Power Quality Audit

PowerLines Sample Site
Anytown, USA

Facility:	**PowerLines Sample Site**	Equipment:	**Generic CT Scanner** **Serial Number 12345**
	45 Springfield Blvd.	Location #:	
	Anytown, USA	District:	
Installation ISE:	**Steve Stephenson**	Survey Type:	☐ **Installation Survey**
Primary FSE:	**Beth Johnson**		☒ **Equipment Installed and Operating**
Project Manager:	**Carl Hibbert**		☐ **Other -**
Area Service Manager:	**Jacqui Arnold**	Power Protection:	**PCDU (Line Side Monitoring)**

Problem Description

Frequent system resets and lockups

Start Monitoring:	06/20/2002 6:13 PM	Stop Monitoring:	07/18/2002 6:13 PM
Current Monitored:	☒ **Yes** ☐ **No**	Equipment in Use:	☒ **Yes** ☐ **No** ☐ **Unknown**
RPM Programmed:	**Three Phase Wye**	RPM Monitor Period:	**4 Weeks**
RPM Meter S/N:		RPM Meter Set-up:	**Properly Connected and Programmed**
Received Data:	**31-Aug-02**	Report Generated:	**2-Sep-02**

Summary Power Quality Analysis

Low frequency power factor capacitor impulses are occurring, which cause large (~200 Amp) current to be drawn by the system. These currents may be drawn by the PCDU filters, the CT Scanner rectifier, or other loads within the CT Scanner. This type of event is a known cause of problems for some CT systems.

The PCDU is not designed to attenuate these events due to the extremely low frequency and low amplitude of the ringing impulses.

Check the time and date of these events and compare these to the system event logs or error logs. If there is a correlation, a UPS system or other type of double conversion power conditioning device would be the most appropriate solution.

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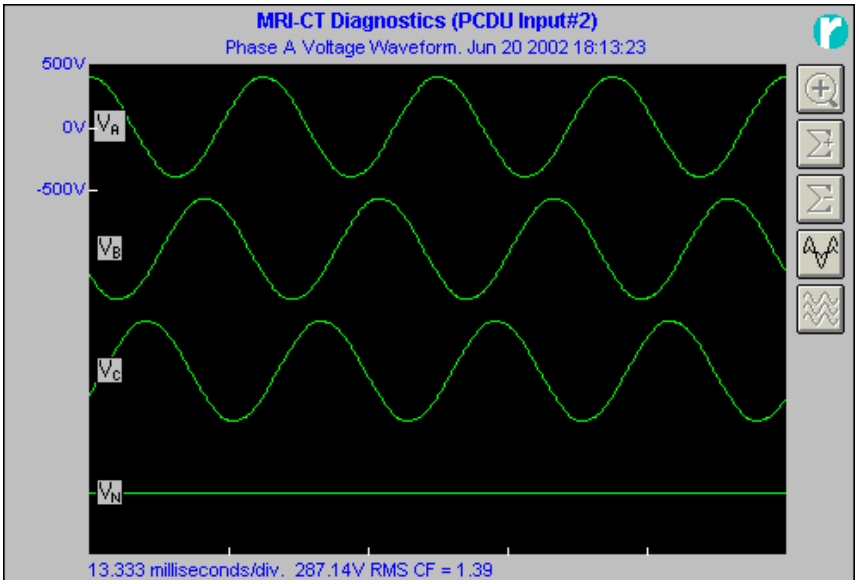
Category	Summary Analysis	Acceptable	Needs Follow-up	Problem	Not Applicable
Voltage Continuity	No Voltage Outages Recorded	☒	☐	☐	☐
RMS Voltage Level	RMS Voltage Level Acceptable	☒	☐	☐	☐
Voltage Waveforms	Voltage is Sinusoidal and Low THD	☒	☐	☐	☐
Sags and Swells	Minor Voltage Sags - Utility Sourced	☒	☐	☐	☐
Transient Voltages	PF Correction Capacitor Switching Transients	☐	☐	☒	☐
Mains Impedance	Mains Impedance Acceptable (RPM Calculation)	☒	☐	☐	☐
Voltage Balance	Voltages Balanced	☒	☐	☐	☐
Neutral-Ground Bonding	Neutral-Ground Appear to be Properly Bonded	☒	☐	☐	☐
Ground Current	Insufficient Data	☐	☐	☐	☒
Load Current	Moderate Equipment Use During Survey	☒	☐	☐	☐
Load Generated Disturbances (LGD)	No Load Generated Disturbances	☒	☐	☐	☐

Recommended Actions

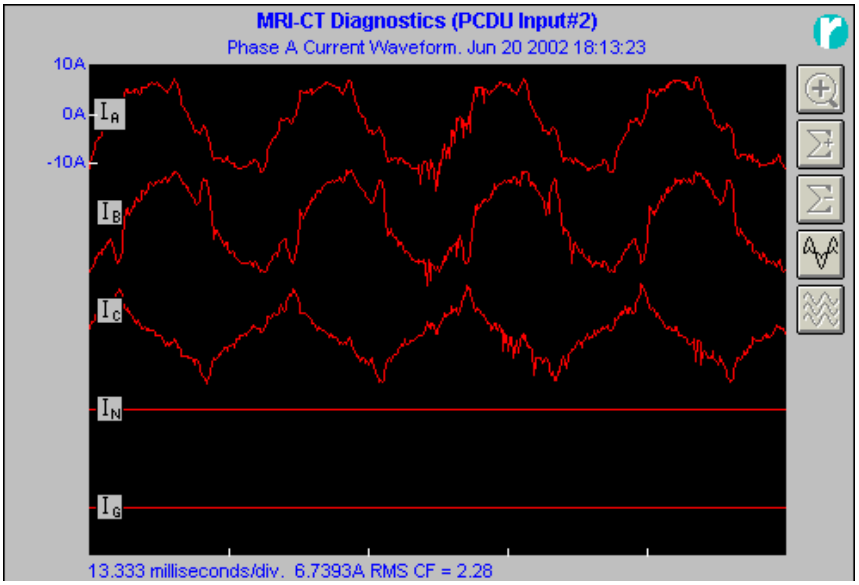
1. Compare the impulse log found on page 14 of this report to any recorded errors or events during the monitored period.
2. If there is a correlation, consult with the AC utility to determine if the capacitor switching transients can be reduced or eliminated. This would involve removing the capacitors, reprogramming the capacitor switching times, or purchasing special zero crossing switches that are designed to reduce switching transients.
3. If utility correction is not possible, a UPS or other type of Double Conversion power protection would be required.
4. See the attached applications note on Power Factor Capacitor switching transients for additional information about this type of event.
5. Consider retapping the PCDU for a slightly lower output voltage (if such a tap is available) since RMS voltage comes close to 8% above nominal.

RMS Voltage and Current Snapshots



Voltage Snapshot

Voltage waveforms were sinusoidal with no significant harmonics or voltage distortion.



Current Snapshot

Current waveforms were typical for a medical imaging system in stand-by condition. The Neutral and Ground current probes did not appear to be conencted, or the currrent level was too low to be recorded.

The RPM Power Analyzer is programmed to take a single "snapshot" of voltage and current waveforms at the start of the monitored period. To acquire the most useful data, the monitoring should be started with all current probes / test leads connected, with AC voltage applied, and with the equipment switched on in stand-by or normal operating modes.

