Single-Site Power Quality Summary Report

Date
May 1, 2001

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1. Single-Site Power Quality Summary Report - SITE1 - From 5/1/95 to 6/1/95

This power quality summary will focus on monitor availability, voltage regulation, harmonic distortion, voltage sags and interruptions, transient overvoltages, and most significant events for a single monitoring site.

Site Name: SITE1
Site Description: 13.2 kV, 25 MVA Substation
Date Range: From 5/1/95 to 6/1/95

1.1 Monitor Availability

Monitor availability is a measure of an instrument's availability each day to record power quality measurements. It is computed by searching for triggered measurements and steady-state sampled measurements on each day. On days when no measurements are found, the monitor is considered offline or otherwise unavailable. Instrument unavailability can be caused by communication problems, monitoring instrument malfunction, or lost data.

Number of Days Possible for Monitoring: 31
Actual Number of Days that the Monitor was Online: 31
Online Availability: 100.00%

1.2 RMS Voltage

The following trends present rms voltage plotted against time. Also presented are histograms that show the distribution of rms voltage. The accompanying summary table presents the minimum, CP05, average, CP95, and maximum values of the distribution for each of the three phases. The CP95, or 95th percentile, tells us the value that was greater than 95% of the other samples. The last two columns respectively display the percentage of samples that had values less than 10% or more than 10% of the site's nominal voltage. The ±10% limits are the steady-state limits from the 1997 ITIC (CBEMA) Curve. The voltage measurements have been normalized by the base voltage.

Base Voltage: 7448 V

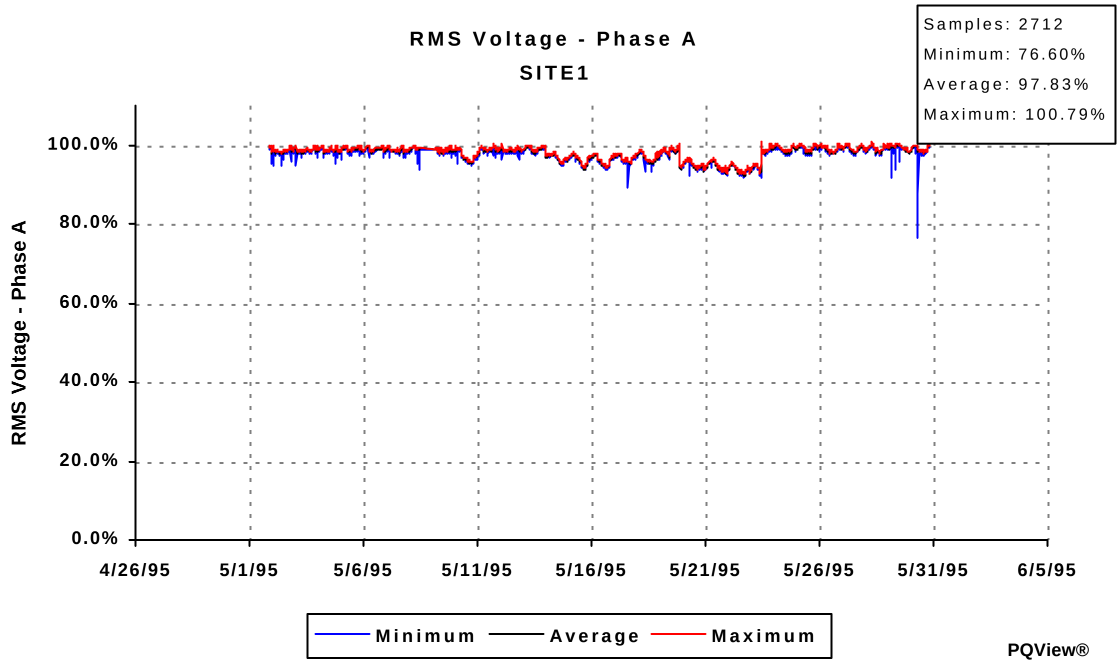

Figure 1: RMS Voltage - Phase A: Trend

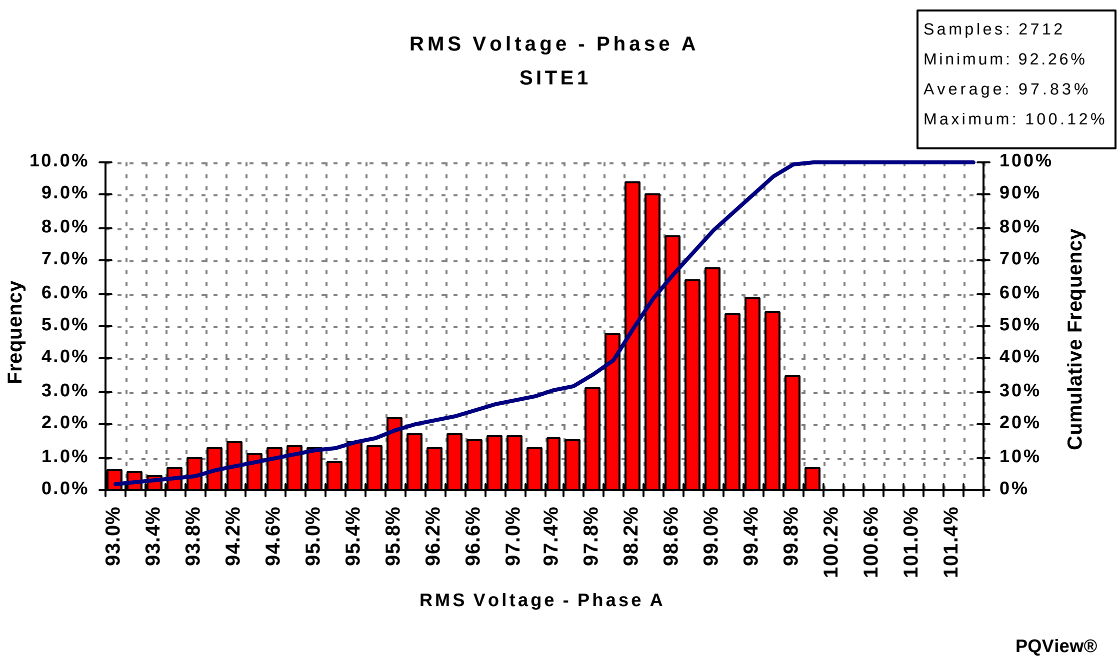

Figure 2: RMS Voltage - Phase A: Histogram

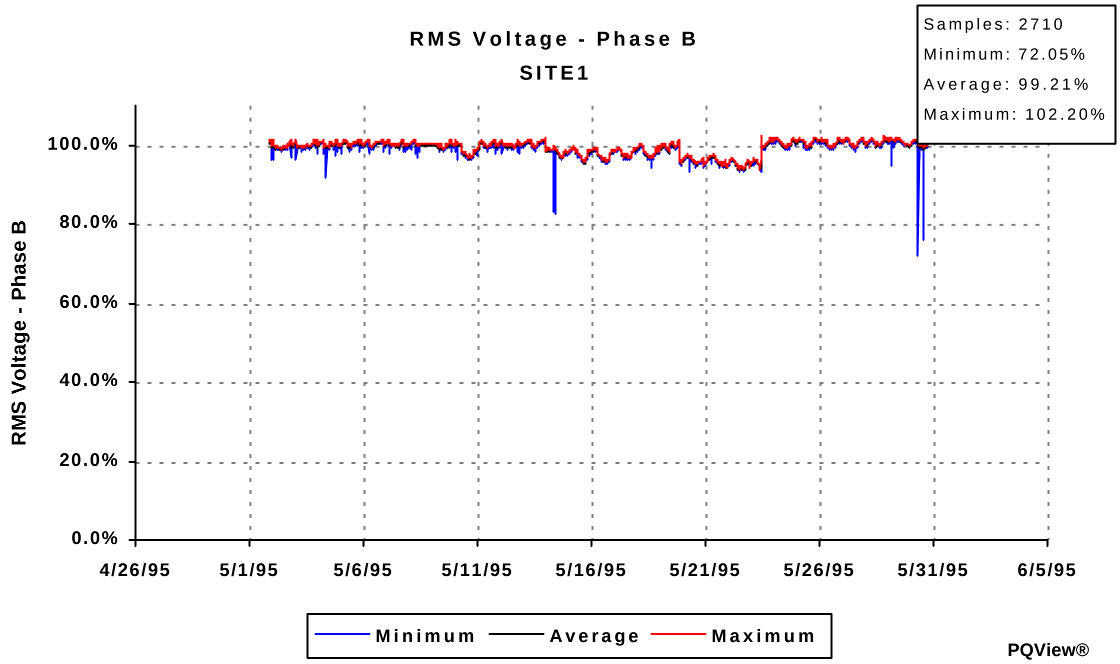

Figure 3: RMS Voltage - Phase B: Trend

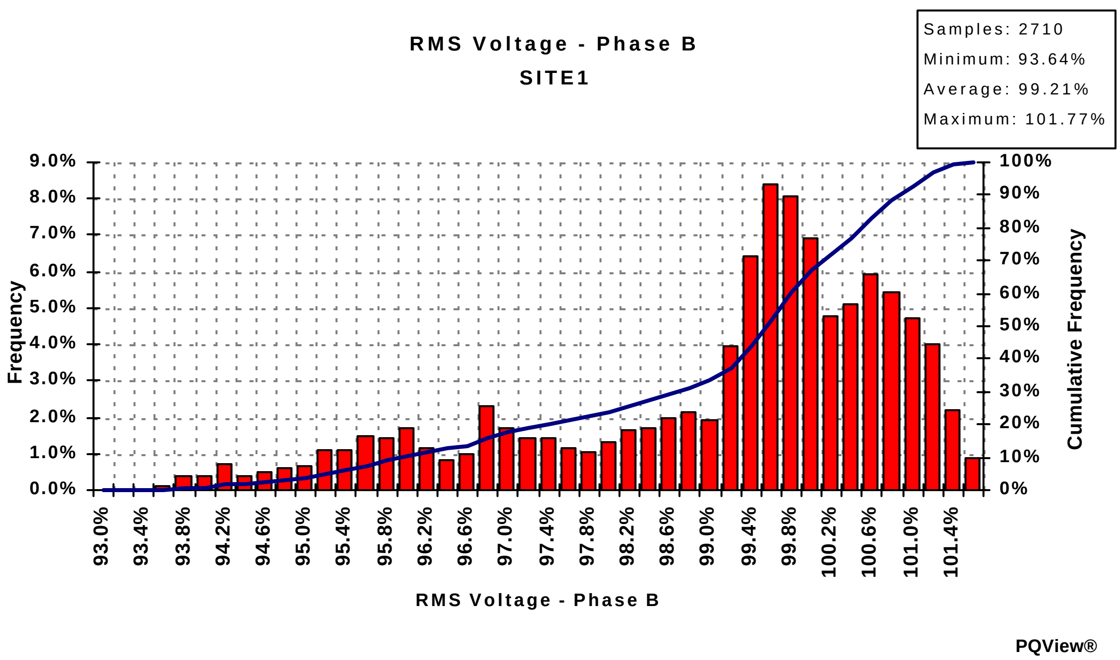

Figure 4: RMS Voltage - Phase B: Histogram

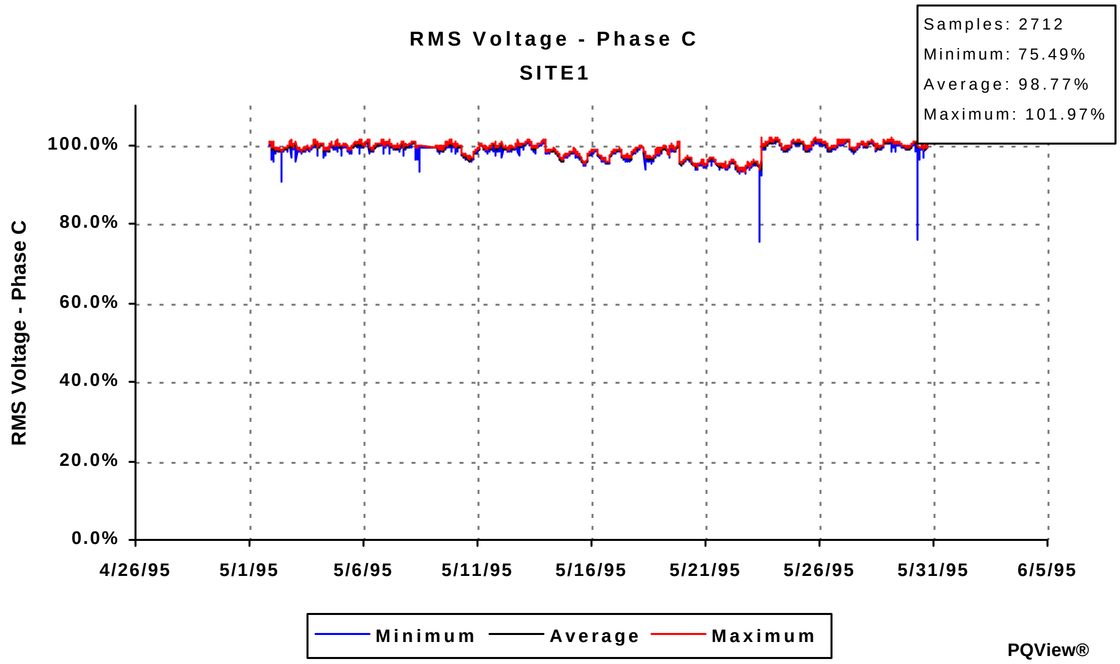

Figure 5: RMS Voltage - Phase C: Trend

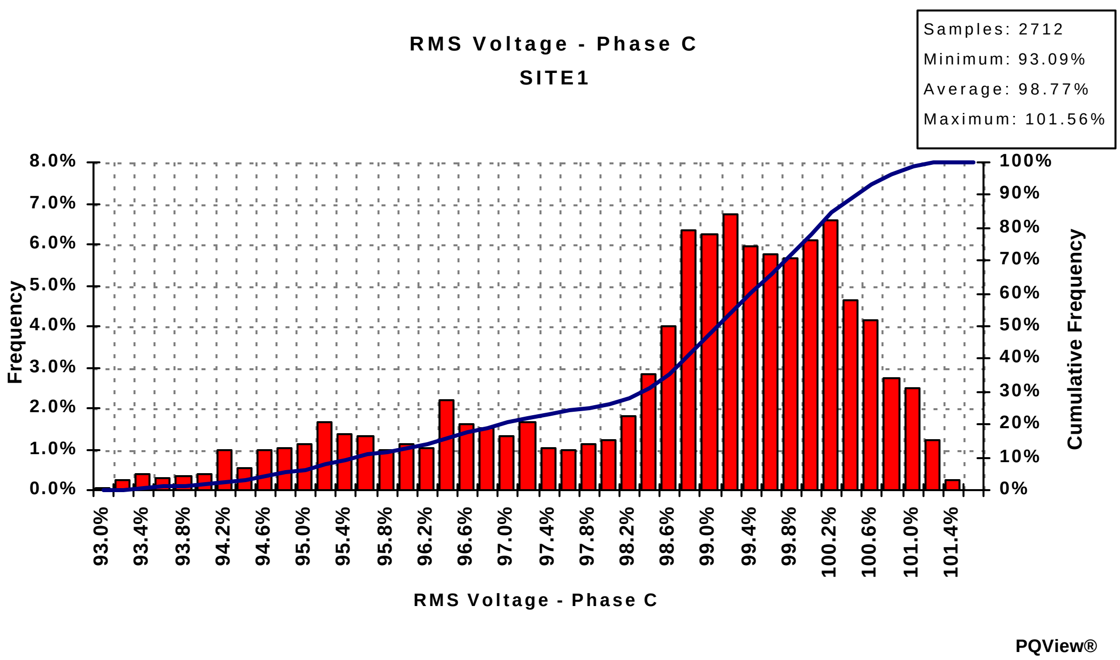

Figure 6: RMS Voltage - Phase C: Histogram

Table 1: Statistics of RMS Voltage

Phase	Minimum	CP05	Average	CP95	Maximum	Count	< 0.9 pu	> 1.1 pu
A	92.26%	94.07%	97.83%	99.76%	100.12%	2712	0.00%	0.00%
B	93.64%	95.46%	99.21%	101.31%	101.77%	2710	0.00%	0.00%
C	93.09%	94.97%	98.77%	100.90%	101.56%	2712	0.00%	0.00%

1.3 RMS Current

The following trends present rms current plotted against time. Also presented are histograms that show the distribution of rms voltage. The accompanying summary table presents the minimum, CP05, average, CP95, and maximum values of the distribution for each of the three phases. The CP95, or 95th percentile, tells us the value that was greater than 95% of the other samples.

