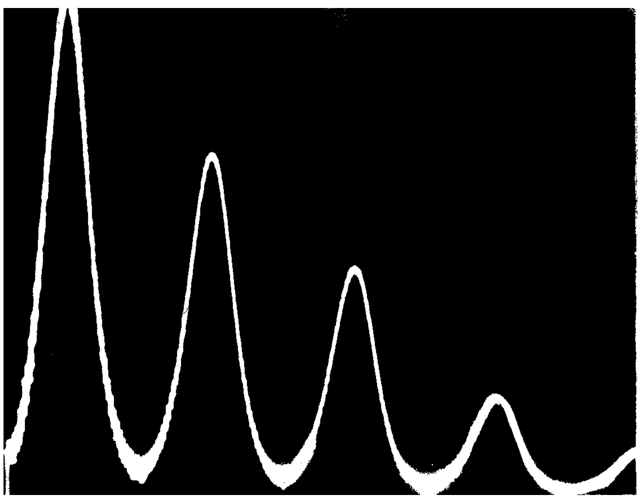
PICTURE #3

CHEQUE ENCODING MACHINE

"FED UTILITY POWER TO FERRO TYPE TRANSFORMER" - SITE 2

PHASE CURRENT - HARMONIC FREQUENCY SPECTRA



Horizontal Scale: 500 HZ. SWEEP

Vertical Scale: LINEAR

TRUE R.M.S. CURRENT: 1.7 AMPS

PREDOMINANT HARMONICS

3rd Harmonic - 70% compared to the fundamental

5th Harmonic - 45% compared to the fundamental

7th Harmonic - 20% compared to the fundamental

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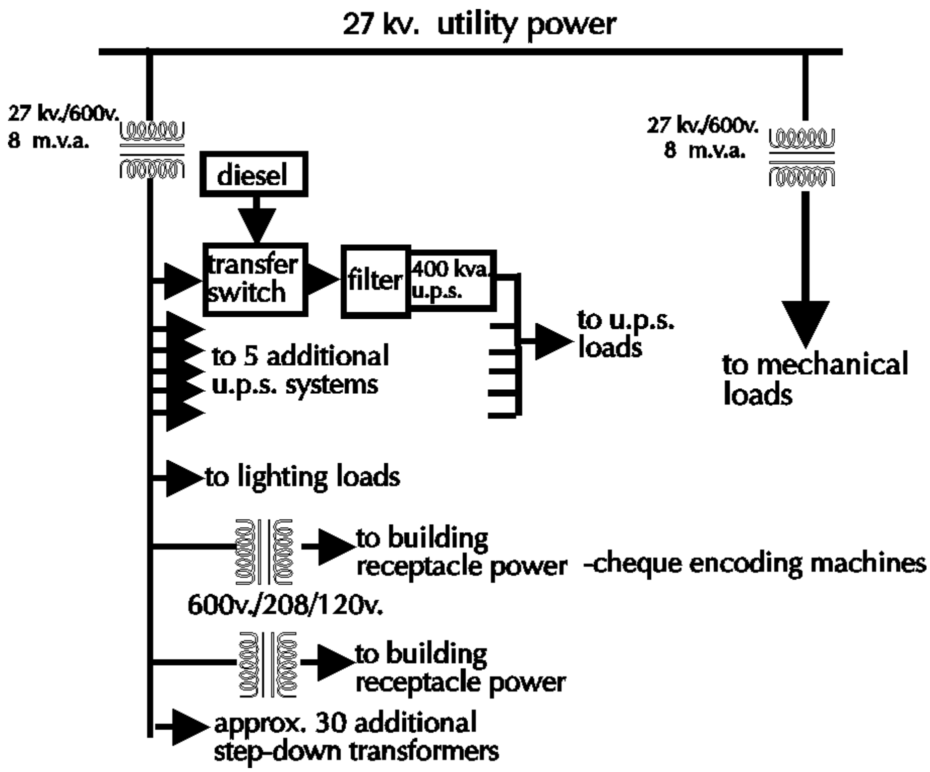
DIAGRAM 1