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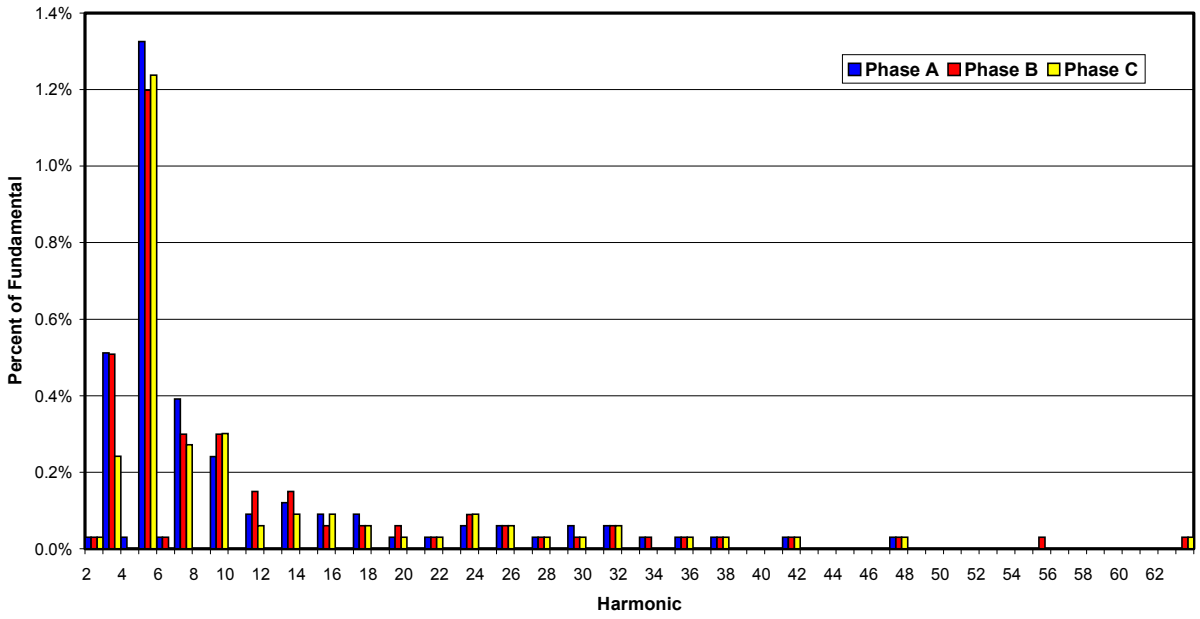
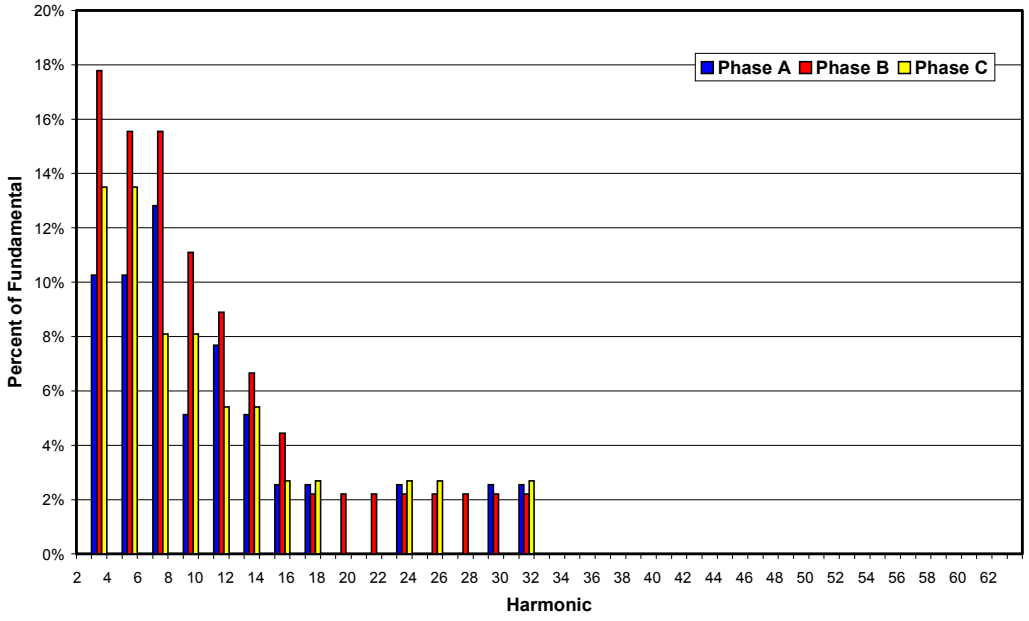
Voltage and Current Harmonics Summary

Average Voltage Harmonics



Average Current Harmonics



The RPM Power Analyzer collects harmonics data continuously during power analysis. The graphs above are a summary or average of harmonics seen during this power survey. These do not necessarily represent the voltage and current harmonics at any specific time, nor the worst case harmonics seen. High voltage harmonics may indicate an excessively distorted voltage waveform.

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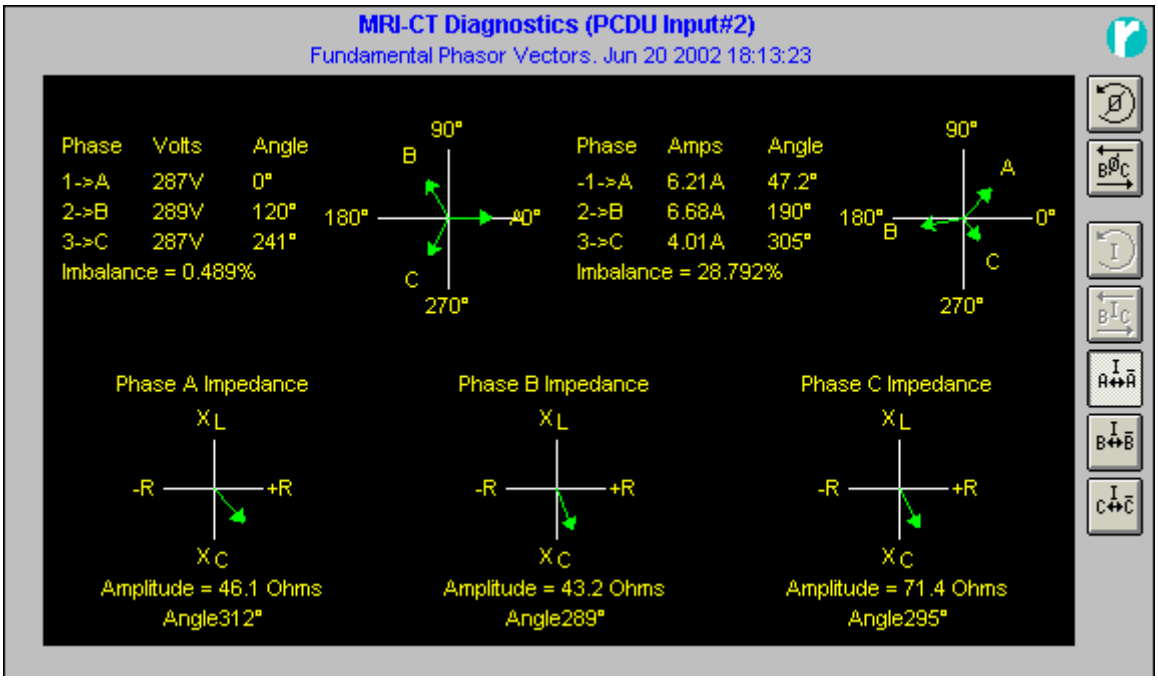


Phase rotation was correct, and phase balance and levels appearred to be normal. Current and Impedance phasors were normal for a medical imaging system in stand-by mode. The capacitive load is typical for the PCDU primary; the PCDU filter circuits dominate the load under stand-by conditions.

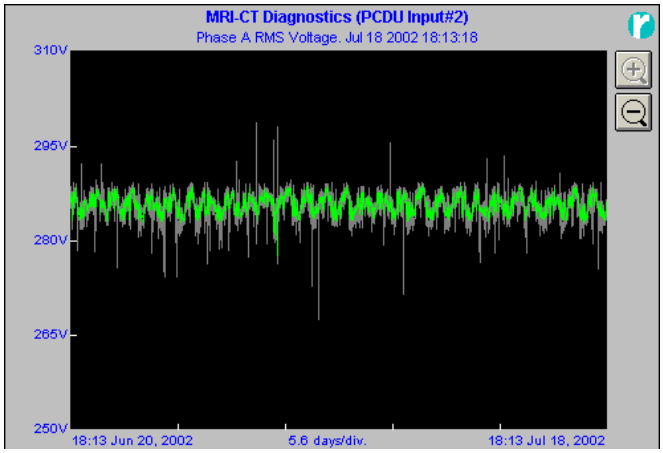
RMS Voltage, Current, and Frequency Levels

Start Date: 06/20/2002 6:13 PM **End Date:** 07/18/2002 6:13 PM

Nominal Voltage 277	Phase A - Neutral	Phase B - Neutral	Phase C - Neutral
Voltage			
Minimum	268.4 V rms	276.2 V rms	263.6 V rms
Percent of Nominal	*-3.10 %*	*-0.29 %*	*-4.84 %*
Average	286.5 V rms	288.0 V rms	285.9 V rms
Percent of Nominal	*3.43 %*	*3.97 %*	*3.21 %*
Maximum	299.4 V rms	297.3 V rms	299.4 V rms
Percent of Nominal	*8.09 %*	*7.33 %*	*8.09 %*
Frequency			
Minimum	59.92 Hz	59.92 Hz	59.92 Hz
Average	59.99 Hz	59.99 Hz	59.99 Hz
Maximum	60.07 Hz	60.07 Hz	60.07 Hz
Current	**Phase A**	**Phase B**	**Phase C**
Minimum	4.2 A rms	4.6 A rms	4.9 A rms
Average	5.4 A rms	6.3 A rms	6.8 A rms
Maximum	80.0 A rms	84.8 A rms	78.7 A rms

RMS Voltages were within System Requirements of +/-10% throughout the monitored period. RMS voltages were slightly high - if the system has a small adjustment tap (2.5%) then a lower tapped voltage would be recommended to better align the facility voltage with the system requirements. Frequency was stable, and current was normal for a lightly used medical imaging system.