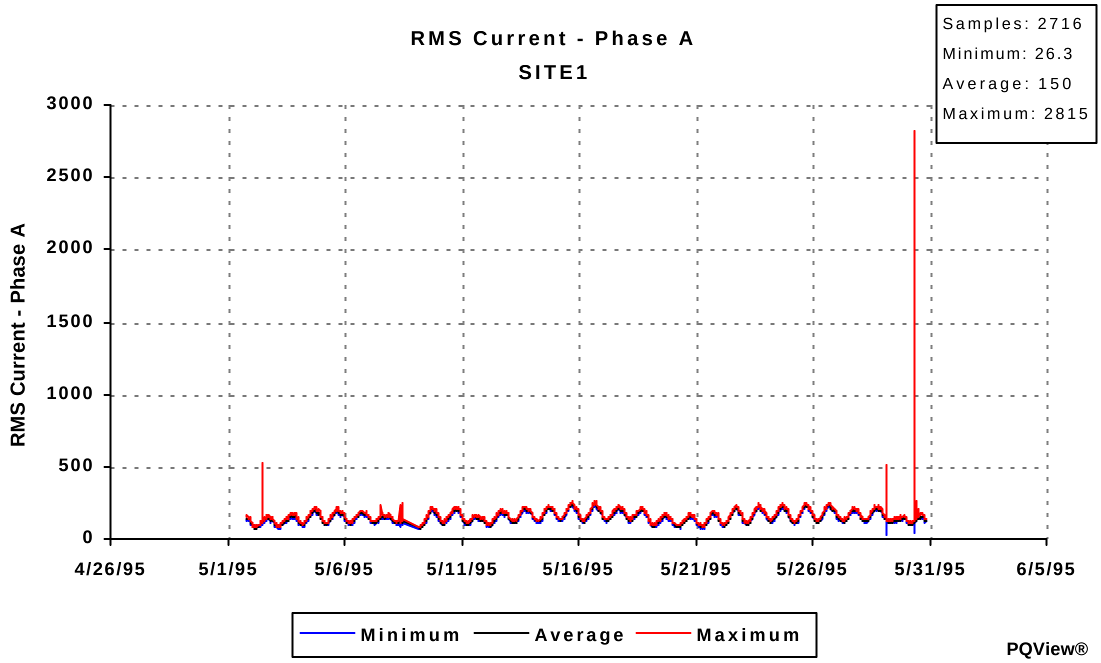

Figure 7: RMS Current - Phase A: Trend

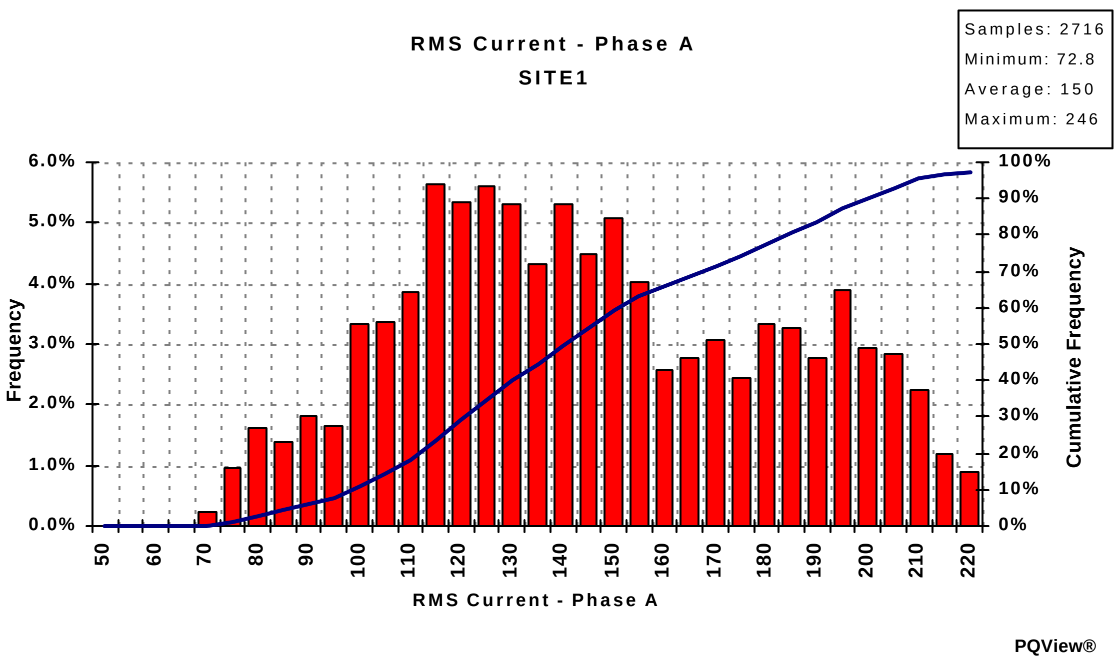

Figure 8: RMS Current - Phase A: Histogram

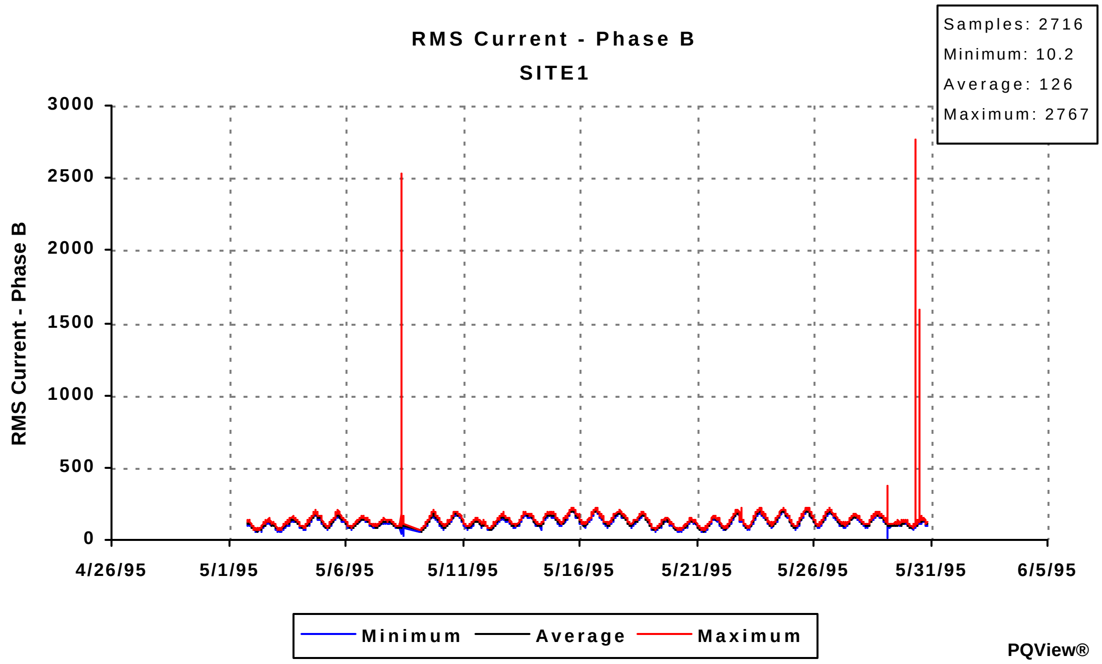

Figure 9: RMS Current - Phase B: Trend

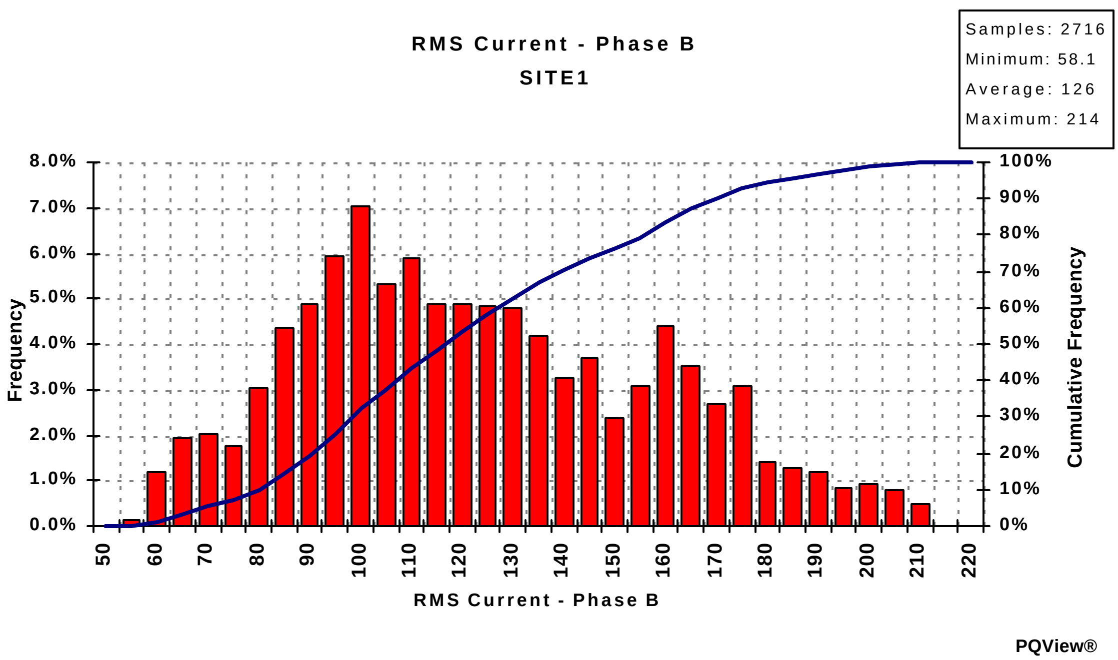

Figure 10: RMS Current - Phase B: Histogram

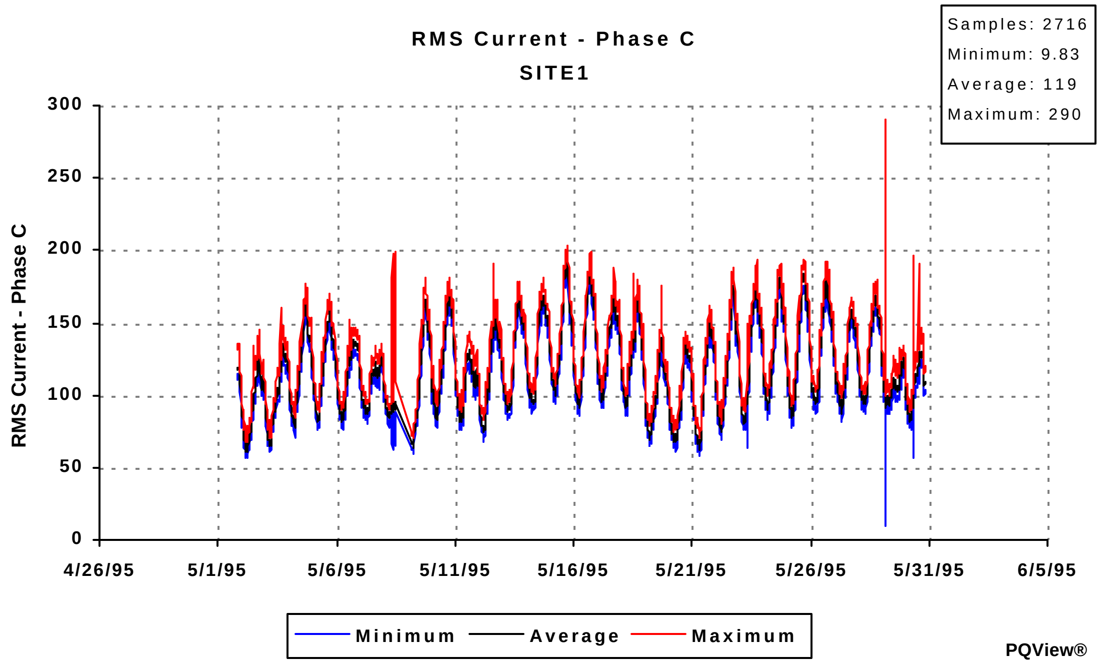

Figure 11: RMS Current - Phase C: Trend

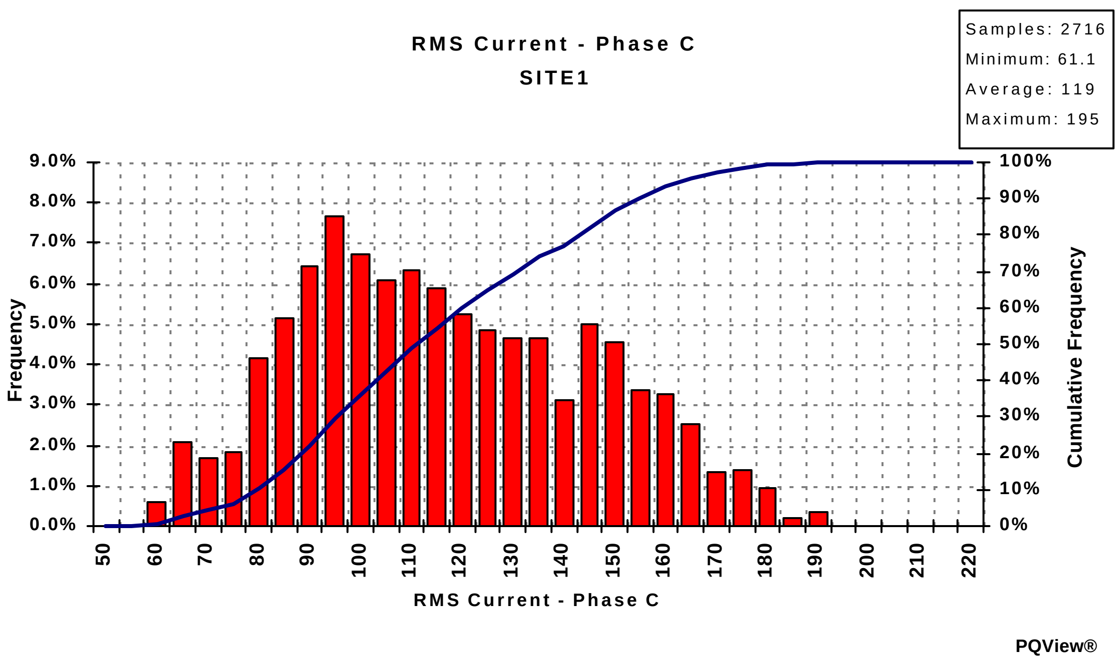

Figure 12: RMS Current - Phase C: Histogram

Table 2: Statistics of RMS Current

Phase	Minimum	CP05	Average	CP95	Maximum	Count
A	72.8	92.1	150	214	246	2716
B	58.1	74.0	126	187	214	2716
C	61.1	76.5	119	168	195	2716

1.4 Voltage THD

Harmonic distortion levels can be important if the facility includes power factor correction capacitors that can result in resonance problems or if a significant percentage of the facility load involves nonlinear devices like adjustable speed drives or power converters. Harmonic distortion guidelines are provided in IEEE Standard 519-1992, which suggests that voltage total harmonic distortion (THD) should be less than 5%. The summary table shows the number of samples that exceed 3% distortion and 5% distortion.