DATA PROCESSING CENTRE

SIMPLIFIED SINGLE LINE ELECTRICAL SCHEMATIC



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The above single line (Diagram 1) shows six (6) paralleled 400 KVA. U.P.S. modules are fed from the same utility source as are the lighting and auxilliary receptacle power for this building. A separate main incoming step-down transformer is used to feed all the mechanical equipment. Each U.P.S. module is equipped with an input harmonic filter for the 5th, 7th, 11th and 13th harmonics. Even with the U.P.S. harmonic filters in place, we still suspected harmonic interaction was occurring between these U.P.S. systems and the cheque encoding machines. To confirm our suspicions, the U.P.S. was transferred from utility power to diesel power. With the U.P.S. isolated from the utility supply, the phase current draw immediately dropped from 3.4 Amps to 1.7 Amps for all of the cheque encoding machines. At the instant utility power was restored to the input of the U.P.S., the current to each of the cheque encoding machines doubled again.

These test results confirm the U.P.S. system was the source of the problem. All the U.P.S. input harmonic filters were then checked against specification, both by ourselves and the U.P.S. manufacturer. The test results confirmed all the filter units were all within design specification limits.

At this point in this investigation, there now appeared several viable options:

1. Electrically feed the cheque encoding machines directly with U.P.S. power.

2. Supply all the cheque encoding machines with ferroresonant transformers.
3. Re-design the U.P.S. filtering to further attenuate the harmonics generated at the input side of each U.P.S.

4. Electrically feed all the cheque encoding machines with clean utility power (not con taminated with U.P.S. harmonics).

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A large ferroresonant transformer was temporarily loaned to the customer to "power up" all the cheque encoding machines at this site. This enabled the customer to clear the cheque backlog and resume normal daily operations and avoid any further financial penalties. It also provided some "breathing room" to examine each of the above options more closely.

This data centre had 5 floors. Each floor had the lights, the wall and floor 120 Volt receptacles on the same electrical feed as the U.P.S. New future electrical equipment may be plugged into these "contaminated" receptacles and experience similar problems as the cheque encoding machines. Therefore in this case, the broader solution base involving all the 120 Volt building outlets could not be electrically supported by U.P.S. or by cost effective ferroresonant transformers throughout the entire building. Re-designing the input harmonic filter system for each of the six (6) U.P.S. modules, theoretically could be accomplished. However, U.P.S. filter space limitations and additional re-design and component costs could be as high as 20% of the original cost of each of the U.P.S. systems.

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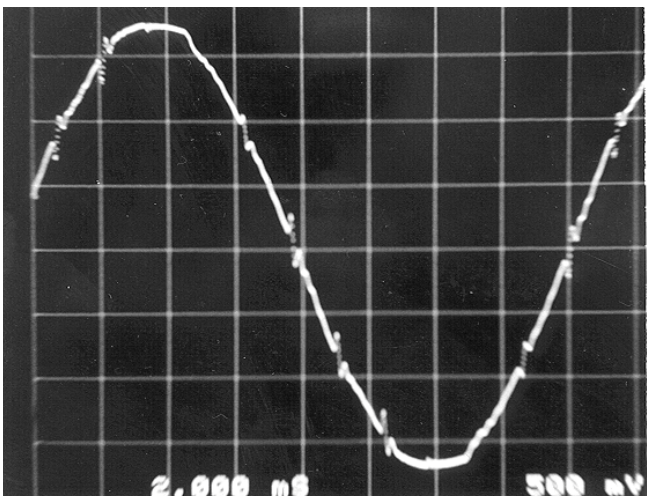
PICTURE #4

CHEQUE ENCODING MACHINE

(COMMON UTILITY POWER TO U.P.S. INPUT FEED)

VOLTAGE WAVEFORM



Horizontal Scale:
TIME: 2 Milliseconds/division

Vertical Scale: VOLTAGE

TRUE R.M.S. VOLTAGE:
120 VOLTS - T.H.D. 4.1%

NOTE: DISPLAYS MINOR SYMMETRICAL NOTCHING

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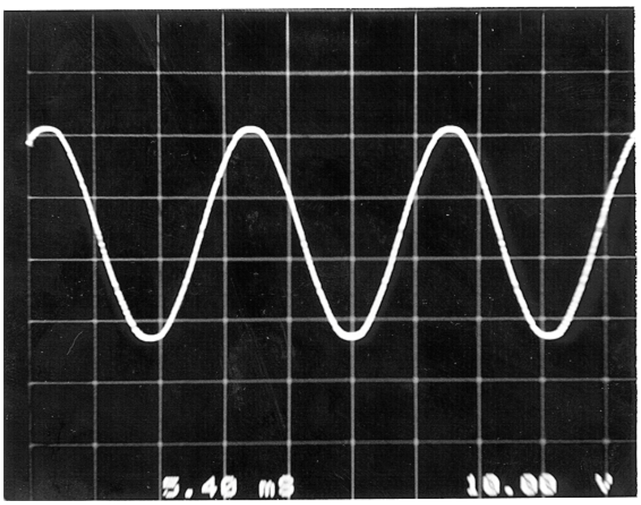
PICTURE #5