RMS Voltage Log Graphs



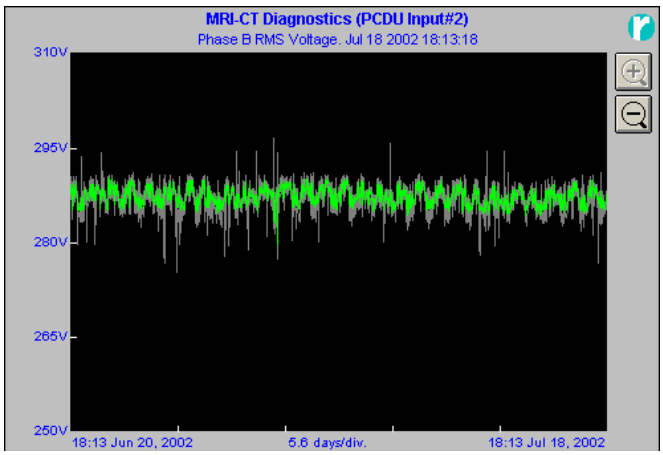
Phase: Phase A - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

RMS voltages were stable, with a small daily fluctuation, and occasional minor sags and swells, not outside of system requirements.



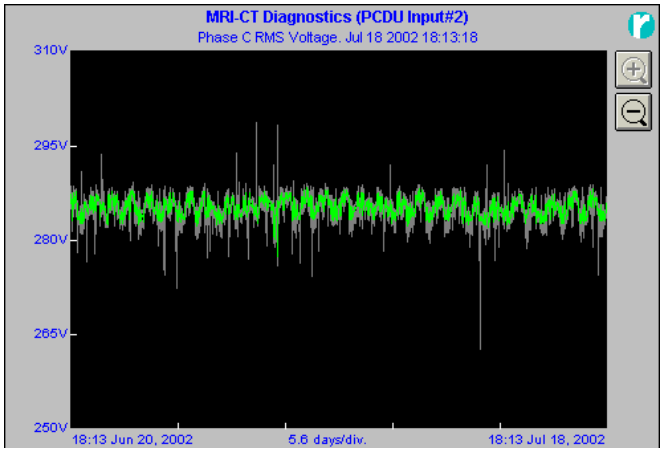
Phase: Phase B - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

RMS voltages were stable, with a small daily fluctuation, and occasional minor sags and swells, not outside of system requirements.



Phase: Phase C - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

RMS voltages were stable, with a small daily fluctuation, and occasional minor sags and swells, not outside of system requirements.

The RPM Power Analyzer records Minimum and Maximum RMS voltage deviations with a one cycle resolution.
High and Low voltage deviations as reported above may be a short as one cycle.
Significant deviations in RMS voltage will also be reported as voltage sags and swells.

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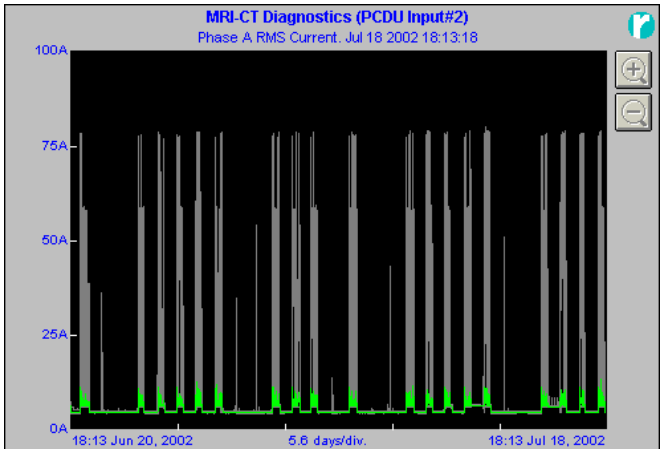
RMS Current Log Graphs



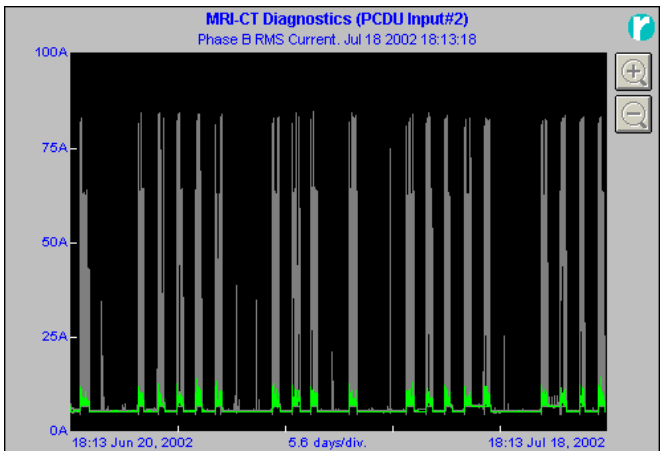
Phase: Phase A

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

RMS Current graphs show three specific operating conditions: system off (night), system ready to image (daytime, slightly higher) and system imaging (current surges or spikes).



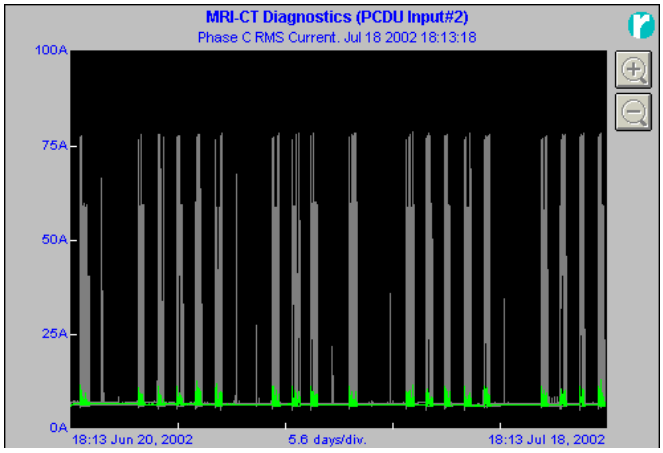
Phase: Phase B

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

RMS Current graphs show three specific operating conditions: system off (night), system ready to image (daytime, slightly higher) and system imaging (current surges or spikes).



Phase: Phase C

Start Date: 06/20/2002 6:13 PM

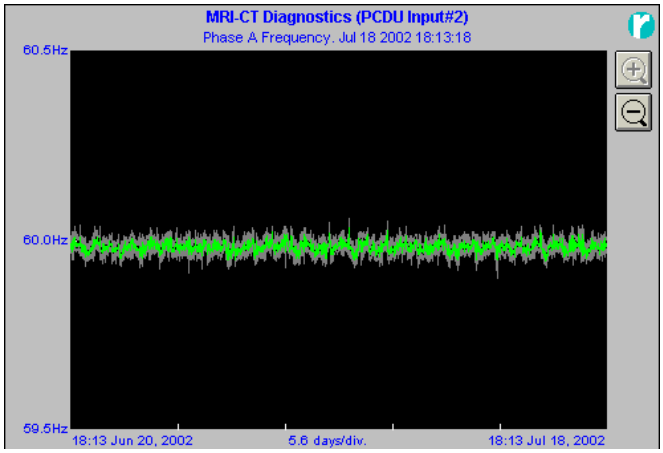
End Date: 07/18/2002 6:13 PM

Analysis

Phase C current was not measured - the Phase C current channel was used to monitor the system ground current.

The RPM Power Analyzer records Minimum and Maximum RMS current deviations with a one cycle resolution.
High current deviations as reported above may be a short as one cycle, possibly due to equipment switch-on inrush.
Significant changes in current which affect the voltage level or waveshape will also be reported as Load Generated Disturbances.

Frequency Log Graphs



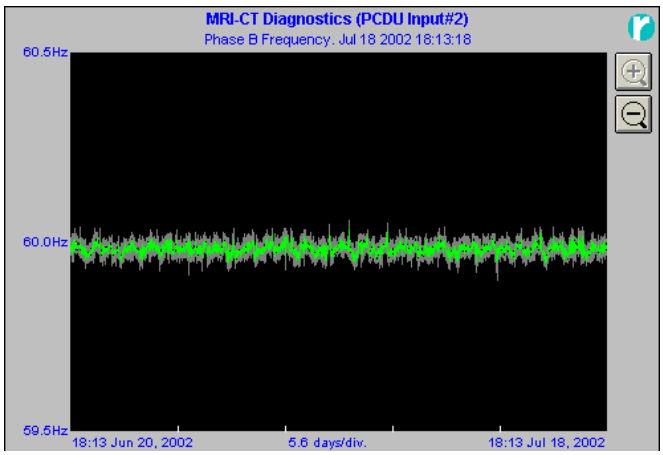
Phase: Phase A - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Frequency was stable throughout the monitored period. (Typical for North American facilities and electrical systems)



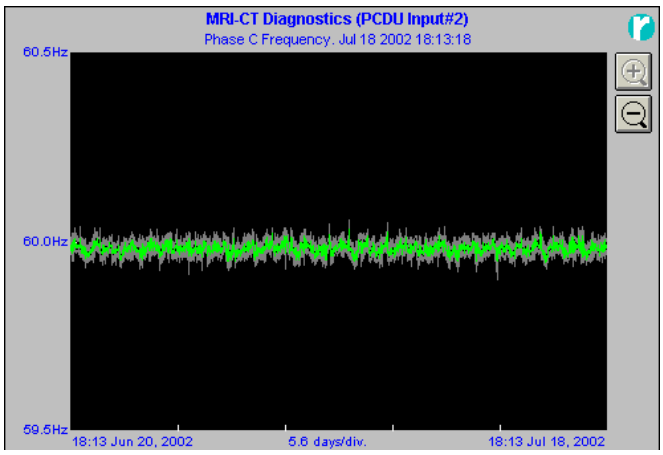
Phase: Phase B - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Frequency was stable throughout the monitored period. (Typical for North American facilities and electrical systems)



Phase: Phase C - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Frequency was stable throughout the monitored period. (Typical for North American facilities and electrical systems)

The RPM Power Analyzer records frequency continuously. In the United States, frequency deviations from 60.0 Hz are very rare. In the hospital environment, small frequency changes are often seen on the output of free-running emergency generators or UPS systems, not synchronized to the Utility. Larger frequency deviations are often the result of voltage outages or transients.