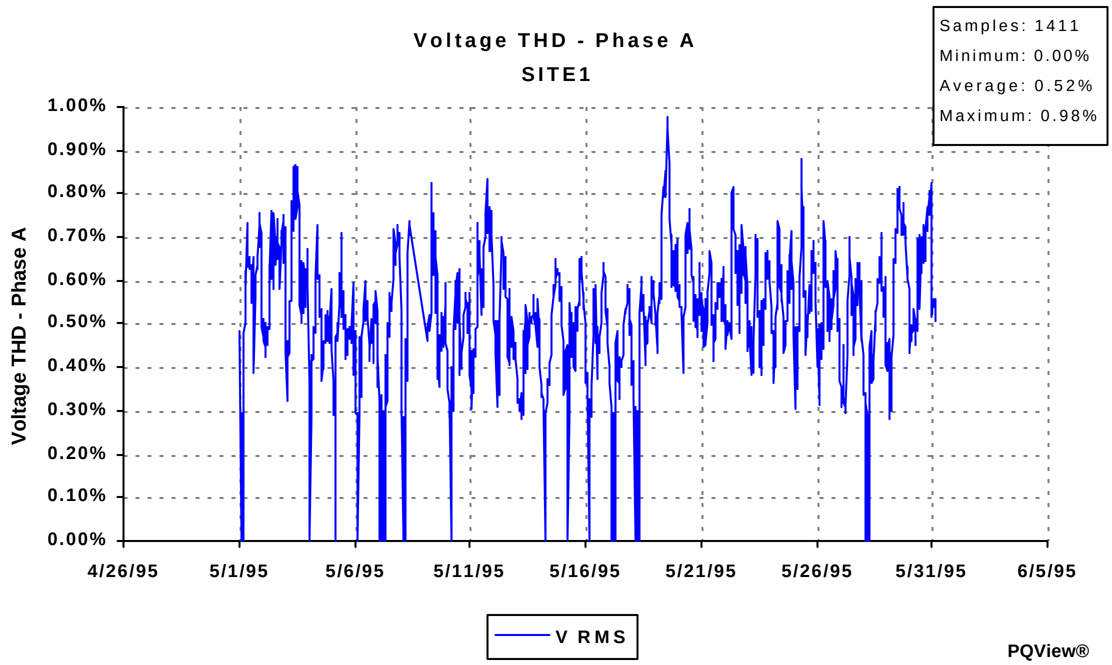

Figure 13: Voltage THD - Phase A: Trend

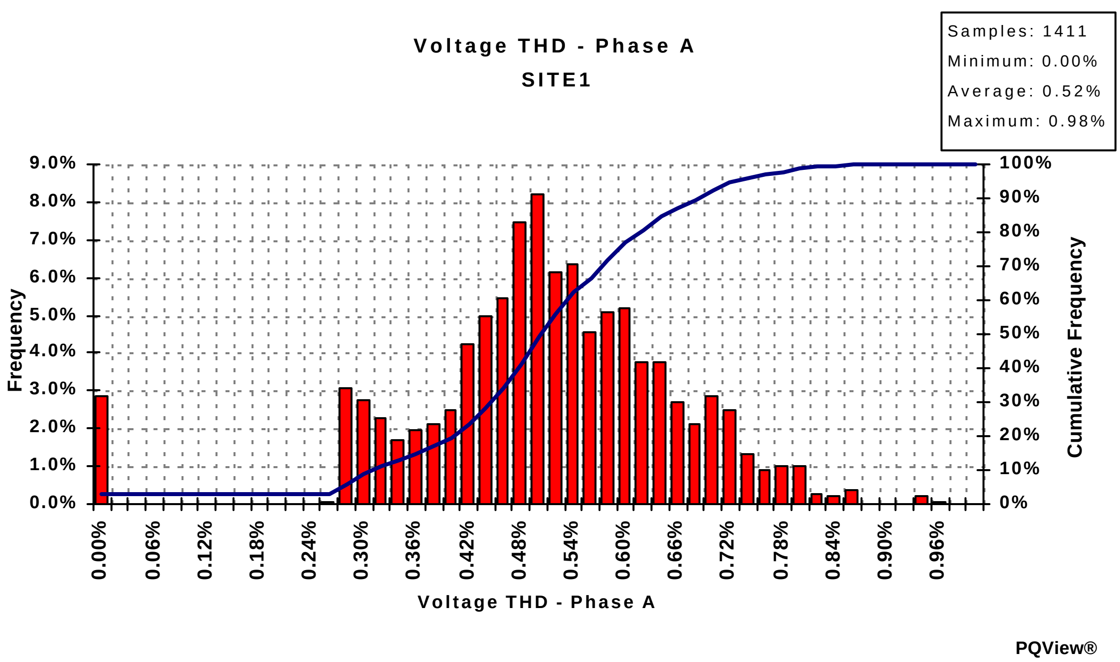

Figure 14: Voltage THD - Phase A: Histogram

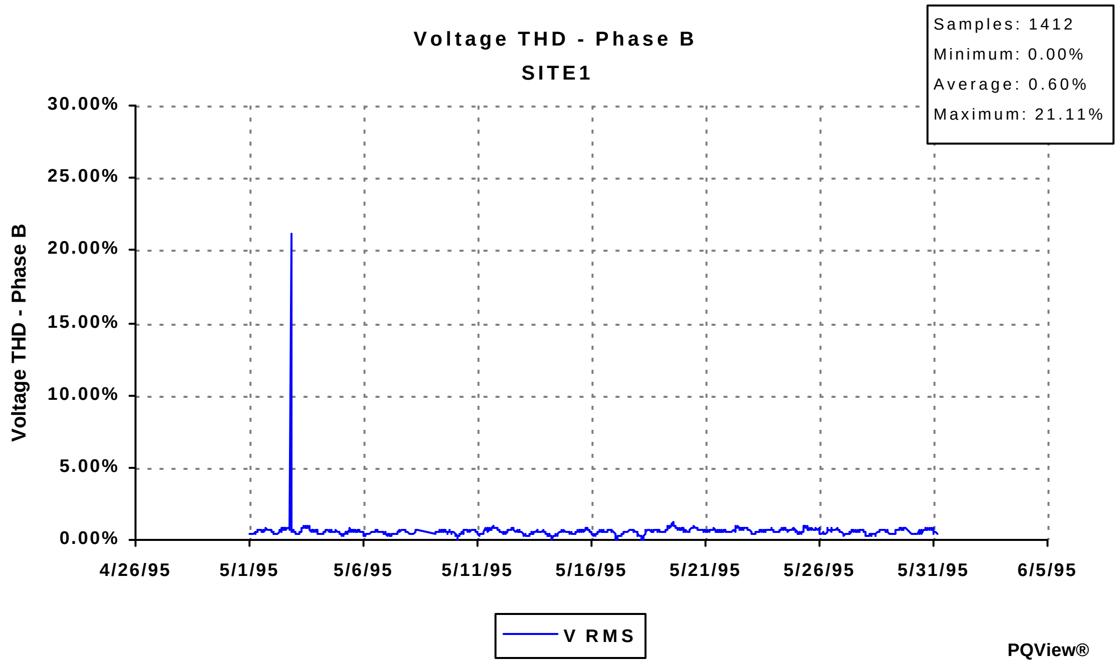

Figure 15: Voltage THD - Phase B: Trend

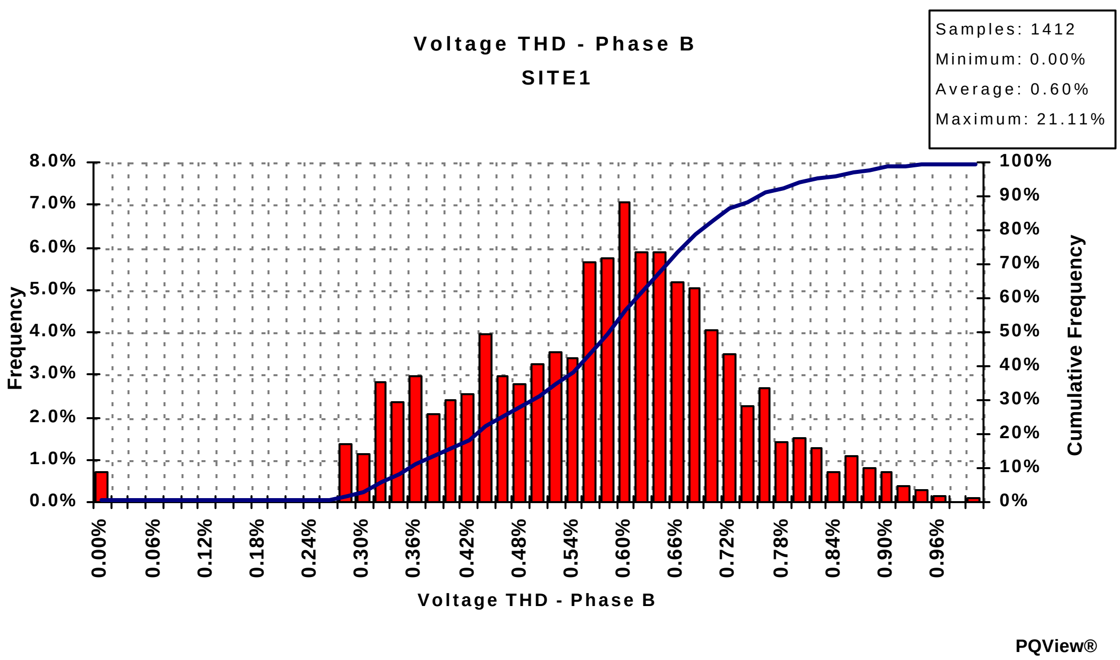

Figure 16: Voltage THD - Phase B: Histogram

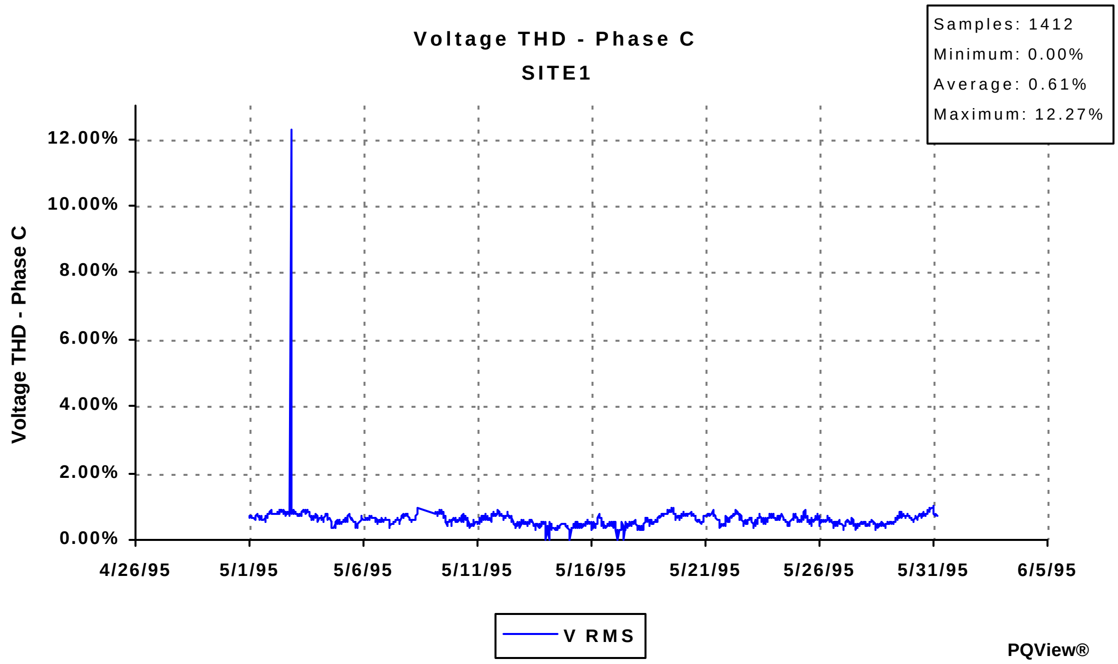

Figure 17: Voltage THD - Phase C: Trend

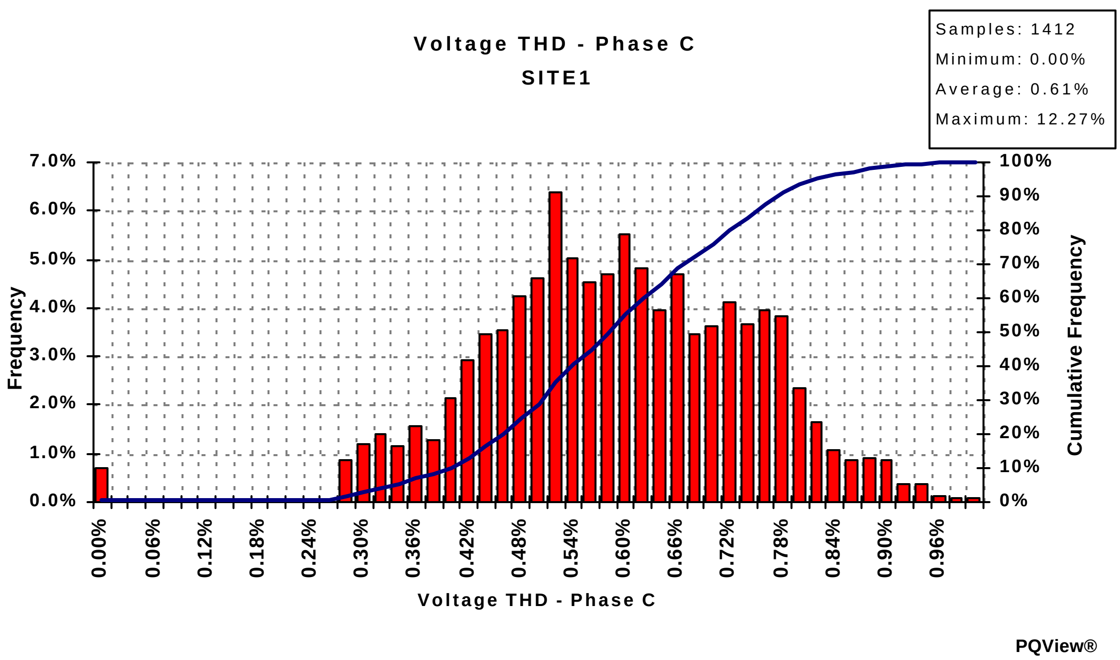

Figure 18: Voltage THD - Phase C: Histogram

Table 3: Statistics of Voltage THD

Phase	Minimum	CP05	Average	CP95	Maximum	Count	> 3%	> 5%
A	0.00%	0.29%	0.52%	0.75%	0.98%	1411	0.00%	0.00%
B	0.00%	0.33%	0.60%	0.83%	21.11%	1412	0.07%	0.07%
C	0.00%	0.35%	0.61%	0.84%	12.27%	1412	0.07%	0.07%

1.5 Current TDD

IEEE Standard 519-1992 provides guidelines for harmonic current distortion levels that will prevent problems on the power system. The following figure and table summarize the harmonic current distortion levels measured with respect to the IEEE 519 limits. The quantity investigated is total demand distortion (TDD).