CHEQUE ENCODING MACHINE

"FED WITH (MECHANICAL FEED) RAW UTILITY POWER"

120 VOLT VOLTAGE WAVEFORM



Horizontal Scale:

TIME: 5.4 Milliseconds/division

Vertical Scale: VOLTAGE

TRUE R.M.S. VOLTAGE:

120 VOLTS

NOTE: ABSENSE OF U.P.S. SCR SYMMETRICAL FIRING TRANSIENT

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With the cost being nominal, it was decided on a "trial basis" to change the main 600 Volt transformer / receptacle feed from the feed common with the 600 Volt U.P.S. feed to the 600 Volt feed common with all the mechanical loads (chillers, pumps, fans, etc.). The mechanical power feed has traditionally been termed the "dirty feed". However, in comparison to the utility U.P.S. feed at this site, it was relatively clean (Refer to above Pictures #4 and #5). All receptacle power in this building has now been converted over to this mechanical electrical feed as the final solution. The cheque encoding machines have been connected to this feed for approximately 5 years now without experiencing any further problems.

In 20/20 hindsight, could this problem have been averted at the design stage? The answer is a resounding "yes". However, when originally specifying the U.P.S. and filter system for this site was there any justification to increase the standard U.P.S. input filter requirements for any harmonically sensitive non-U.P.S. electronic loads that might be connected to this system? This is a very difficult question to answer. If these loads had been identified as "sensitive to harmonic interaction" to the system designer, either by the customer or by the cheque encoding machine manufacturer then suitable design precautions / harmonic modelling etc. could have been used to avoid this situation.

Just in the last 2 months, we have noticed the exact same failure mechanism occurring within high speed data switch power supplies for the communication industry. The manufacturers of both the cheque encoding machines and the data power supplies did not appear to be aware of this type of electrical system interaction occurring with their equipment. We suspect, for competitive market reasons, the equipment suppliers, if they knew about the problem, they would generally not volunteer this type of "negative type" information on their product to the electrical system designers.

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In today's ever evolving complex harmonic electrical environment, it requires very careful design practice and analysis to examine all the "what if" scenarios. Any identified associated increase in harmonic design costs (ie. a higher grade U.P.S. filtering system) would have to be first justified by the system designer and then authorized by their clients, prior to casting the final electrical design in stone.

PROBLEM 2:
U.P.S. MOLDED CASE INPUT BREAKER TRIPPING DURING HIGH SPEED TRANSFERS

Over the last 2 to 3 years at this same site, during utility to "hot" diesel transfer switch U.P.S. testing, U.P.S. input breakers have tripped. ("Hot" diesel tests - means the diesel is already up to speed and ready to transfer prior to the beginning of testing sequence.) The majority of the U.P.S. breaker trips have occurred on U.P.S. module #2. Various components within this U.P.S. module #2 have been replaced or substituted from other U.P.S. modules, but this intermittent breaker tripping problem primarily still remains with module #2. On a true power outage, where the diesel has a 10 to 15 second delay start-up to supply power to the U.P.S. modules, no input breaker trips have ever been recorded at this site. The breakers only intermittently trip, during the once a month "hot diesel" transfer switch testing. An investigation was undertaken by Power Line Systems Engineering Inc. to more clearly understand the electrical mechanisms at work.

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TABLE 1
U.P.S. PHASE CURRENT
TOTLAL HARMONIC DISTORTION LEVELS (T.H.D.)