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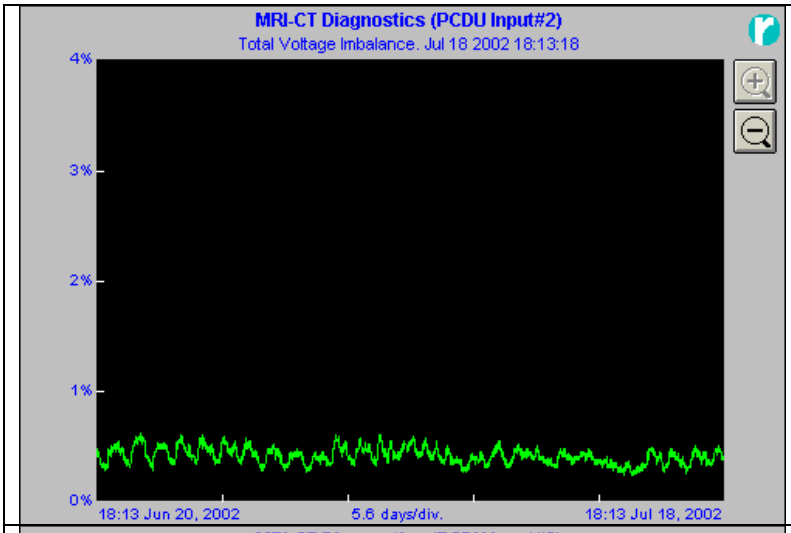
Voltage and Current Balance Log Graphs



Voltage Balance

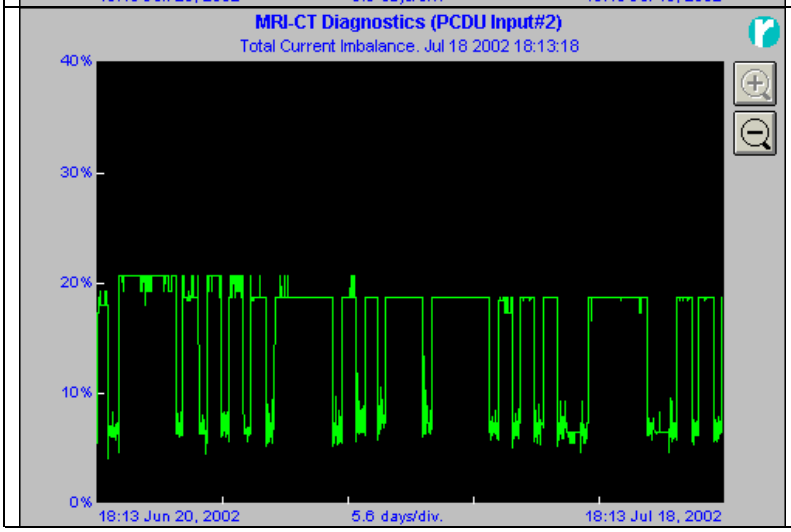
Maximum: 0.63 %

Minimum: 0.24 %

Typical: **0.42 %**

Analysis

Phase voltages were balanced throughout the monitored period.



Current Balance

Maximum: 20.65 %

Minimum: 4.14 %

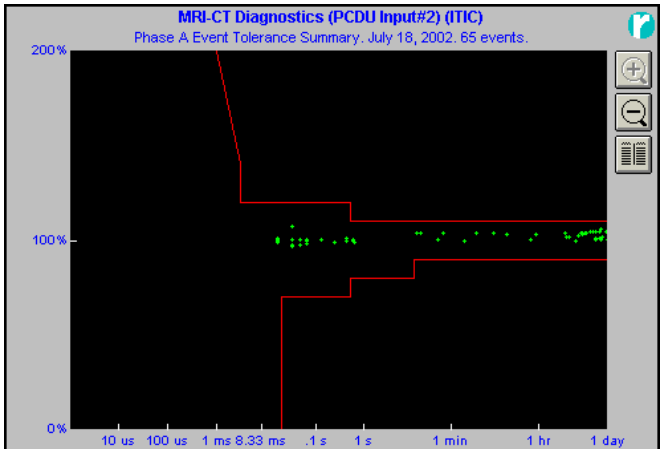
Typical: **15.39 %**

Analysis

Current was balanced when the imaging system was in use (acquiring images, drawing current). During stanby conditions (extremely low load) the current was less balanced. This is normal for this type of medical imaging system.

Voltage Balance is the percentage difference between the RMS voltage of the highest phase and the lowest phase, divided by the average of all phases. Voltage Balance problems can be caused at the Utility level, or within the facility due to unbalanced loading. Current Balance often fluctuates widely, especially in intermittent loads such as medical imaging systems.

Voltage Disturbances: Magnitude vs. Duration Curve



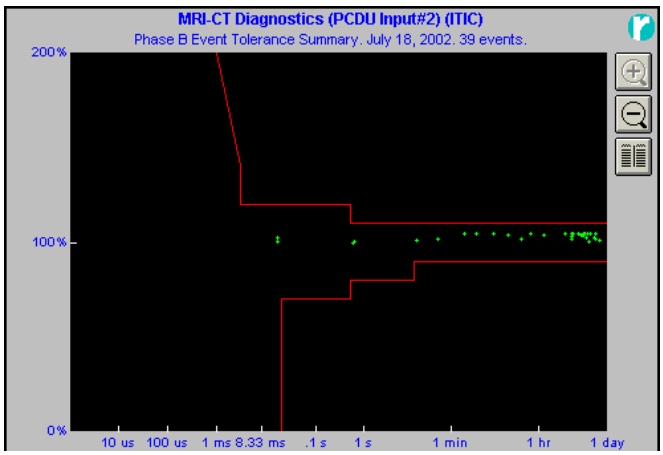
Phase: Phase A - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Voltage Disturbances plotted against typical system requirements (ITIC Curve). All disturbances were within this envelope. However, the RPM Power Analyzer does not always plot some disturbances properly; these may still exceed system requirements.



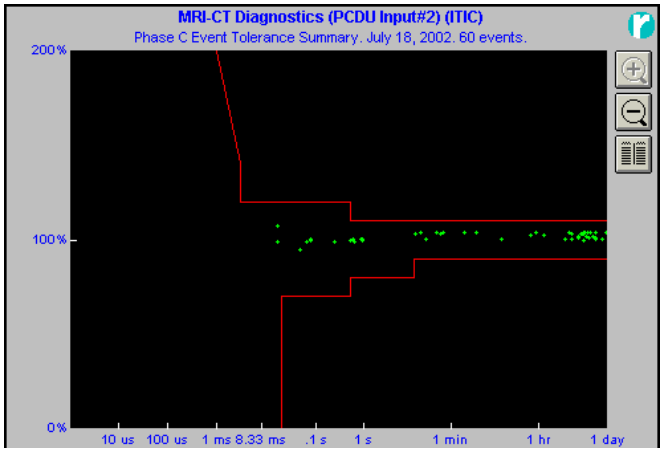
Phase: Phase B - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Voltage Disturbances plotted against typical system requirements (ITIC Curve). All disturbances were within this envelope. However, the RPM Power Analyzer does not always plot some disturbances properly; these may still exceed system requirements.



Phase: Phase C - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Voltage Disturbances plotted against typical system requirements (ITIC Curve). All disturbances were within this envelope. However, the RPM Power Analyzer does not always plot some disturbances properly; these may still exceed system requirements.

Voltage disturbances are plotted by Magnitude (Vertical) and Duration (Horizontal). Disturbances within the Red Lines above are generally less serious; those outside of the red lines are more likely to cause system problems.
Disturbances to the left are higher frequency / shorter (transients, short sags) and those to the right are longer.