Base Current: 229 A

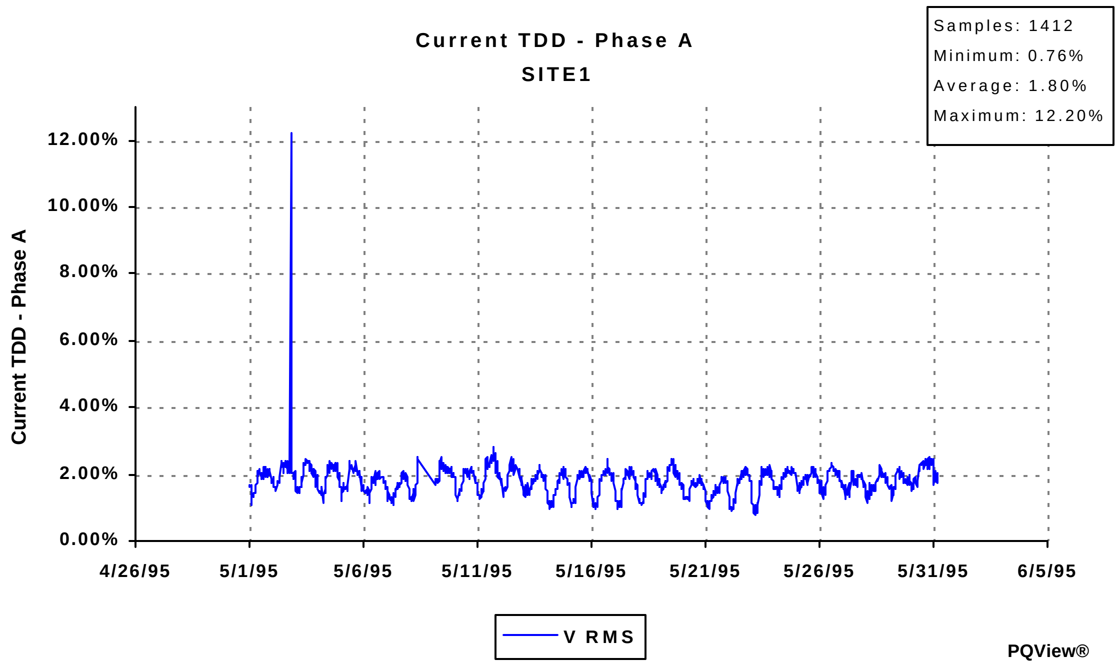

Figure 19: Current TDD - Phase A: Trend

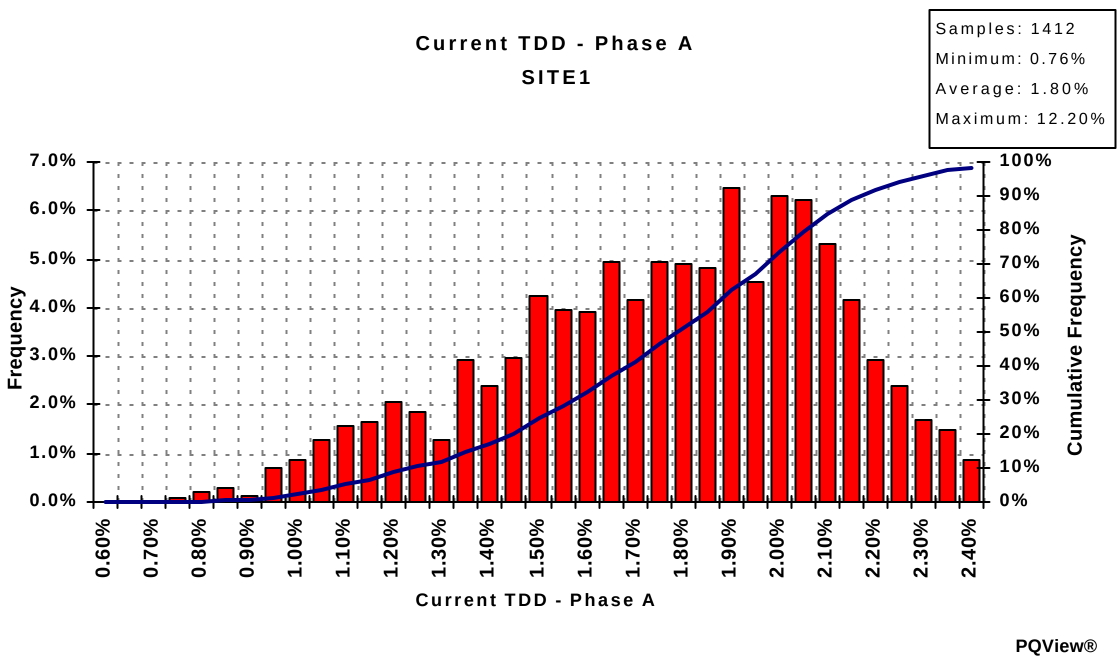

Figure 20: Current TDD - Phase A: Histogram

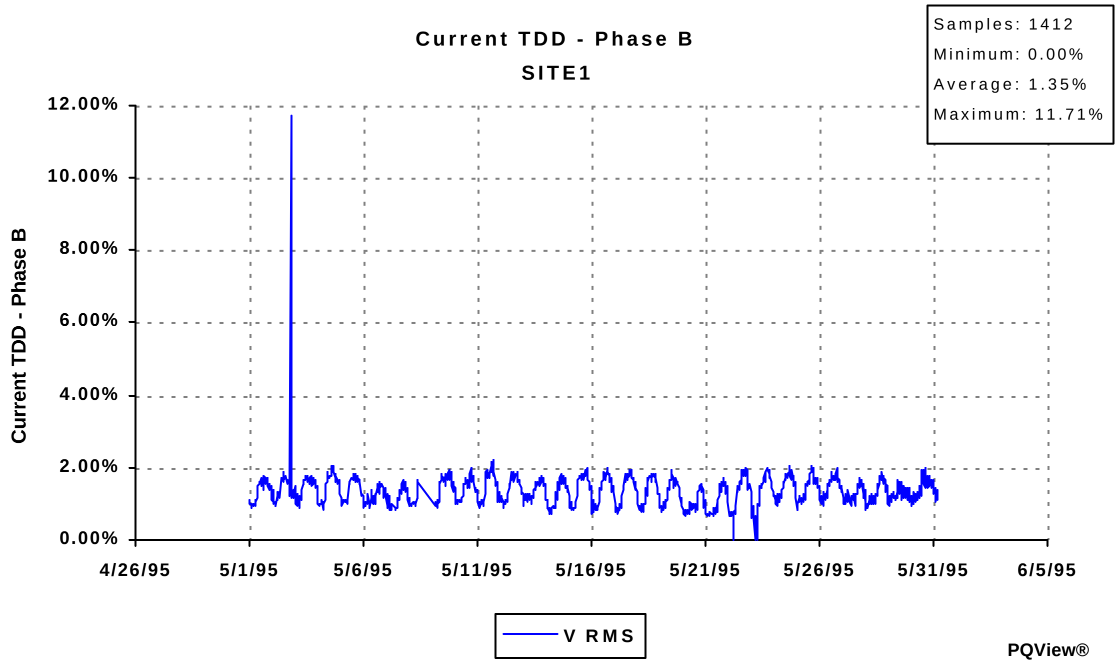

Figure 21: Current TDD - Phase B: Trend

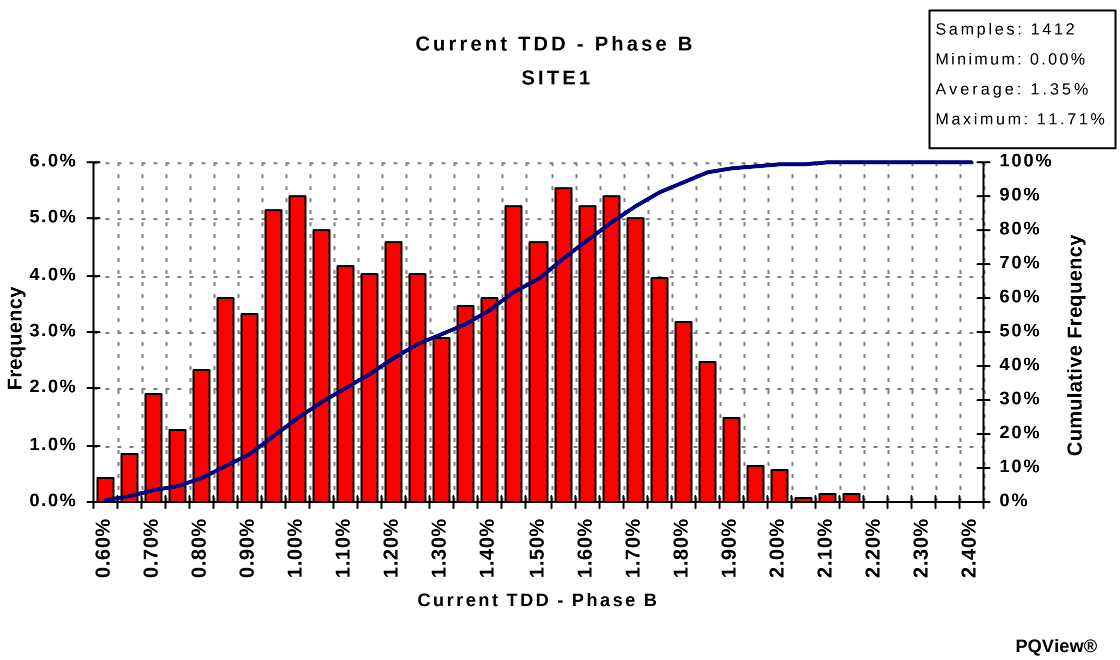

Figure 22: Current TDD - Phase B: Histogram

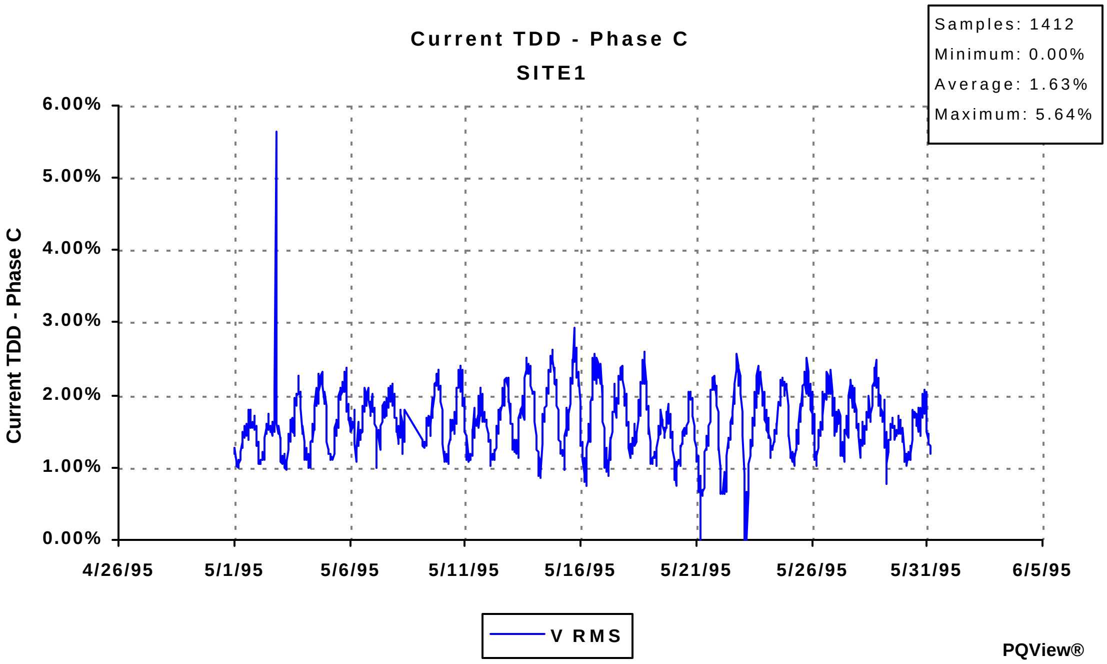

Figure 23: Current TDD - Phase C: Trend

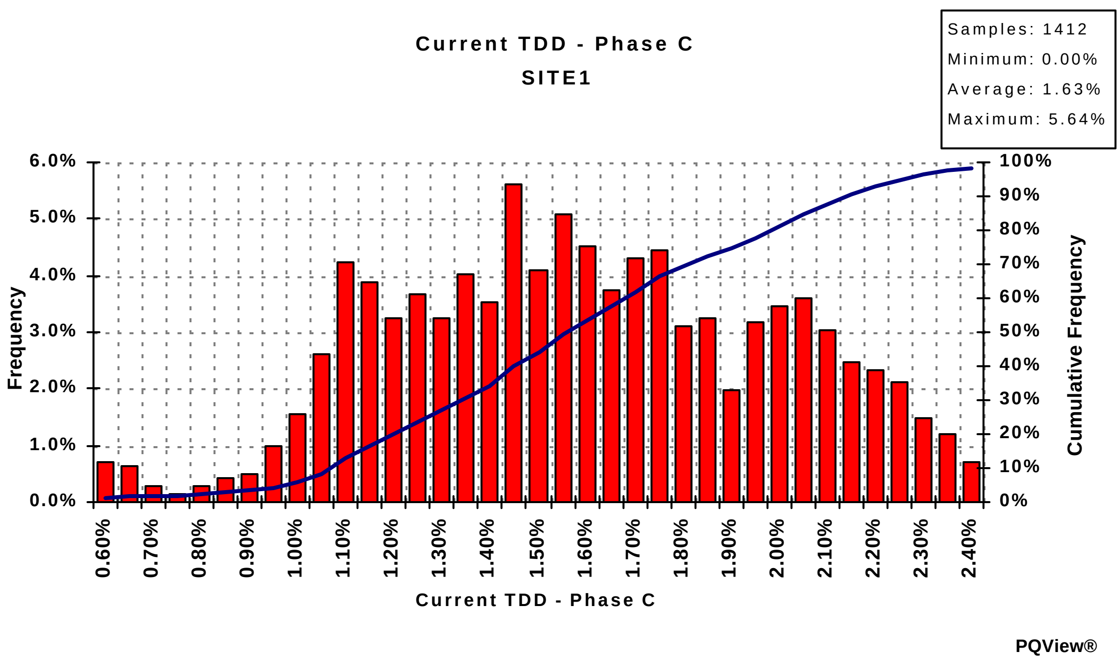

Figure 24: Current TDD - Phase C: Histogram

Table 4: Statistics of Current TDD

Phase	Minimum	CP05	Average	CP95	Maximum	Count	> 5%	> 20%
A	0.76%	1.14%	1.80%	2.32%	12.20%	1412	0.07%	0.00%
B	0.00%	0.80%	1.35%	1.86%	11.71%	1412	0.07%	0.00%
C	0.00%	1.03%	1.63%	2.31%	5.64%	1412	0.07%	0.00%

1.6 Statistical Summary of Voltage THD and Harmonics

This section presents a chart that summarizes statistics for voltage THD and selected individual harmonics. Each graph presents the 5th percentile value (CP05), average value, and 95th percentile value of voltage THD and voltage harmonics.

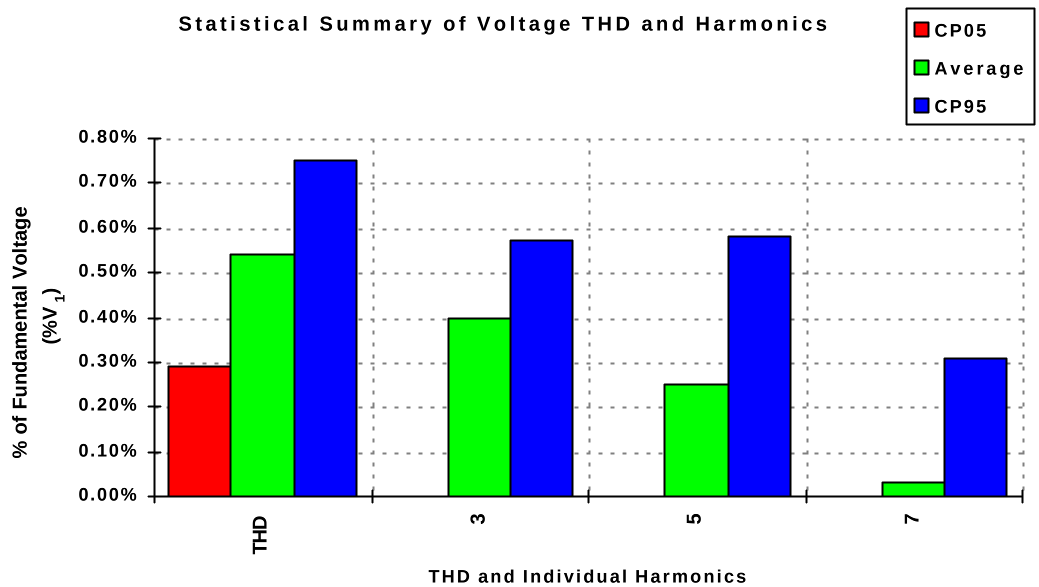

Figure 25: Statistical Summary of Voltage THD and Harmonics

1.7 Statistical Summary of Current TDD and Harmonics

This section presents a chart that summarizes statistics for current TDD and selected individual harmonics. Each graph presents the 5th percentile value (CP05), average value, and 95th percentile value of current TDD and current harmonics.

Base Current: 229 A

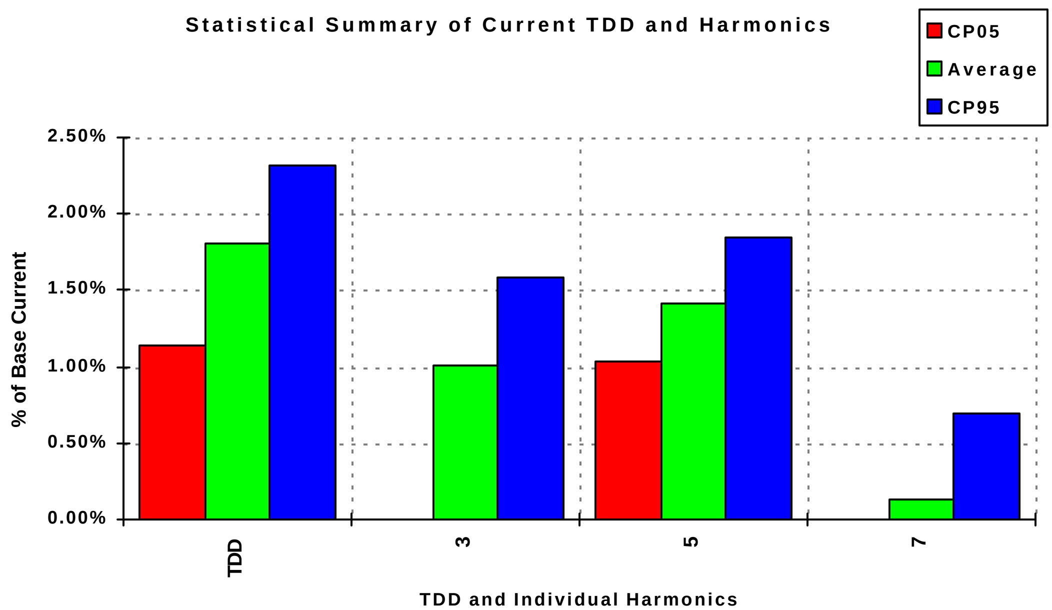

Figure 26: Statistical Summary of Current TDD and Harmonics

1.8 Voltage Unbalance

When the rms voltage of a three-phase set of voltages is not equal in magnitude, the voltage set is said to be unbalanced. This condition is mainly caused by unbalanced three-phase loads or by a large number of single-phase loads that are not distributed symmetrically to the three phases. One negative effect of unbalanced voltages is in the heating of polyphase induction motors. A negative sequence voltage may produce currents in the windings considerably in excess of those present under balanced voltage conditions. A relatively small unbalance in voltage will cause a considerable increase in temperature rise. For example, a 3% voltage unbalance could cause a 25% increase in motor temperature. IEEE Standard 100-1992 defines voltage unbalance as the ratio of the maximum deviation of a phase voltage from the average of the total phases to the average of the phase voltages, expressed in percent.