U.P.S. ELECTRICAL FEED STATUS	U.P.S. LOADING CONDITIONS NO LOAD	U.P.S. LOADING CONDITIONS 100 KW LOAD	U.P.S. LOADING CONDITIONS 400 KW LOAD
On Utility (Filter Disconnected)	46%	19%	11%
On Utility (Filter Connected)	8%	5%	2%
On Diesel (Filter Disconnected)	72%	17%	11%
On Diesel (Filter Connected)	24%	14%	3%

This facility had an auxilliary air cooled resistor load bank that could be used in a U.P.S. "off-line" mode to examine different U.P.S. load current T.H.D. levels. Table 1 itemizes the results. As expected, the U.P.S. input filter reduces the current T.H.D. and is more effective with a "hard" utility source compared to a "soft" (low short-circuit current capability) diesel source.

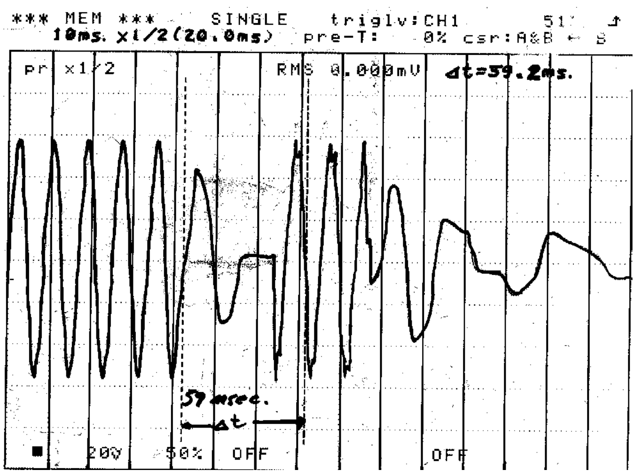
The in-phase monitor on the transfer switch was checked next. Ten transfers were performed. Each transfer occurred within the specified manufacturer’s design specification limits. The "electrical dead time" on the transfer switch was approximately 35 to 50 milliseconds.

PICTURE #6

U.P.S. INPUT VOLTAGE WAVEFORM DURING TRANSFER

LOAD SIDE OF BREAKER

U.P.S. INPUT FILTER CONNECTED



Horizontal Scale:

TIME - 20 MILLISECONDS/DIVISION

Vertical Scale: 600 VOLT NOMINAL

SINUSOIDAL VOLTAGE WAVEFORM

TRUE R.M.S. CURRENT: 1.7 AMPS

NOTE: Breaker tripped within 3 power cycles after transfer

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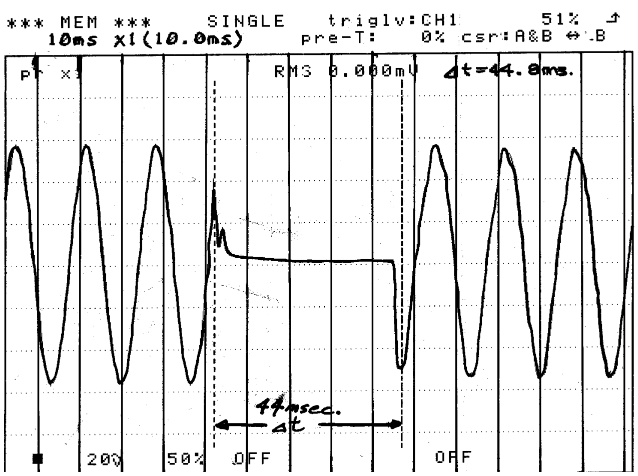
PICTURE #7

U.P.S. INPUT VOLTAGE WAVEFORM DURING TRANSFER

LOAD SIDE OF BREAKER

U.P.S. INPUT FILTER DISCONNECTED



Horizontal Scale:

TIME - 10 MILLISECONDS/DIVISION

Vertical Scale:

600 VOLT NOMINAL SINUSOIDAL VOLTAGE WAVEFORM

According to the operators at this site, the input breaker for module #2 had been exchanged with other module breakers and even a new breaker had been installed in module #2. Module #2's input breaker consistently would trip, sometimes with a magnetic core snapping sound radiating from the U.P.S. during transfer. Other modules would also trip in a similar mode, but less frequently.

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The manufacturers of the transfer switch, U.P.S. system and electrical breaker system were all contacted by the client in a desperate attempt to find a quick fix. Reliability of this U.P.S. system and the entire data centre had now been put in serious jeopardy.

A high speed voltage chart recorder was next installed on the load side of this breaker. It was observed that the voltage present on the U.P.S. input breaker during this 35 to 50 millisecond transfer "dead time" appeared to be a slowly decaying voltage waveform (Refer to Picture 6). NOTE: The input breaker tripped after transfer by approximately 3 power cycles.