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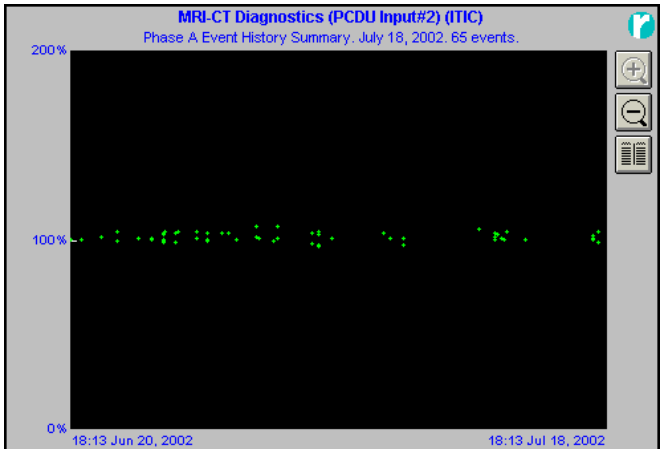
Voltage Disturbances: Magnitude vs. Time



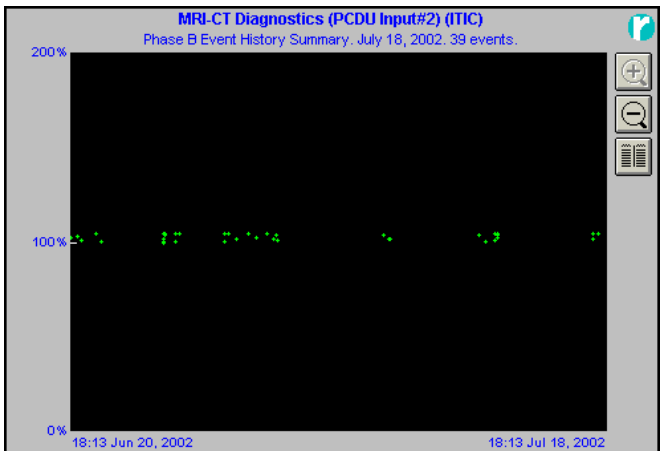
Phase: Phase A - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Voltage Disturbances plotted versus the Time of Occurrence. Disturbances were evenly distributed over the course of the monitored period.



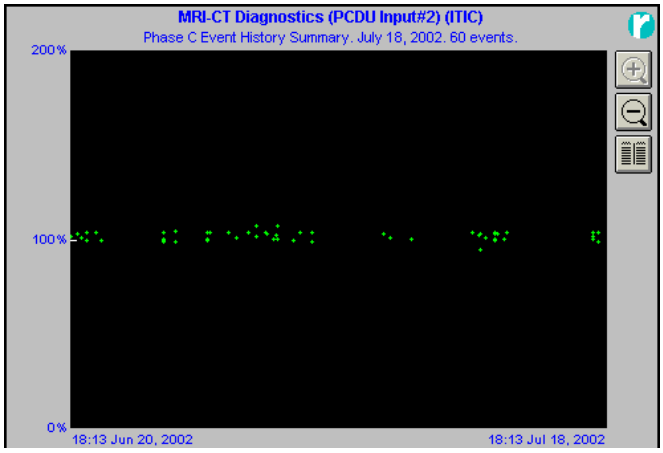
Phase: Phase B - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Voltage Disturbances plotted versus the Time of Occurrence. Disturbances were evenly distributed over the course of the monitored period.



Phase: Phase C - Neutral

Start Date: 06/20/2002 6:13 PM

End Date: 07/18/2002 6:13 PM

Analysis

Voltage Disturbances plotted versus the Time of Occurrence. Disturbances were evenly distributed over the course of the monitored period.

Voltage disturbances are plotted by Magnitude (Vertical) and Time of Occurrence (Horizontal). Look for disturbance trends such as time of day, during working hours, or during times when the equipment being monitored is use.

Voltage Outage Events

0 Voltage Outages were recorded during the surveyed period.

Although no voltage outages were recorded, such findings over a relatively short power audit are not conclusive indications of long term facility or utility continuity of service. Protection for computers, consoles, and control systems such as an Uninterruptible Power System (UPS) may be warranted to ensure continuity of service and minimum loss of use during actual Utility outages.

Voltage Sags and Swells

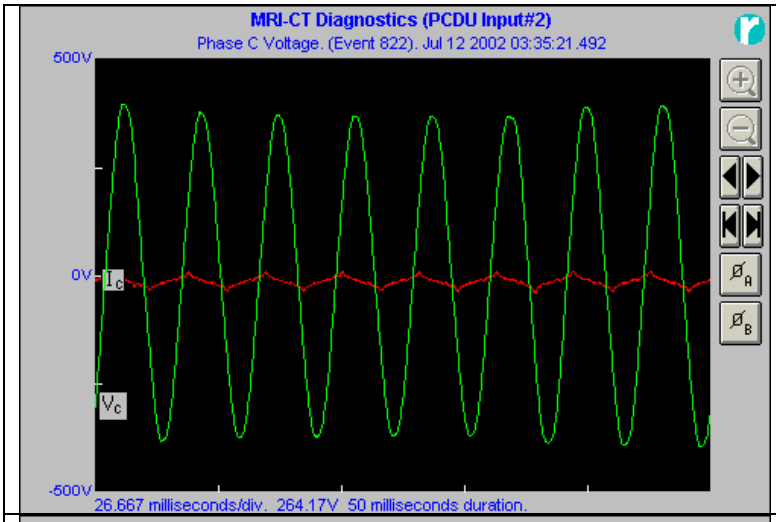
3 Voltage Sags / Swells were recorded during the surveyed period.

All of these voltage sags were less than 5% below nominal - well within the system requirements. They are listed here and detailed for information and interest.

Load generated voltage sags and swells (if any) are included in a separate section of this report.

Number	Type	Amplitude	Duration	Date and Time
822	26	264.176	0.05	Jul 12 2002 03:35:21.492
790	30	268.449	0.017	Jul 03 2002 17:40:18.548
780	26	269.67	0.033	Jul 03 2002 17:40:18.547

Individual Voltage Sags and Swells



Event Number: 822

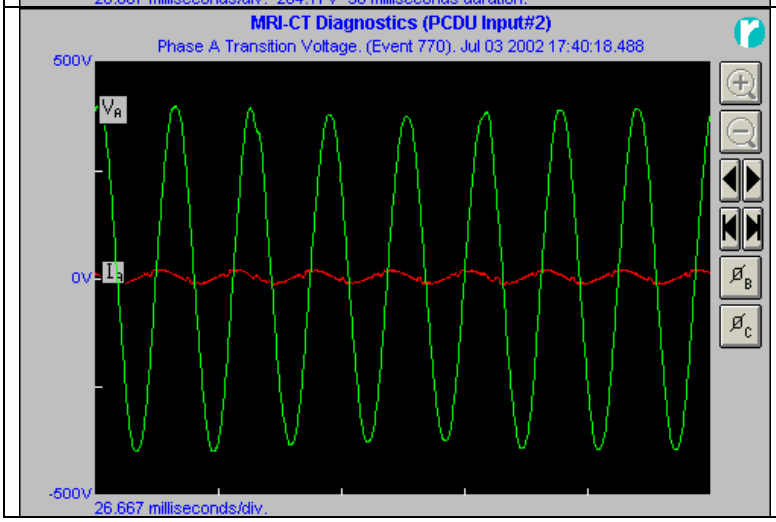
Date: 12-Jul-02

Time: 3:35:00 AM

Duration: 4 cycles

Analysis

A very minor voltage sag, not outside of equipment specifications, and not causing any change in system load current.



Event Number: 770

Date: 3-Jul-02

Time: 5:40:18 PM

Duration: 3 cycles

Analysis

A very minor voltage sag, not outside of equipment specifications, and not causing any change in system load current.

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Voltage Transients and Impulses

32 Voltage Transients and Impulses were recorded during the surveyed period.

The RPM power analyzer captured 32 low frequency transient events, listed here. Unfortunately, the RPM summary software is not able to identify, classify, or highlight these events as voltage transients. Identification of these involves manually reviewing all event data and visually scanning all waveforms.

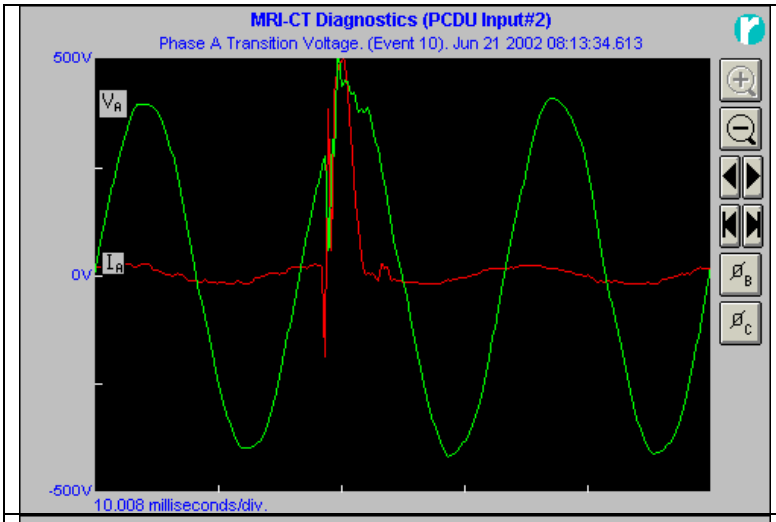
Each of these events is a low frequency impulse, probably related to utility switching of capacitor banks, used to correct low power factor. For a better understanding of these events, review the technical note appended to this report.