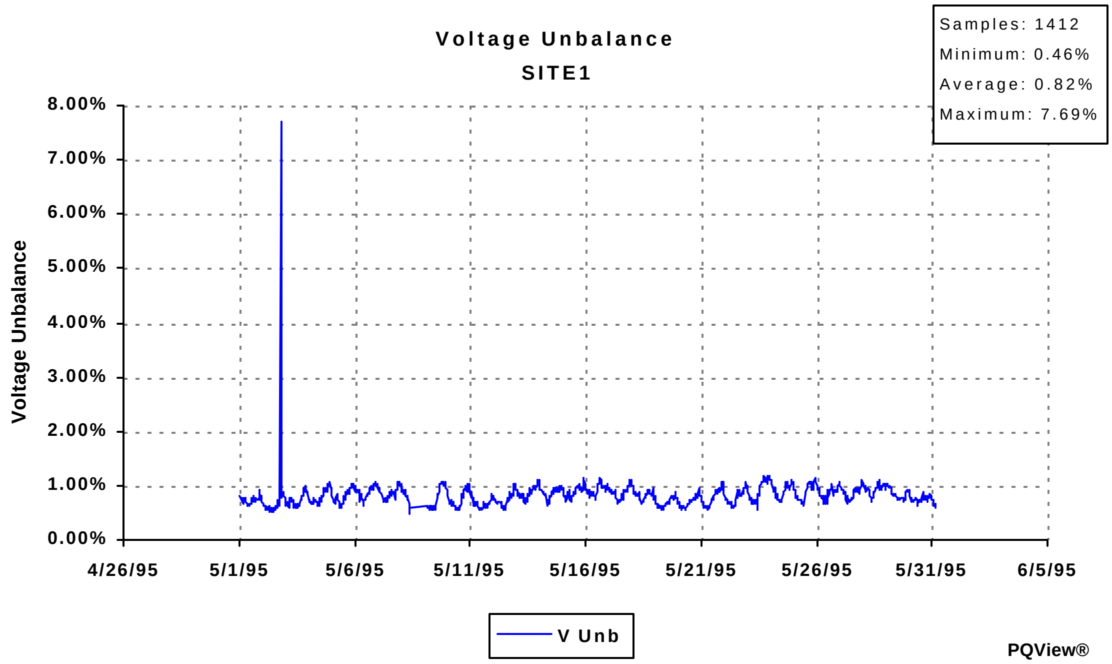

Figure 27: Voltage Unbalance: Trend

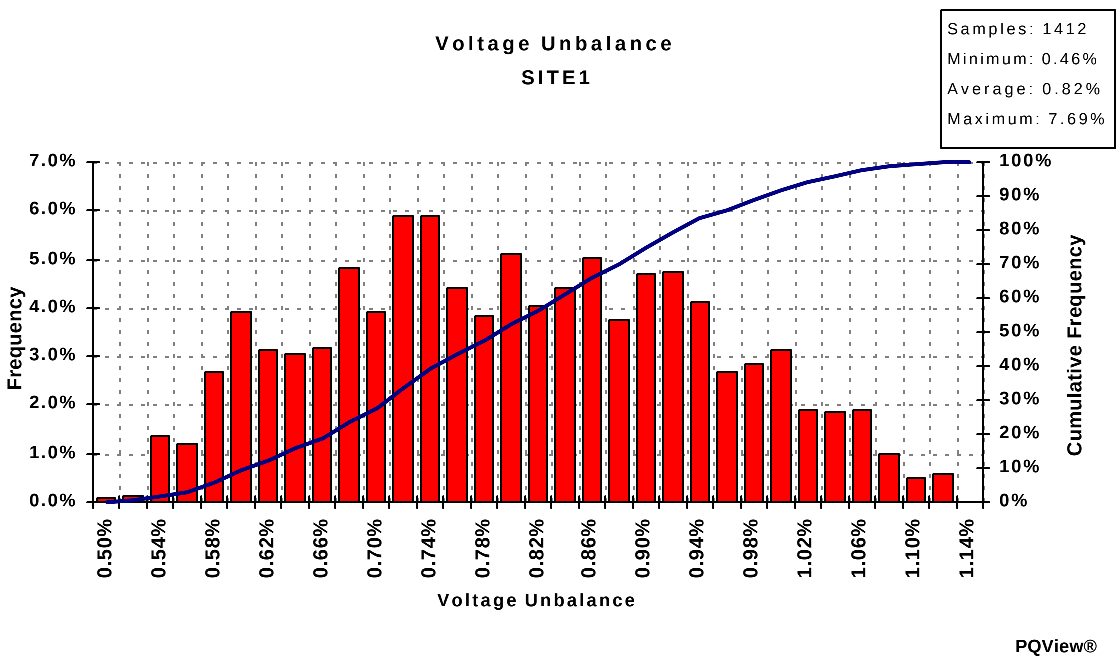

Figure 28: Voltage Unbalance: Histogram

Table 5: Statistics of Voltage Unbalance

Minimum	CP05	Average	CP95	Maximum	Count	> 2%	> 3%
0.46%	0.59%	0.82%	1.05%	7.69%	1412	0.07%	0.07%

1.9 Negative-Sequence Voltage Unbalance

Unbalanced voltages could be the result of a supply fault or a blown line fuse. However, nonlinear loads connected to the same network as the induction machine could also be a source. Arc welding equipment that draws large currents irregularly and single-phase motors with high starting impedances are two examples of common devices that can cause the three-phase line to become asymmetrical.

An induction motor operates in an unbalanced condition either when the voltages applied to the stator terminals do not constitute a balanced three-phase set or when the stator or rotor windings are not symmetrical with respect to the phases. One of the impacts of this imbalance is that currents that are higher than rated values flow through the rotor. The power dissipated as heat coming from higher I^2R conduction losses raises the rotor temperature and can lead to shortened machine life and reduced machine performance.

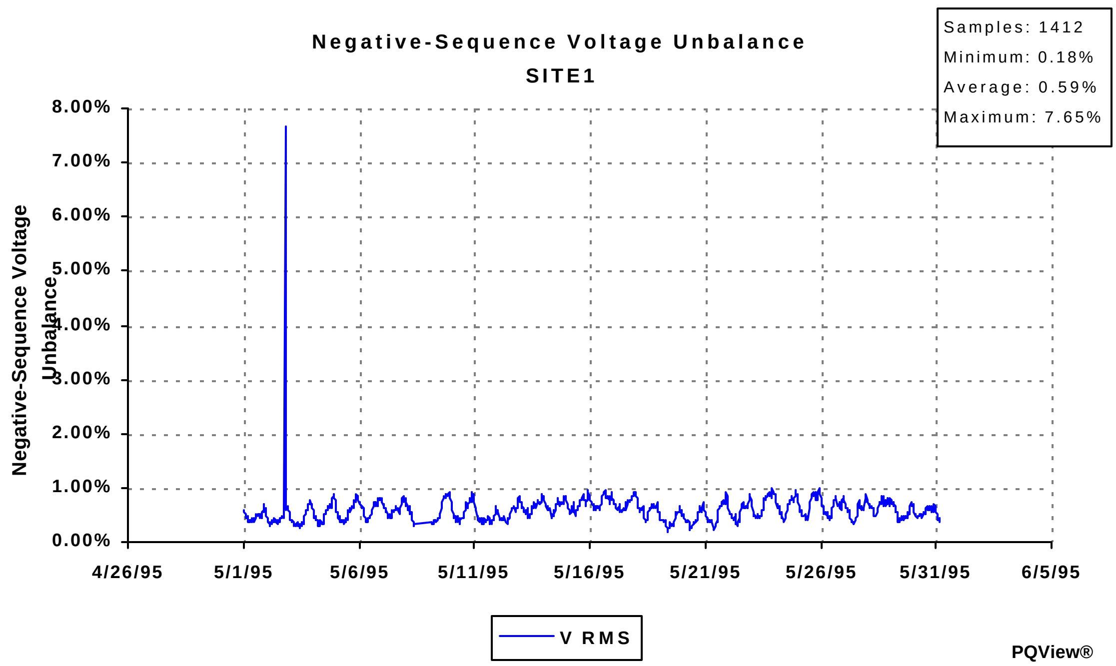

Figure 29: Negative-Sequence Voltage Unbalance: Trend

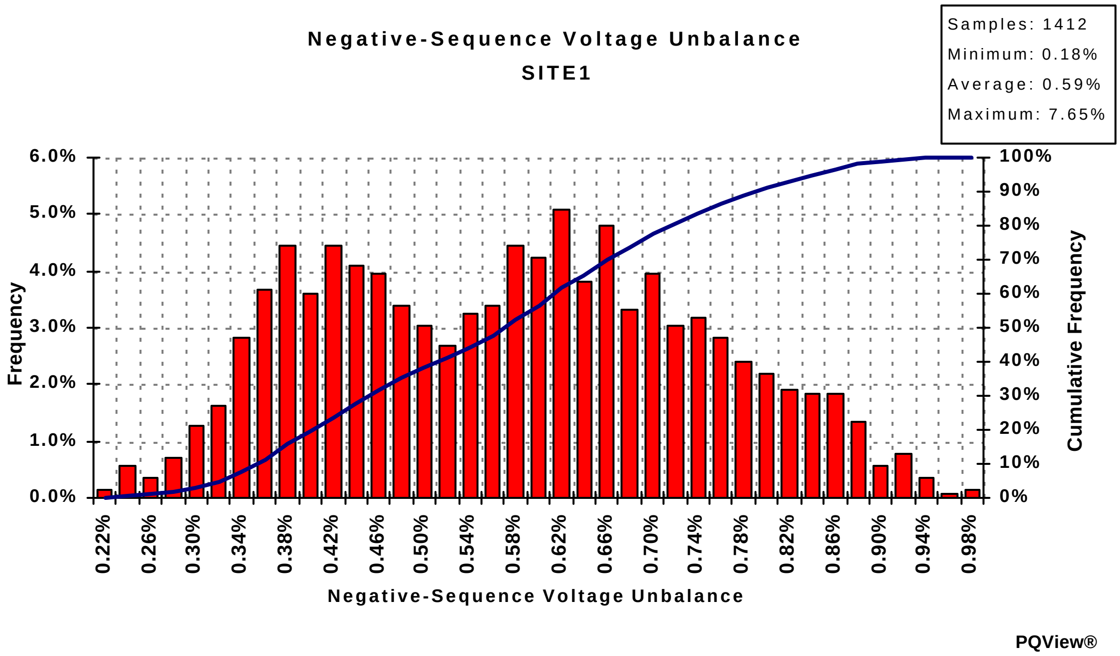

Figure 30: Negative -Sequence Voltage Unbalance: Histogram

Table 6: Statistics of Negative -Sequence Voltage Unbalance

Minimum	CP05	Average	CP95	Maximum	Count	> 2%	> 3%
0.18%	0.34%	0.59%	0.86%	7.65%	1412	0.07%	0.07%

1.10 Power Frequency (Hz)

Power frequency variations are defined as the deviation of the power system fundamental frequency from it specified nominal value (e.g. 50 Hz or 60 Hz).

The power system frequency is directly related to the rotational speed of the generators on the system. At any instant, the frequency depends on the balance between the load and the capacity of the available generation. When this dynamic balance changes, small changes in frequency occur. The size of the frequency shift and its duration depends on the load characteristics and the response of the generation system to load changes.

Frequency variations that go outside of accepted limits for normal steady state operation of the power system are normally caused by faults on the bulk power transmission system, a large block of load being disconnected, or a large source of generation going offline.

Frequency variations that affect the operation of rotating machinery, or processes which derive their timing from the power frequency (clocks), are rare on modern interconnected power systems. Frequency variations of consequence are much more likely to occur when a generator isolated from the utility system powers such equipment. In such cases, governor response to abrupt load changes may not be adequate to regulate within the narrow bandwidth required by frequency sensitive equipment. Note: voltage notching can sometimes cause frequency or timing errors on power electronic machines that count zero crossings to derive frequency or time. The voltage notch may produce additional zero crossings which can cause frequency or timing errors.

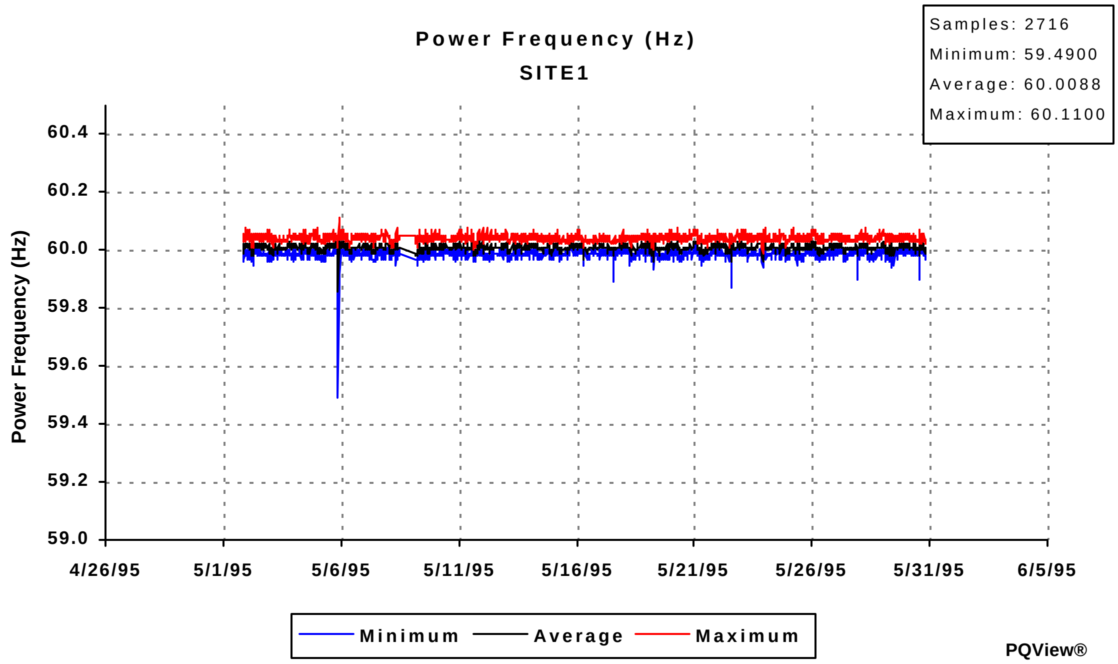

Figure 31: Power Frequency (Hz): Trend

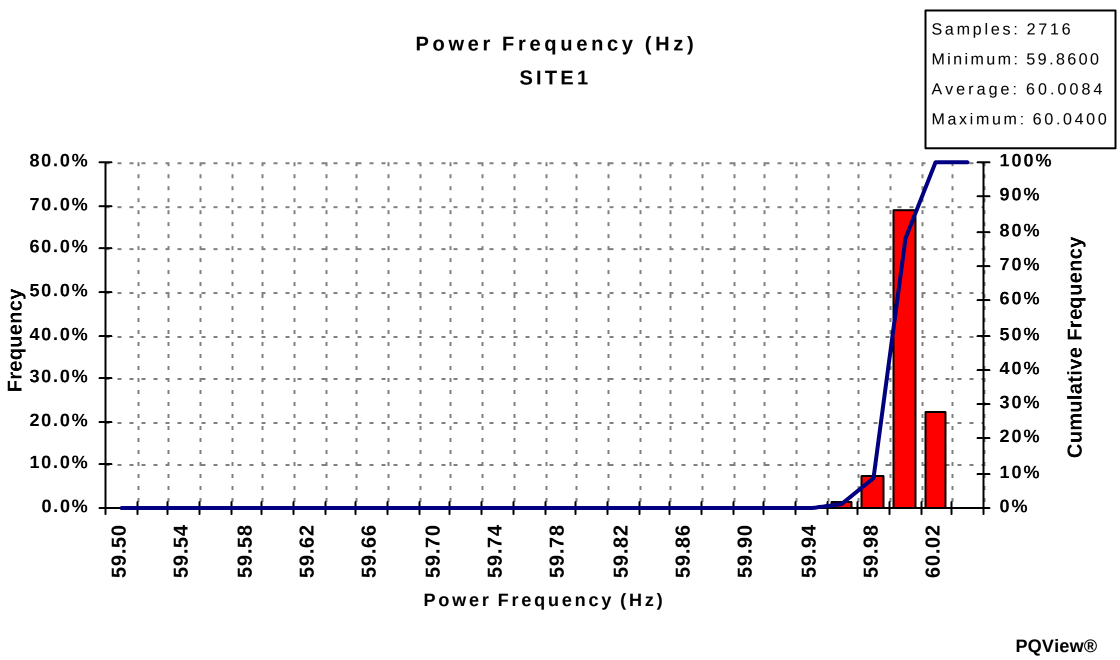

Figure 32: Power Frequency (Hz): Histogram

Table 7: Statistics of Power Frequency (Hz)

Minimum	CP01	Average	CP99	Maximum	Count	< -1%	> +1%
59.9	60.0	60.0	60.0	60.0	2716	0.00%	0.00%

1.11 RMS Voltage Variations

Voltage sags and interruptions, also known as rms voltage variations, are usually the most important power quality variations affecting end use equipment. The chief cause of rms voltage variations measured on the distribution system is faults; measurements taken at utilization voltages can also be attributed to the switching of large loads and regulation problems.

1.11.1 RMS Variation Magnitude Histogram

This figure presents a histogram of the voltage magnitude for each rms variation. Each column represents the rate of rms variations that fell into a particular voltage range.