With the U.P.S. input filter capacitive components disconnected, during the transfer "dead time" (Refer to Picture #7), the decay voltage appearing on this input breaker was now practically zero volts. A small voltage sag also occurred when transferring to the diesel system. These results tend to support a hypothesis that the residual filter capacitive charge is inherently biasing the iron core material within the U.P.S. Upon re-energization, large harmonic inrush currents from the diesel power are travelling through this biased core material and causing the U.P.S. input breaker to quickly trip. The inductance in the length of cable to this particular U.P.S. module and filter components have uniquely combined to intermittently draw (dependant on the transfer point on the voltage waveforms) excessive inrush current and trip this input breaker.

To test this hypothesis, it was decided to remove all input filtering from the six (6) U.P.S. systems and test various combinations of loading conditions and transfer voltage source scenarios during transfer. Over 100 transfers were performed on all these U.P.S. module systems. The results are quite simple. There was no longer any magnetic core snapping sounds during transfers and not one U.P.S. input breaker tripped.

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Having identified the failure mechanism, the customer now had several neutralizing options:

1. Disconnect this input filter, to prevent the U.P.S. intermittent input breaker trips. (NOTE: Refer to Table 1 for the resulting increases in phase current T.H.D. levels within this facility.)

2. Install a timer circuit or transfer switch control signal to momentarily disable the filter circuit during re-energization.

3. Eliminate "hot" diesel transfer switch testing on these U.P.S. systems.

The customer acknowledged the fact that during a true utility power outage, the critical load would be supported by the U.P.S. and battery system for approximately 10 to 15 seconds. After this period, the diesel would be up to speed and would automatically transfer, to electrically support the U.P.S. The 10 to 15 seconds is long enough to drain the residual charge from the harmonic filter system and corresponding U.P.S. input sections. It is now recognized, the 30 to 50 milliseconds (transfer switch "dead time") is too short a time to drain this harmonic filter capacitive charge. Therefore, to increase the reliability of this U.P.S. system and keep it as uncomplicated as possible, the customer has elected to keep the filters installed and eliminate the monthly "hot" diesel transfer switch testing from their testing reliability program on these six (6) U.P.S. systems. NOTE: Approximately 1 year later, the U.P.S. manufacturer now acknowledged the fact that the U.P.S. input filter can cause breaker trips during transfer. Other U.P.S. sites apparently now must have reported the same problem.

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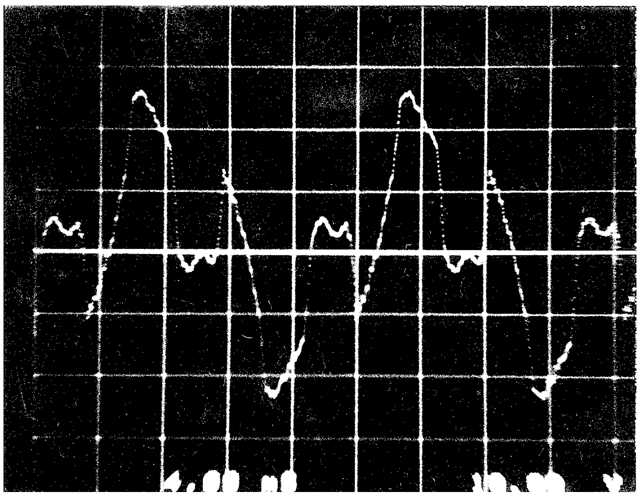
PICTURE #8

MAGNETIC FIELD WAVEFORM



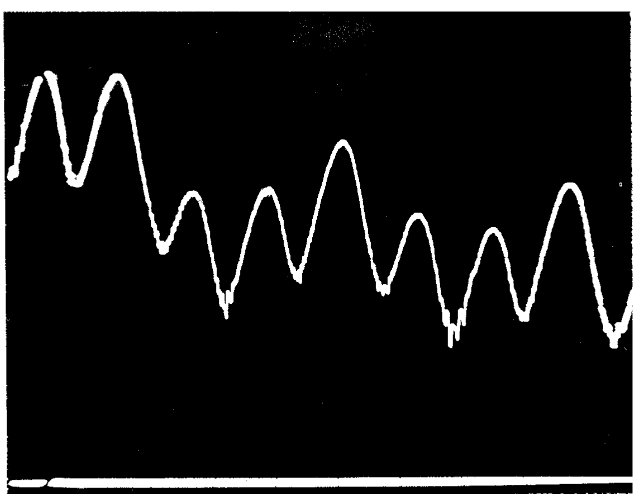
Horizontal Scale:TIME - 4 MILLISECONDS/DIVISION

Vertical Scale:
MAGNETIC FIELD -
35 MILLIGAUSS TRUE R.M.S.