Compare this table (dates and times) to the equipment error or event logs - if there is correlation, these impulses are probably causing system problems. This type of event has been known to affect CT systems at other sites, if the transients are severe enough.

Load generated voltage transients and impulses (if any) are included in a separate section of this report.

Number	Type	Amplitude	Duration	Date and Time
10	30	287.127	0.017	Jun 21 2002 08:13:34.613
31	30	286.028	0.017	Jun 21 2002 08:13:34.615
32	30	284.685	0.017	Jun 21 2002 08:13:34.616
71	30	288.226	0.017	Jun 22 2002 10:03:20.232
30	30	286.272	0.017	Jun 22 2002 10:03:20.233
112	30	285.784	0.017	Jun 22 2002 10:03:20.238
70	30	283.953	0.017	Jun 24 2002 07:08:28.32
590	30	285.906	0.017	Jun 29 2002 10:08:14.579
371	30	287.615	0.017	Jun 29 2002 10:08:14.583
472	30	285.54	0.017	Jun 29 2002 10:08:14.583
610	26	299.457	0.033	Jun 30 2002 10:44:05.460
411	30	287.249	0.017	Jun 30 2002 10:44:05.519
512	26	299.457	0.017	Jun 30 2002 10:44:05.521
630	30	284.93	0.017	Jun 30 2002 14:22:49.307
650	30	286.639	0.017	Jul 01 2002 08:29:15.592
451	30	288.348	0.017	Jul 01 2002 08:29:15.594
572	30	285.784	0.017	Jul 01 2002 08:29:15.596
670	26	298.846	0.033	Jul 01 2002 14:19:57.827
491	30	287.249	0.017	Jul 01 2002 14:19:57.878
612	26	298.968	0.017	Jul 01 2002 14:19:57.884
632	30	284.441	0.017	Jul 02 2002 10:14:35.162
810	30	283.342	0.017	Jul 04 2002 10:35:27.128
732	30	285.662	0.017	Jul 07 2002 10:45:47.181
850	30	286.394	0.017	Jul 07 2002 10:45:47.185
531	30	287.859	0.017	Jul 07 2002 10:45:47.186
752	30	284.563	0.017	Jul 08 2002 14:48:11.398
571	30	288.226	0.017	Jul 12 2002 11:16:05.600
852	30	285.906	0.017	Jul 12 2002 11:16:05.601
691	30	287.981	0.017	Jul 13 2002 10:01:35.872
1010	30	287.127	0.017	Jul 13 2002 10:01:35.873
992	30	286.15	0.017	Jul 13 2002 10:01:35.878
1070	30	283.342	0.017	Jul 16 2002 07:07:18.888

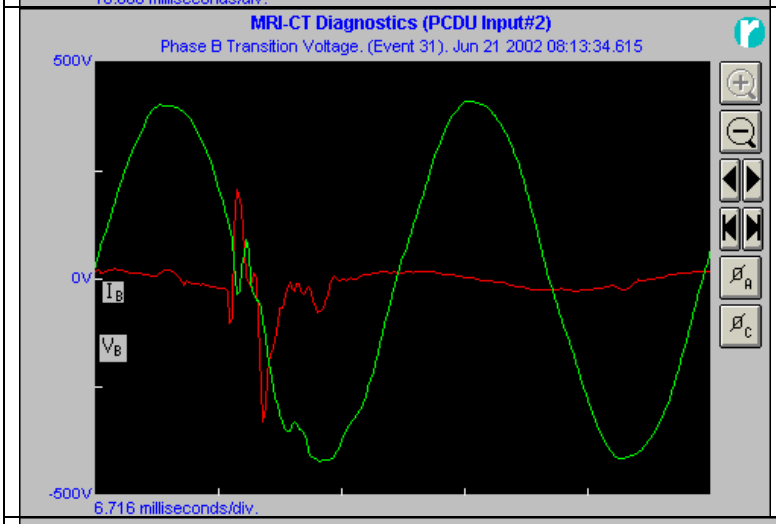
Individual Voltage Transients



Event Number: 10
Date: 21-Jun-02
Time: 8:13:34 AM
Duration: 1/4 cycle

Analysis

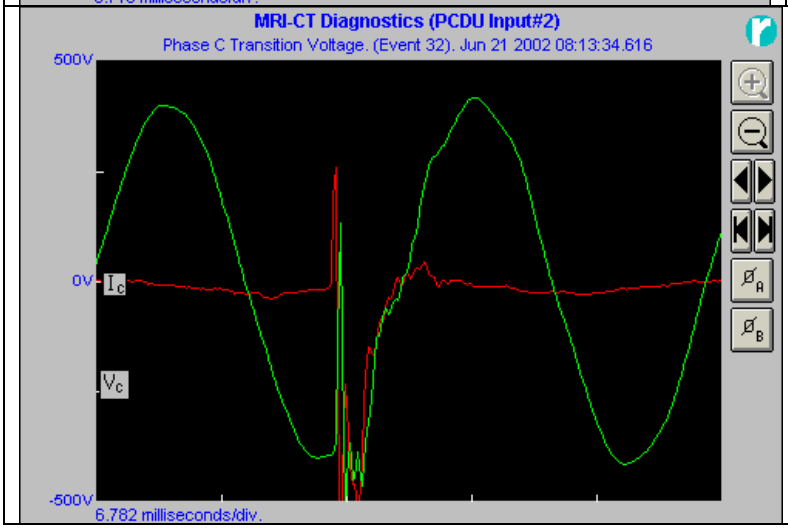
A low frequency impulse, at the voltage peak, causes a significant overvoltage condition. The medical imaging load drawns a large current surge as a result (scale = +/-200 Amps).



Event Number: 31
Date: 21-Jun-02
Time: 8:13:34 AM
Duration: 1/4 cycle

Analysis

A low frequency impulse, near the zero-crossing of voltage, may disrupt control systems and power conversion circuits that are triggerred off the AC frequency or voltage zero-crossing.

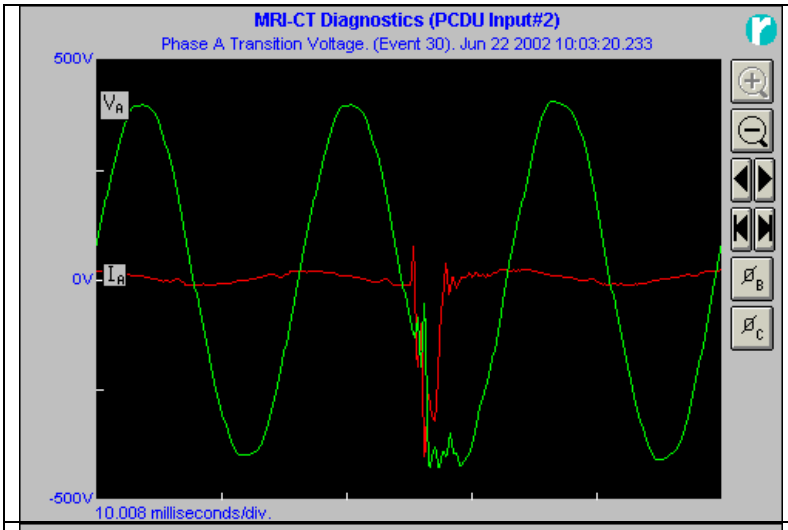


Event Number: 32
Date: 21-Jun-02
Time: 8:13:34 AM
Duration: 1/4 cycle

Analysis

A low frequency impulse, at the voltage peak, causes a significant overvoltage condition. The medical imaging load drawns a large current surge as a result (scale = +/-200 Amps).

Individual Voltage Transients (continued)



Event Number: 30

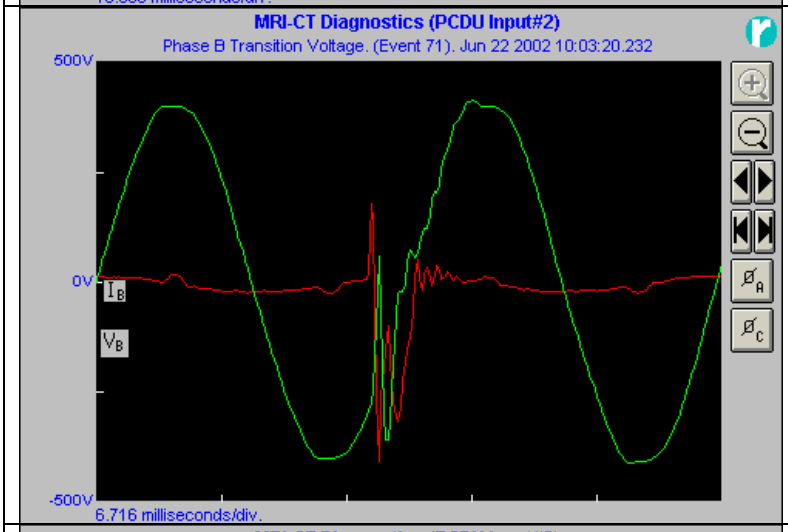
Date: 22-Jun-02

Time: 10:03:20 AM

Duration: 1/4 cycle

Analysis

A low frequency impulse, at the voltage peak, causes a significant overvoltage condition. The medical imaging load drawns a large current surge as a result (scale = +/-200 Amps).