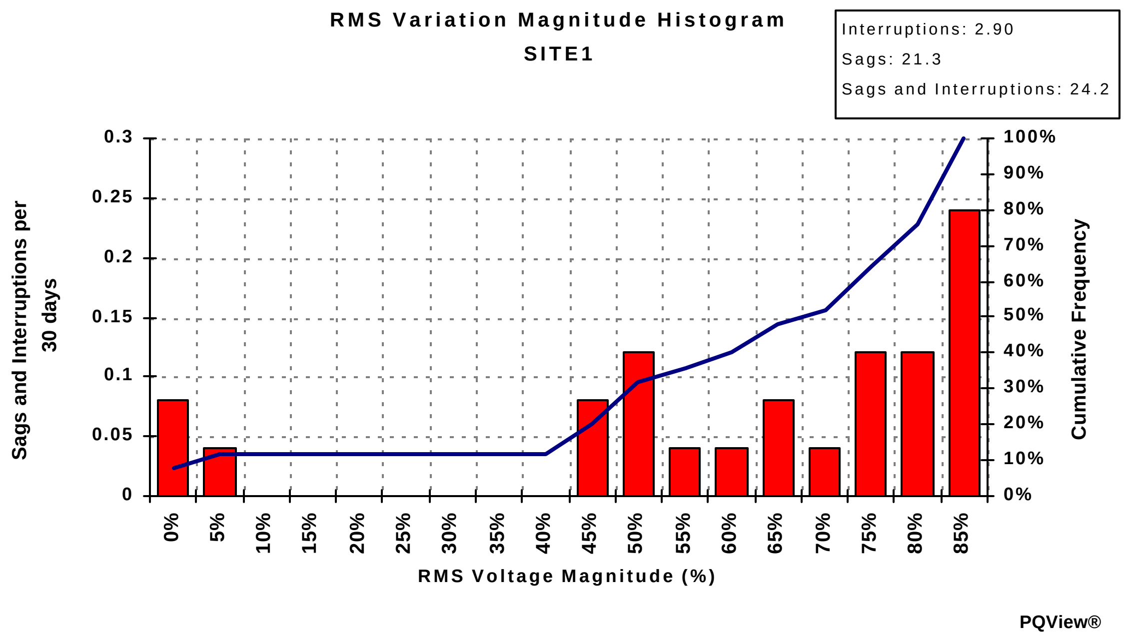

Figure 33: RMS Variation Magnitude Histogram

1.11.2 RMS Variation Event Summary

The following table presents a chronological list of the rms voltage variation events that occurred during the report's date range.

Table 8: RMS Variation Event Summary

Date	Time	Voltage	Duration
5/2/95	09:39:56	69.43%	15 cyc
5/2/95	09:39:58	87.77%	6 cyc
5/8/95	08:22:47	63.12%	15 cyc
5/8/95	08:22:48	85.84%	9 cyc
5/8/95	08:22:52	45.88%	6 cyc
5/8/95	08:23:12	85.34%	7 cyc
5/8/95	08:23:16	54.19%	31 cyc
5/8/95	08:23:38	55.17%	29 cyc
5/8/95	08:36:14	77.23%	2 cyc

5/8/95	08:45:24	83.79%	10 cyc
5/8/95	08:45:55	54.45%	14 cyc
5/8/95	08:46:01	46.97%	8 cyc
5/8/95	08:46:20	89.21%	9 cyc
5/8/95	08:46:26	54.53%	29 cyc
5/8/95	08:46:43	86.14%	7 cyc
5/14/95	08:03:02	83.13%	4 cyc
5/14/95	09:06:59	82.83%	3 cyc
5/17/95	14:39:06	89.12%	4 cyc
5/29/95	03:33:55	1.29%	12 cyc
5/29/95	03:34:19	6.84%	8 cyc
5/29/95	03:34:42	0.81%	4 cyc
5/30/95	07:53:15	72.05%	4 cyc
5/30/95	07:53:18	75.97%	6 cyc
5/30/95	08:00:10	68.44%	2 cyc
5/30/95	13:15:03	76.25%	2 cyc

1.11.3 DISDIP Table

The following table presents a cross tabulation of voltage sags by magnitude and event duration. The value of each cell is a rate of events per 30 days.

Table 9: DISDIP Table

Voltage Magnitude	0.5<5 cycle	5<30 cycle	.5<1 second	1<3 second	3<20 second	20<60 second	>60 second
70% to 90%	6.0	7.0	0.0	0.0	0.0	0.0	0.0
40% to 70%	1.0	7.0	1.0	0.0	0.0	0.0	0.0
1% to 40%	0.0	2.0	0.0	0.0	0.0	0.0	0.0
<1%	1.0	0.0	0.0	0.0	0.0	0.0	0.0

1.11.4 ESKOM Voltage Sag Table

The following table presents a tabulation of voltage sags by magnitude and event duration. The table is based on the approached used by the South African utility ESKOM to divide voltage sags and interruptions into groups that represent their severity. The value of each cell is a rate of events per 30 days.

Table 10: ESKOM Voltage Sag Table

T	X	S	Z	Y	O
Mag: 0 to 40%, Dur: 1 to 30 cycle	Mag: 40 to 80%, Dur: 1 to 7.5 cycle	Mag: 40 to 80%, Dur: 7.5 to 30 cycle	Mag: 0 to 80%, Dur: 30 to 150 cycle	Mag: 80 to 90%, Dur: 1 to 150 cycle	Other Events
3.0	6.0	6.0	1.0	9.0	0.0

1.11.5 CBEMA Curve Scatter Plot

The CBEMA chart presents a scatter plot of the voltage magnitude and event duration for each rms variation. The overlaid curves define a tolerance envelope developed by the Computer Business Equipment Manufacturers Association (CBEMA), which is described in the IEEE Orange book. The CBEMA group created the chart as a means to predict equipment misoperation due to rms variations. An rms variation event with a magnitude and duration that falls above the upper curve or below the lower curve has a high probability to cause misoperation in computer equipment connected to the monitored voltage source.

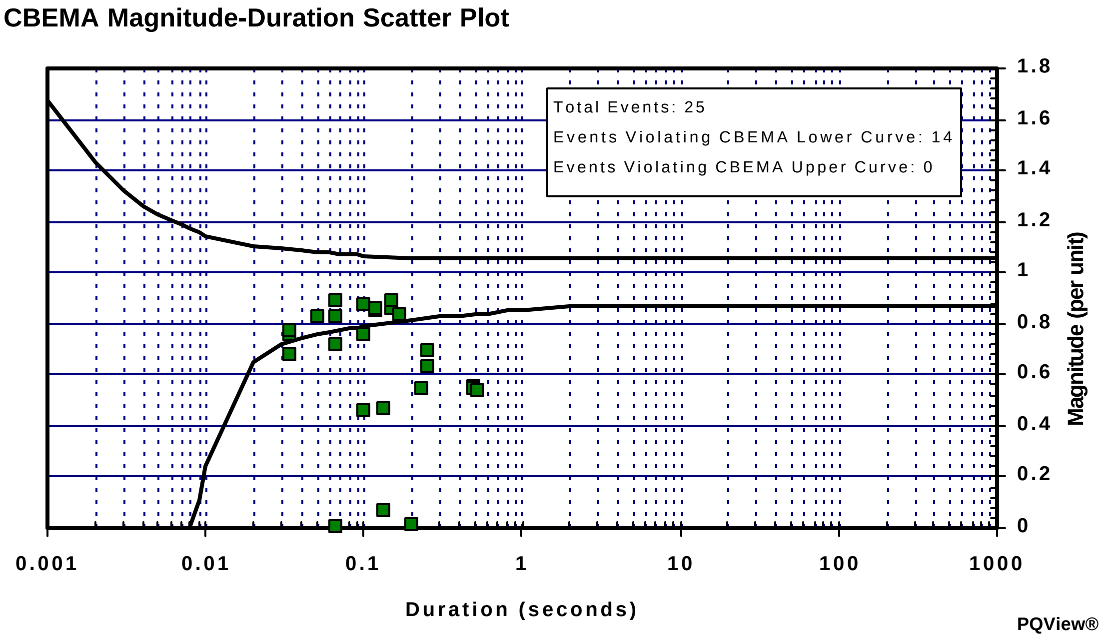

Figure 34: CBEMA Curve Scatter Plot

1.11.6 ITIC Curve Scatter Plot

The ITIC Curve describes an ac input voltage boundary that typically can be tolerated (i.e., without an interruption in function) by most information technology equipment. The ITIC Curve -- like its predecessor, the CBEMA Curve -- consists of a scatter plot of rms voltage variations in terms of voltage magnitude and event duration. The scatter plot also includes two overlay curves that represent upper and lower limits. Events above the upper curve or below the lower curve are presumed to cause the mis operation of information technology equipment (e.g., computers, computer network components, and communications networks). The curve describes both steady-state and transitory conditions, and is applicable to 120V nominal voltages obtained from 120V, 208Y/120V, and 120/240V 60Hz systems. For rms voltage variations, the ITIC Curve Application note defines four event categories:

ITIC Magnitude-Duration Scatter Plot

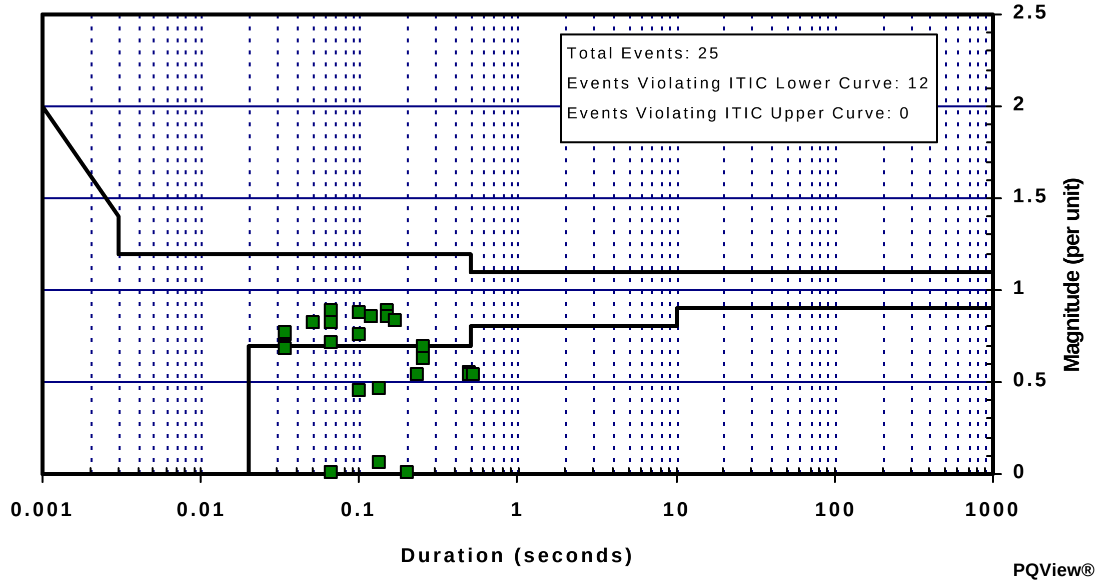

Figure 35: ITIC Curve Scatter Plot

Steady-State Tolerances. The steady-state range describes an rms voltage that is either very slowly varying or is constant. The subject range is ±10% from the nominal voltage. Any voltages in this range may be present for an indefinite period, and are a function of normal loading and losses in the distribution system.

Line Voltage Swell. This region describes a voltage swell having an rms amplitude of up to 120% of the rms nominal voltage with a duration of up to 0.5 seconds. This event may occur when large loads are removed from the system or when voltage is supplied from sources other than the electric utility.

Voltage Sags. Two different rms voltage sags are described. Generally, these transients result from application of heavy loads, as well as fault conditions, at various points in the ac distribution system. Sags to 80% of nominal are assumed to have a typical duration of up to 10 seconds, and sags to 70% of nominal are assumed to have a duration of up to 0.5 seconds.

Dropout. A voltage dropout includes both severe RMS voltage sags and complete interruptions of the applied voltage, followed by immediate reapplication of the nominal voltage. The interruption may last up to 20 milliseconds. This transient typically results from the occurrence and subsequent clearing of faults in the ac distribution system.

The curve is not intended to serve as a design specification for products or ac distribution systems. However, the normal functional state of information technology equipment is not typically expected when rms variations occur that are outside the upper and lower magnitude-duration limits described by curve.

1.11.7 SEMI Curve Scatter Plot

In 1998, the SEMI Power Quality and Equipment Ride Through Task Force recommended SEMI Standard F-47 Curve to predict voltage sag problems for semiconductor manufacturing equipment. SEMI is the Semiconductor Equipment and Materials International Group.

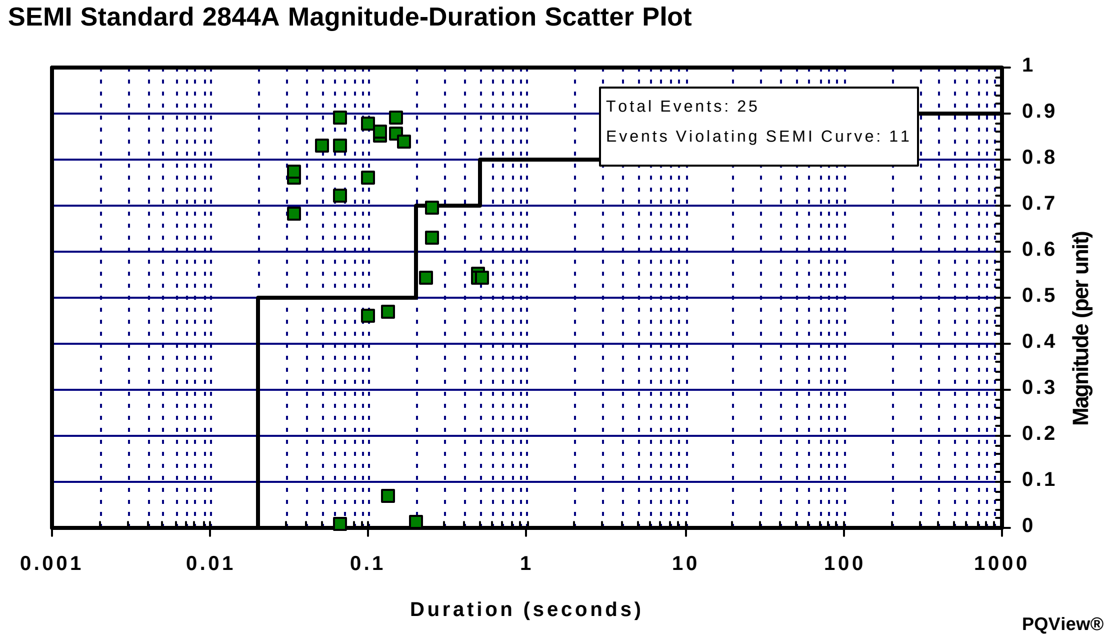

Figure 36: SEMI Curve Scatter Plot

1.11.8 RMS Variation Magnitude-Duration Bar Chart

The following chart presents a three-dimensional cross tabulation of the rms variation measurements.

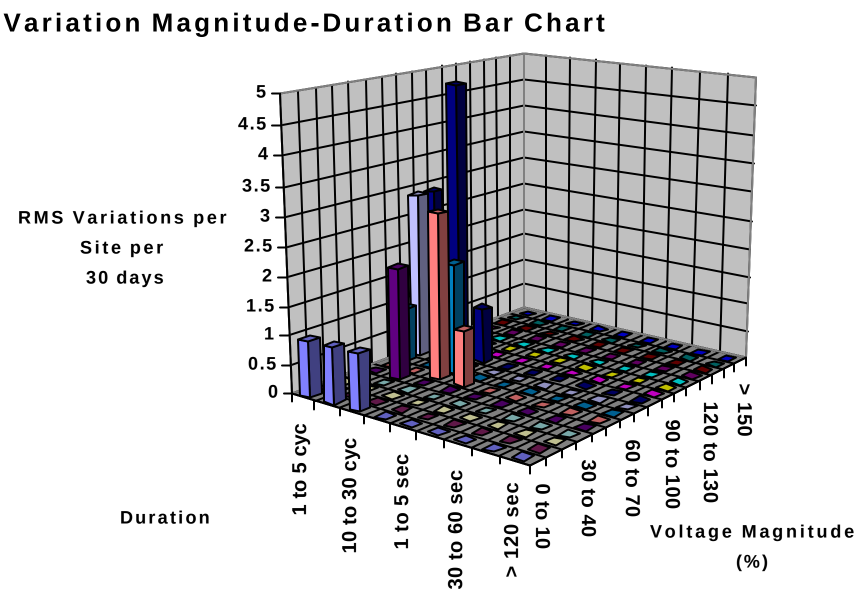

Figure 37: RMS Variation Magnitude-Duration Bar Chart

1.11.9 RMS Variation Cumulative Magnitude-Duration Chart

The following chart presents a cumulative cross tabulation of the magnitude and duration of the rms variation measurements. This type of chart is described in IEEE Standard 1346-1998.