PICTURE #9

MAGNETIC FIELD

HARMONIC FREQUENCY SPECTRA



Horizontal Scale: 1000 HZ. SWEEP

Vertical Scale:
10 DB./DIVISION (TOP OF SCREEN 0 DB.)
35 MILLIGAUSS TRUE R.M.S.

PREDOMINANT HARMONICS

3RD Harmonic - almost equal to the fundamental

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PROBLEM 3: COMPUTER SCREEN TEXT WAVERING

At this same location, there were approximately 80 to 100 computer workstations set-up within one room. Approximately 40% to 50% of these computer screens displayed constant text wavering back and forth across the screen (NOTE: The operators could only use the screens for 20 to 30 minutes before eye fatigue set in, also numerous human data entry errors were also occurring, as a result.). Periodically, throughout the day, all 100% of the computer screens' text would simultaneously waver back and forth for a duration lasting 10 to 15 seconds. This text wavering was so severe at this time, the operators would be unable to read the screens. The computer monitor manufacturer stated the problem was due to the "bad electrical computer system grounding".

We were then asked by our client to come in and investigate the phenomenon more fully. Low frequency magnetic field readings indicated there was a 30 to 40 milligauss A.C. field present. Harmonic frequency spectra pictures revealed 3rd harmonic components present almost equal to the fundamental (Refer to Picture #8 and #9).

The periodic increases in all the computer screen text wavering related to an approximate 10 to 15 times increase in magnetic field, primarily the 60 Hz. component peaking at 590 milligauss. The magnetic field became stronger towards the ceiling area. Upon removing the ceiling tiles, it was discovered a main 13 KV. high voltage cable system was visible and went directly through this area to the nearby electrical room.

We were not convinced we had found the culprit. The harmonic frequency spectra had revealed relatively high levels of 3rd harmonic magnetic field components. This is not a typical magnetic field harmonic spectra generated by a high voltage cable! Generally, on a high voltage system, it has been our experience these frequency components are severely attenuated through the downstream step-down transformers. Upon reviewing as built drawings, it was discovered, a high current electrical feeder was in conduits within the poured ceiling concrete floor slab. These conduit runs were in the same vicinity as the computer screens with the constant screen text wavering. In addition to computer loads, part of the downstream electrical load on this feeder was the chiller system. Every 20 to 30 minutes, these chillers would cycle on and cause an increase in start-up inrush current, which corresponded to the higher magnetic fields measured in this computer room area. Various neutralizing options were then examined by the client at this point:

1. Magnetically shield the ceiling area.

2. Magnetically shield the computer monitors.

3. Change monitor screens to a less sensitive monitor type.

4. Relocate this data processing activity and re-assign this area as non-computer use only.

5. Relocate the offending power cable runs.

Entering into the client's decision making process, was also the underlying concern with respect to potential employee health concerns. The employees would be exposed to these magnetic fields continually throughout an 8 hour working day. Medical scientific research and government regulation standards at the present time are not clearcut or straightforward. With respect to any potential future employee class action lawsuits, our client chose a cost-effective prudent avoidance approach. In this particular situation, the low voltage power cable run was re-located outside the building away from any employee areas.

CONCLUSION

The initial premise for selecting a totally redundant data processing centre was to increase the overall system reliability and flexibility of this complete banking operation. Electrically compatible system designs play an integral part in this premise. As discussed, sensitive electrical and electronic component interactions can generate catastrophic consequences for key facilities. Detailed electrical system analysis / modelling and standard "boiler plate" type electrical specifications have to be relentlessly re-examined, monitored and modified, as we surge ahead into this new "high tech" millennium.

POWER LINE SYSTEMS ENGINEERING INC.
Patrick J. Lynch, P.Eng.
Principal

Phone: (905) 294-5468
Email: plynch@powerlinesystems.ca