Event Number: 71

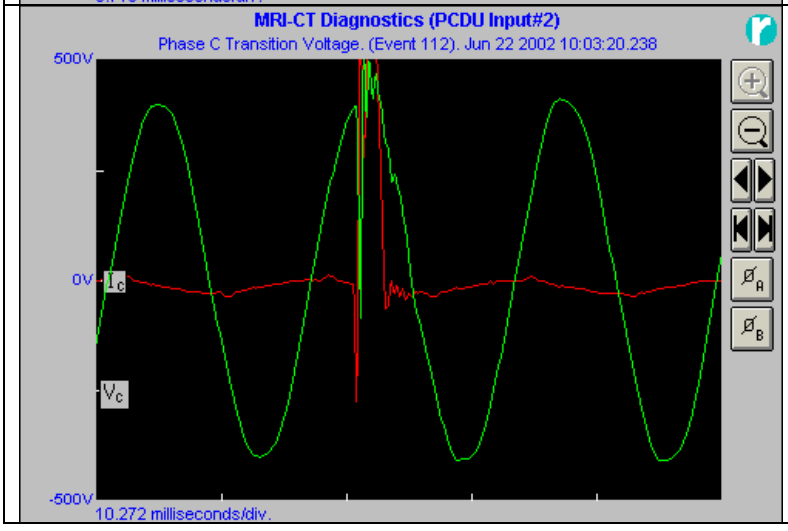
Date: 22-Jun-02

Time: 10:03:20 AM

Duration: 1/4 cycle

Analysis

A low frequency impulse, near the zero-crossing of voltage, may disrupt control systems and power conversion circuits that are triggerred off the AC frequency or voltage zero-crossing.



Event Number: 112

Date: 22-Jun-02

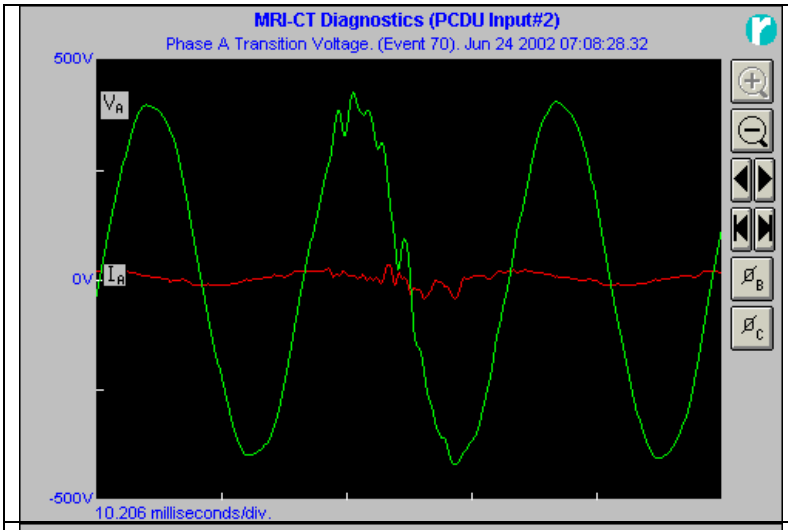
Time: 10:03:20 AM

Duration: 1/4 cycle

Analysis

A low frequency impulse, at the voltage peak, causes a significant overvoltage condition. The medical imaging load drawns a large current surge as a result (scale = +/-200 Amps).

Individual Voltage Transients (continued)



Event Number: 70

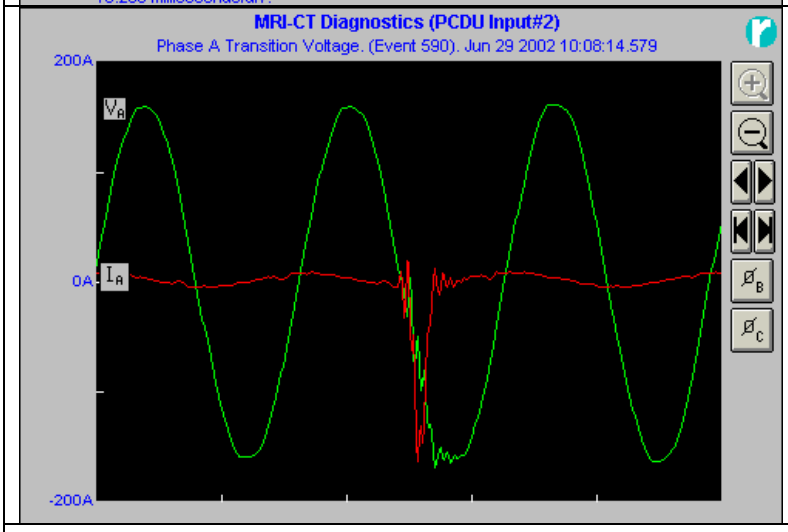
Date: 24-Jun-02

Time: 7:08:28 AM

Duration: 1/4 cycle

Analysis

A low frequency impulse, which does not appear to cause equipment disruption or a significant flow of current.



Event Number: 590

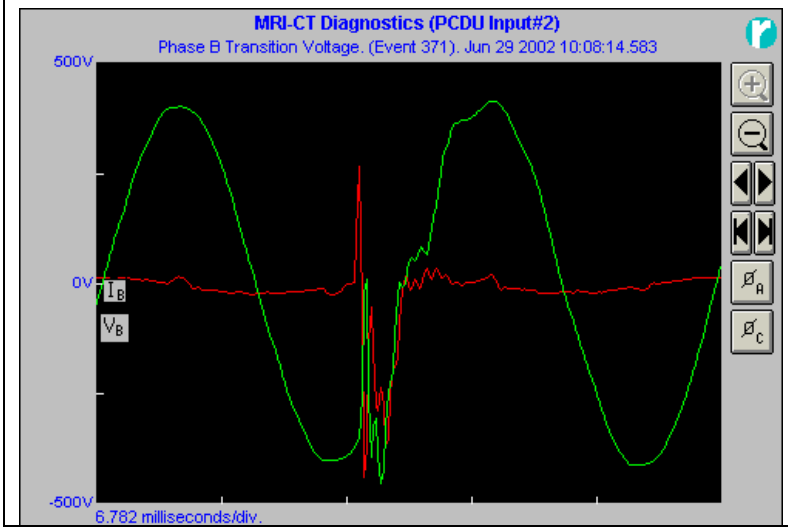
Date: 29-Jun-02

Time: 10:08:14 AM

Duration: 1/4 cycle

Analysis

A low frequency impulse, at the voltage peak, causes a significant overvoltage condition. The medical imaging load drawns a large current surge as a result (scale = +/-200 Amps).



Event Number: 371

Date: 29-Jun-02

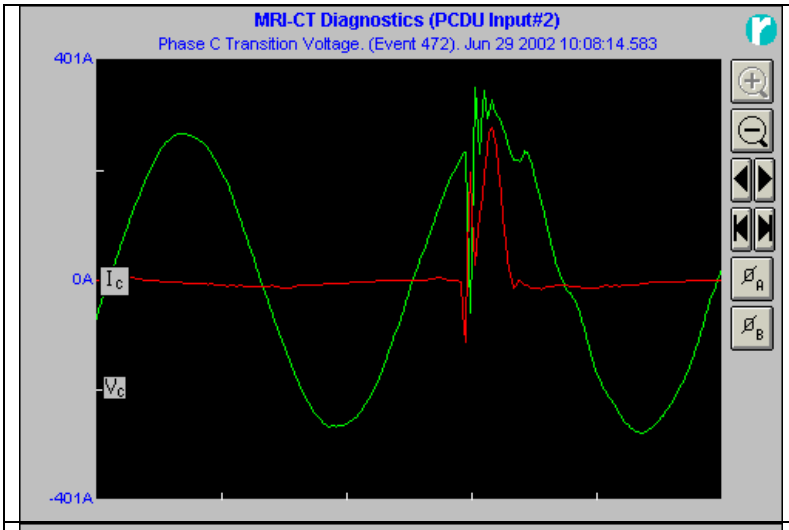
Time: 10:08:14 AM

Duration: 1/4 cycle

Analysis

A low frequency impulse, at the voltage peak, causes a significant overvoltage condition. The medical imaging load drawns a large current surge as a result (scale = +/-200 Amps).