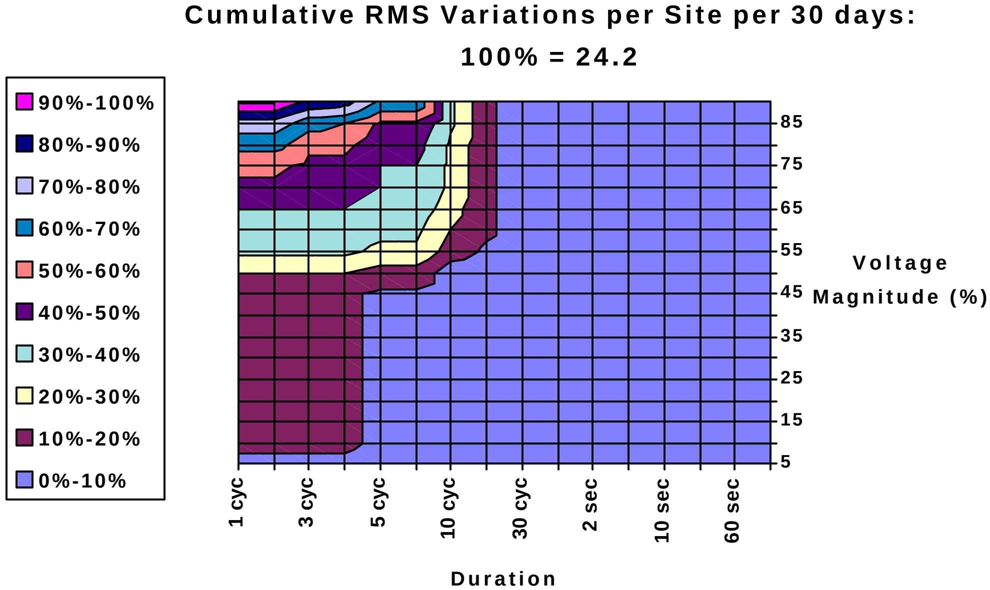

Figure 38: RMS Variation Cumulative Magnitude-Duration Chart

1.11.10 Individual RMS Variation Events

The following section presents individual rms variation events. The events chosen for the report had the lowest rms voltage magnitude and are presented in ascending order by voltage magnitude.