Individual Voltage Transients (continued)



Event Number: 472

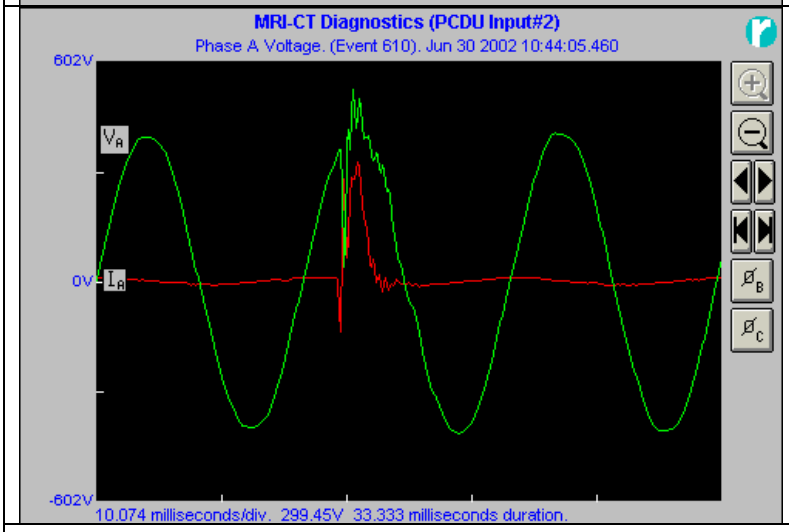
Date: 29-Jun-02

Time: 10:08:14 AM

Duration: 1/4 cycle

Analysis

A low frequency impulse, at the voltage peak, causes a significant overvoltage condition. The medical imaging load drawns a large current surge as a result (scale = +/-400 Amps).



Event Number: 610

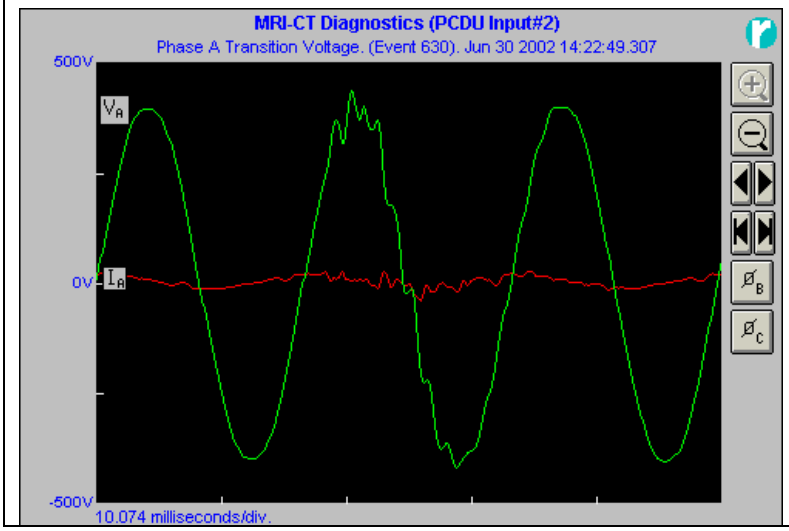
Date: 30-Jun-02

Time: 10:44:05 AM

Duration: 1/4 cycle

Analysis

A low frequency impulse, at the voltage peak, causes a significant overvoltage condition. The medical imaging load drawns a large current surge as a result.



Event Number: 630

Date: 30-Jun-02

Time: 2:22:49 PM

Duration: 1/4 cycle

Analysis

A low frequency impulse, which does not appear to cause equipment disruption or a significant flow of current.

Load Generated Events

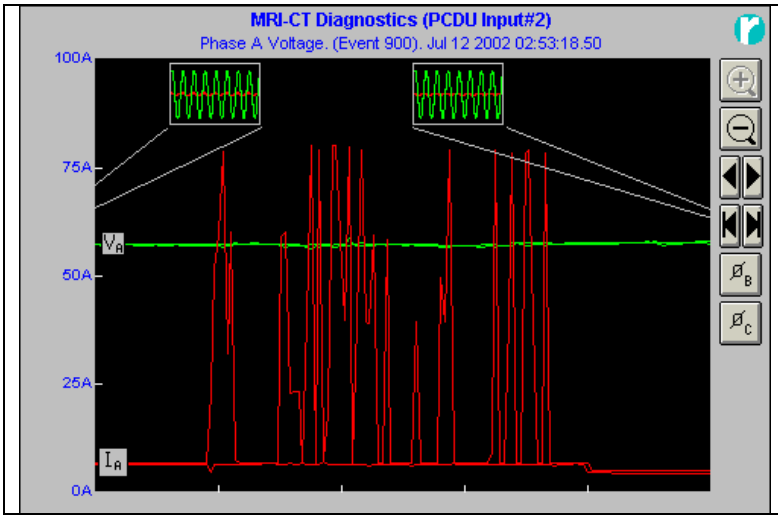
In many cases, the source impedance of the facility electrical system, or the output impedance of a transformer, power conditioner, or UPS system will contribute to voltage disturbances when the medical imaging load draws current. The voltage events can be sags, swells, or transients (impulses). The current changes that cause these may be normal equipment operating currents, switch-on inrush currents, or unexpected fault currents. This type of disturbance is referred to as a ***Load Generated Disturbance***.

Load Generated Disturbances are not caused by the Electrical Utility, or by other loads in the facility. Instead, they are a product of the load current, acting upon the source impedance (resistance or inductance).

An excessive magnitude or number of Load Generated Disturbances can indicate that the electrical system or power source feeding this equipment is undersized, requires maintenance, or is misapplied to the medical imaging system.

No significant load generated disturbances were recorded. It appears that the source is fairly stiff, with low impedance, and is able to supply the instantaneous demand of the medical imaging load.

Individual Load Generated Disturbances



Event Number: 900

Date: 12-Jul-02

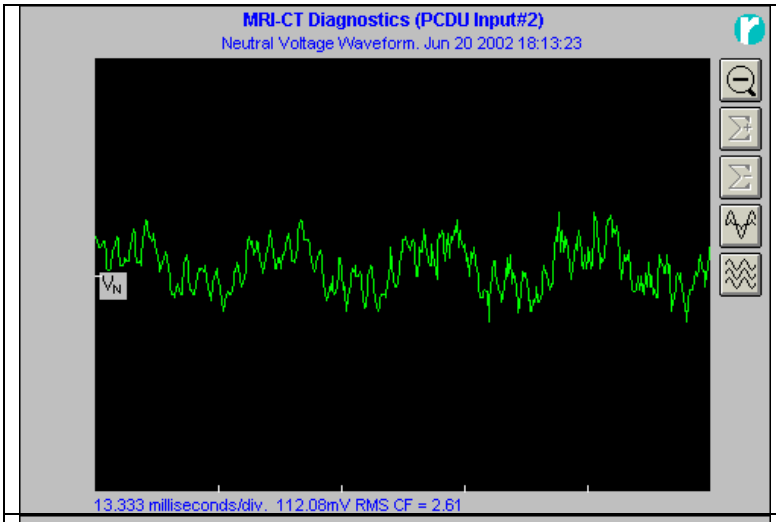
Time: 2:53:18 AM

Duration: 18 hours

Analysis

RMS voltage and current logs over the course of a typical work day. Despite large current surges due to CT Scanner imaging, the source voltage did not collapse or sag significantly.

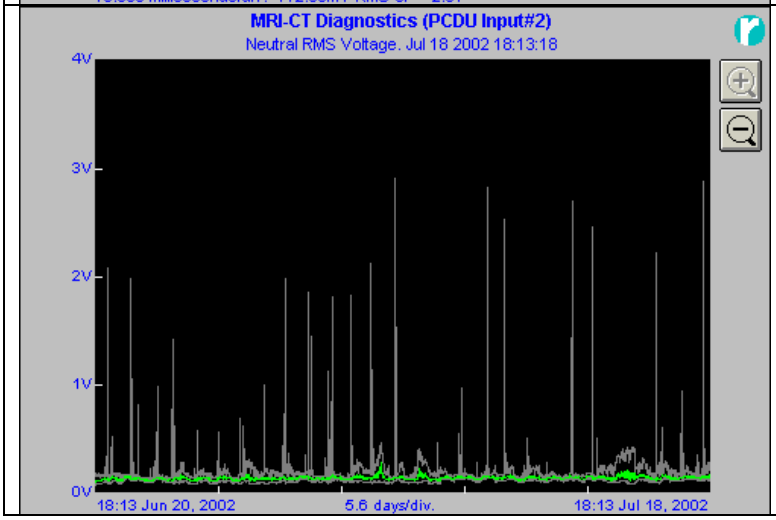
Neutral / Ground Voltage and Current Graphs



Neutral-Ground Voltage Waveform

Analysis

Neutral-Ground Voltage was low during stand-by conditions. Period voltage surges were recorded during the monitred period, probably related to the operation of other medical imaging loads. The Aquilion system, powered via the PCDU, does not require a neutral or a Wye connected system.



Neutral-Ground Voltage

Start Date:	06/20/2002 6:13 PM
End Date:	07/18/2002 6:13 PM
Maximum:	2.91 Volts rms
Minimum:	0.07 Volts rms
Typical:	0.14 Volts rms

Analysis

Neutral-Ground Voltage surges were recorded, probably related to the operation of other medical imaging loads. The steady-state or baseline voltage level was very low.