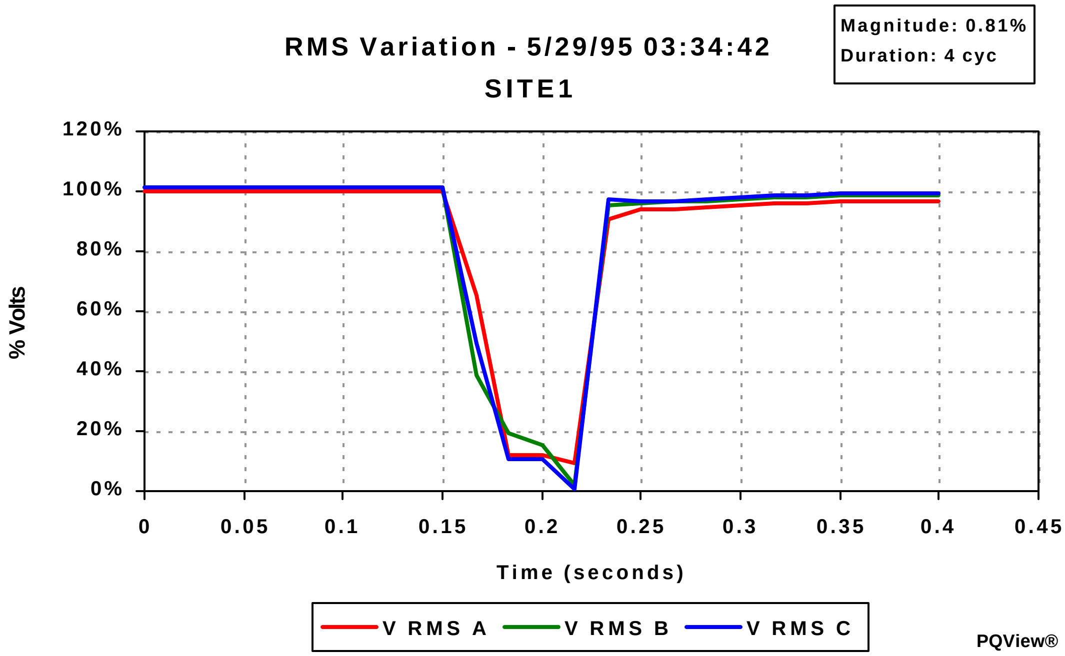

Figure 39: RMS Variation Voltage 5/29/95 03:34:42

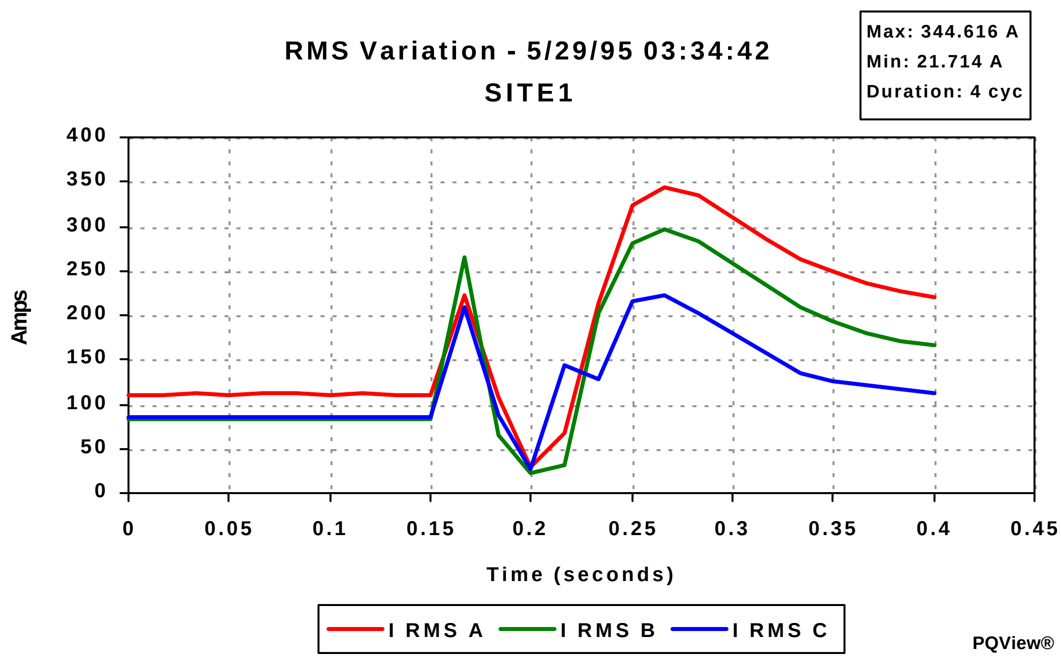

Figure 40: RMS Variation Current 5/29/95 03:34:42

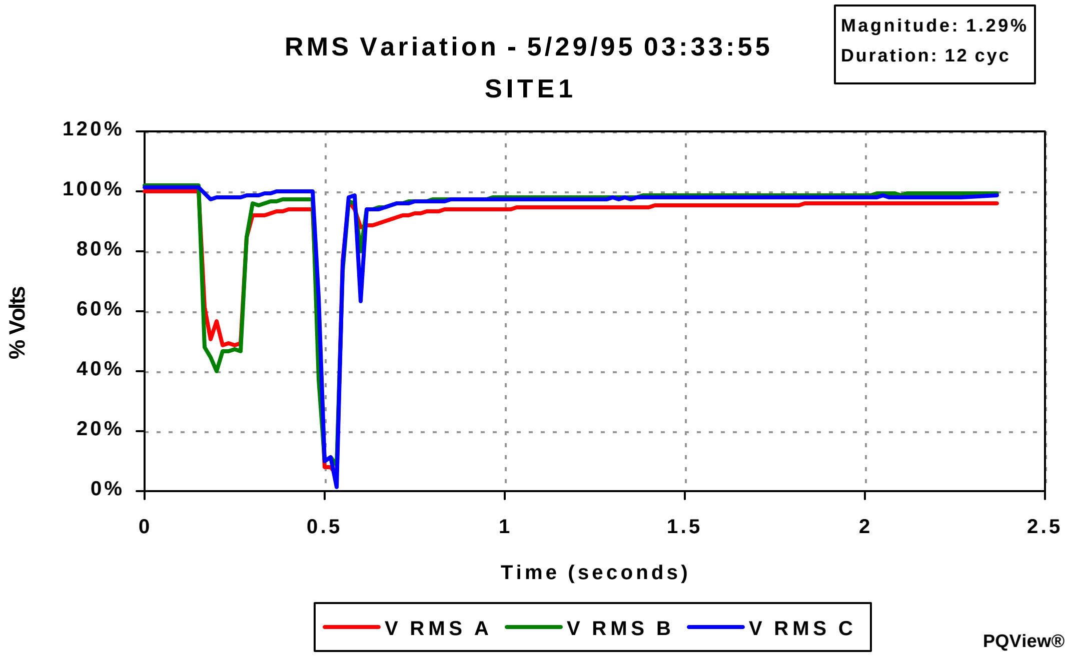

Figure 41: RMS Variation Voltage 5/29/95 03:33:55

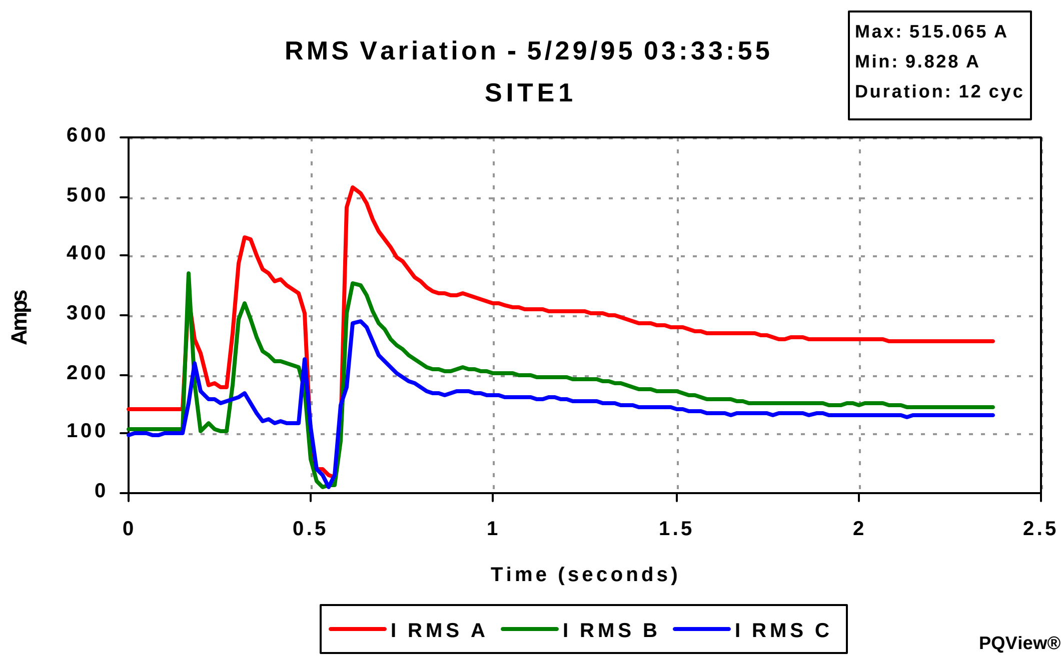

Figure 42: RMS Variation Current 5/29/95 03:33:55

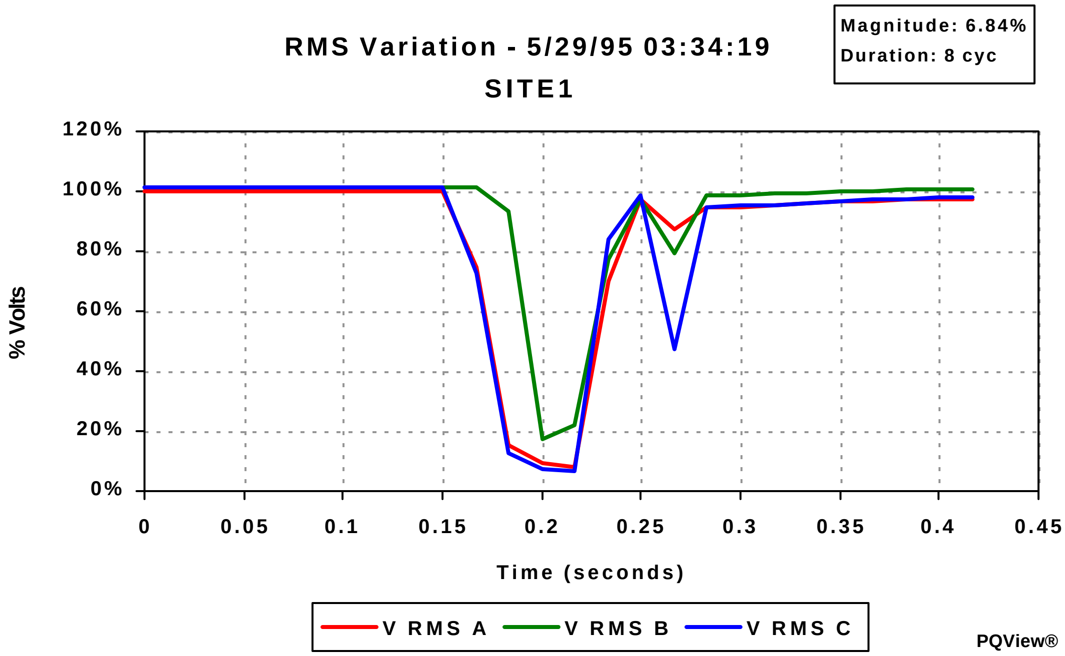

Figure 43: RMS Variation Voltage 5/29/95 03:34:19

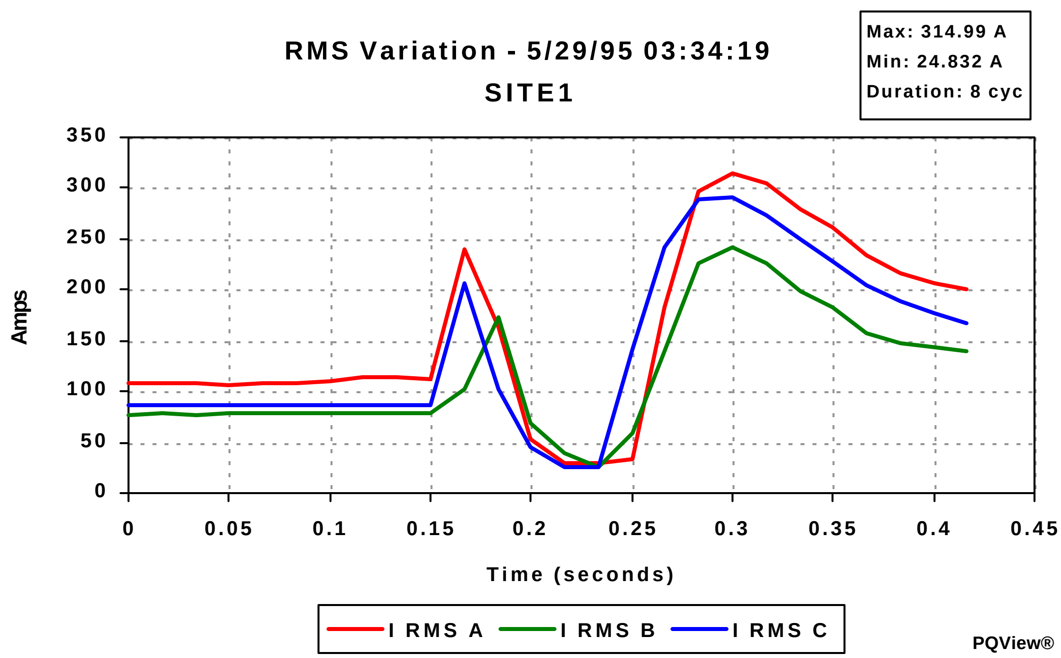

Figure 44: RMS Variation Current 5/29/95 03:34:19

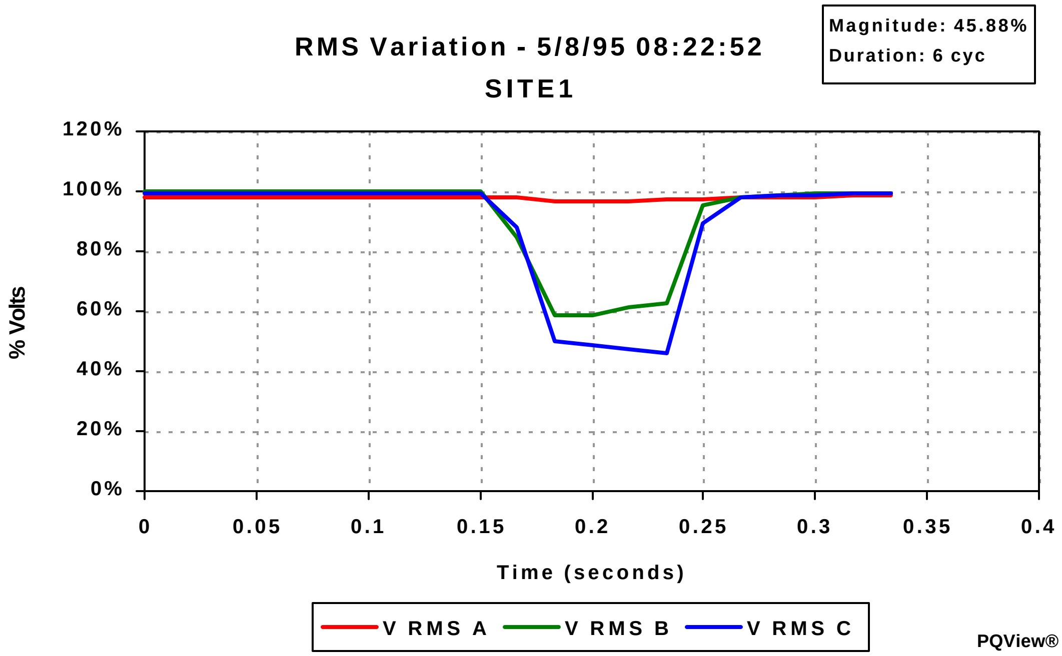

Figure 45: RMS Variation Voltage 5/8/95 08:22:52

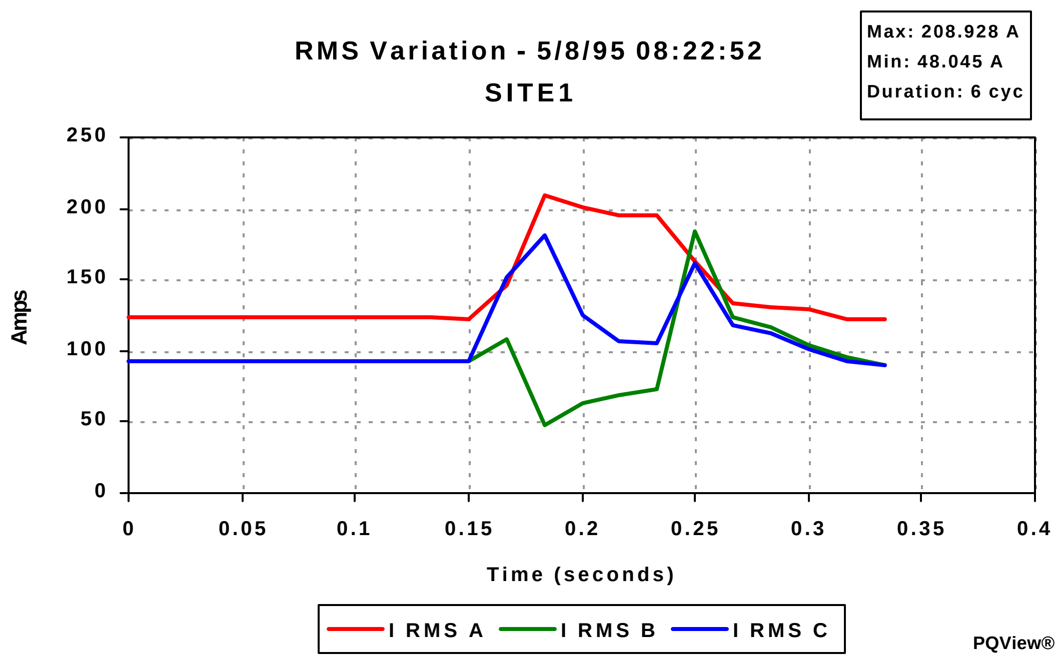

Figure 46: RMS Variation Current 5/8 /95 08:22:52

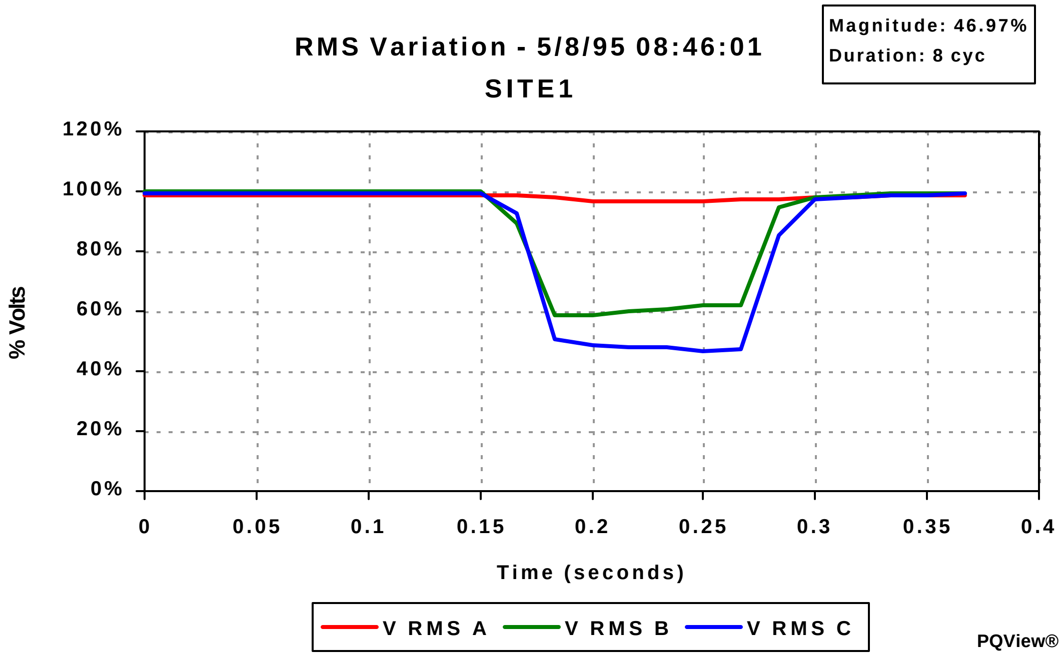

Figure 47: RMS Variation Voltage 5/8/95 08:46:01

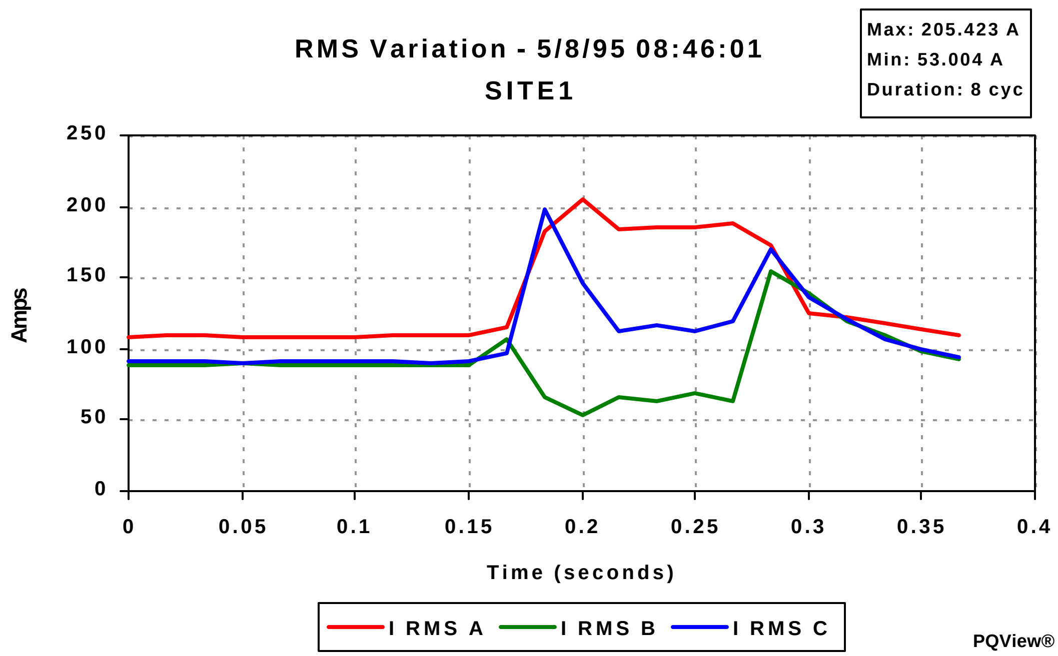

Figure 48: RMS Variation Current 5/8/95 08:46:01

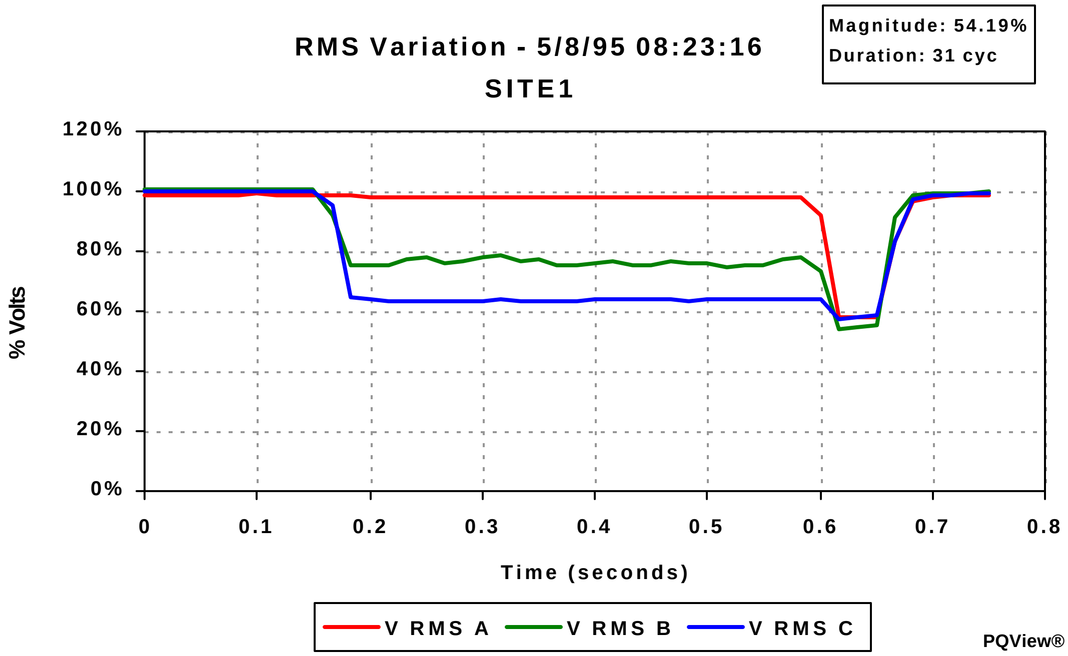

Figure 49: RMS Variation Voltage 5/8/95 08:23:16

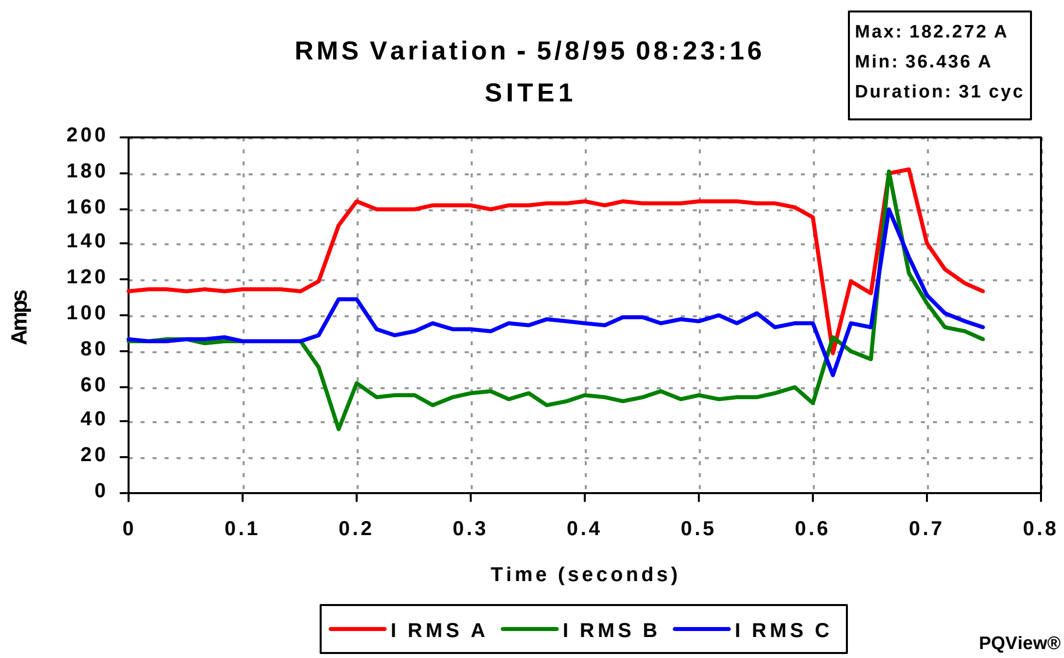

Figure 50: RMS Variation Current 5/8/95 08:23:16

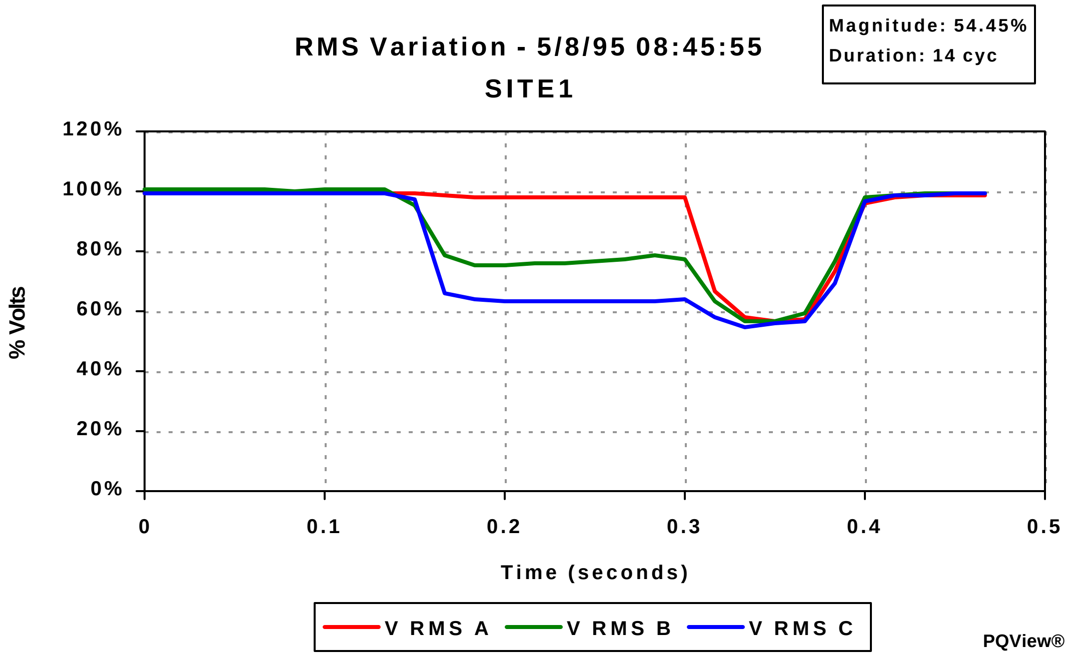

Figure 51: RMS Variation Voltage 5/8/95 08:45:55

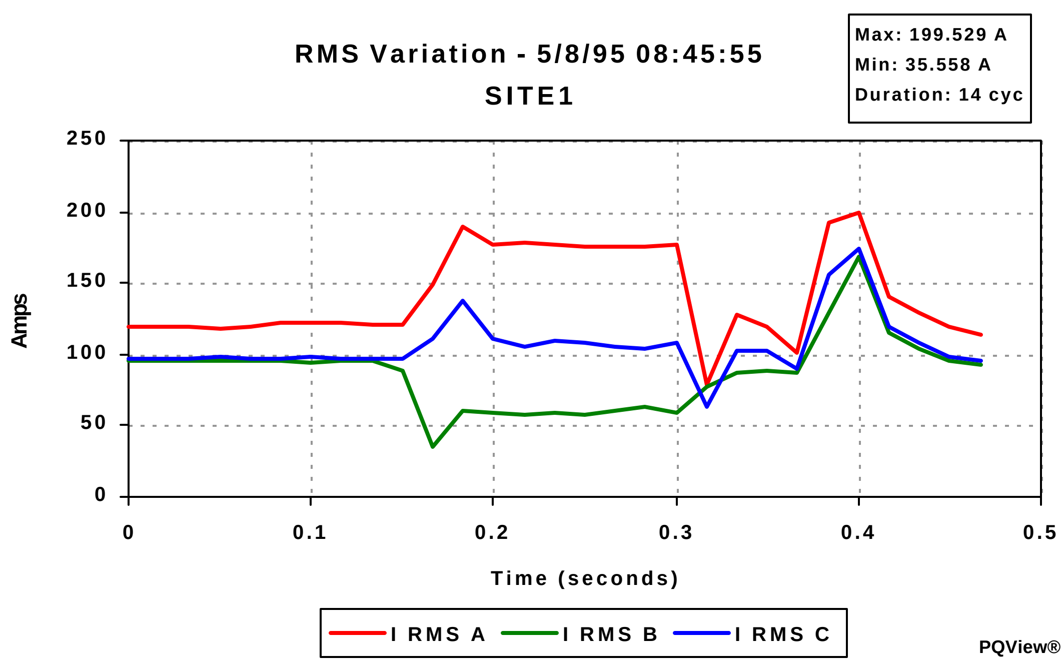

Figure 52: RMS Variation Current 5/8/95 08:45:55

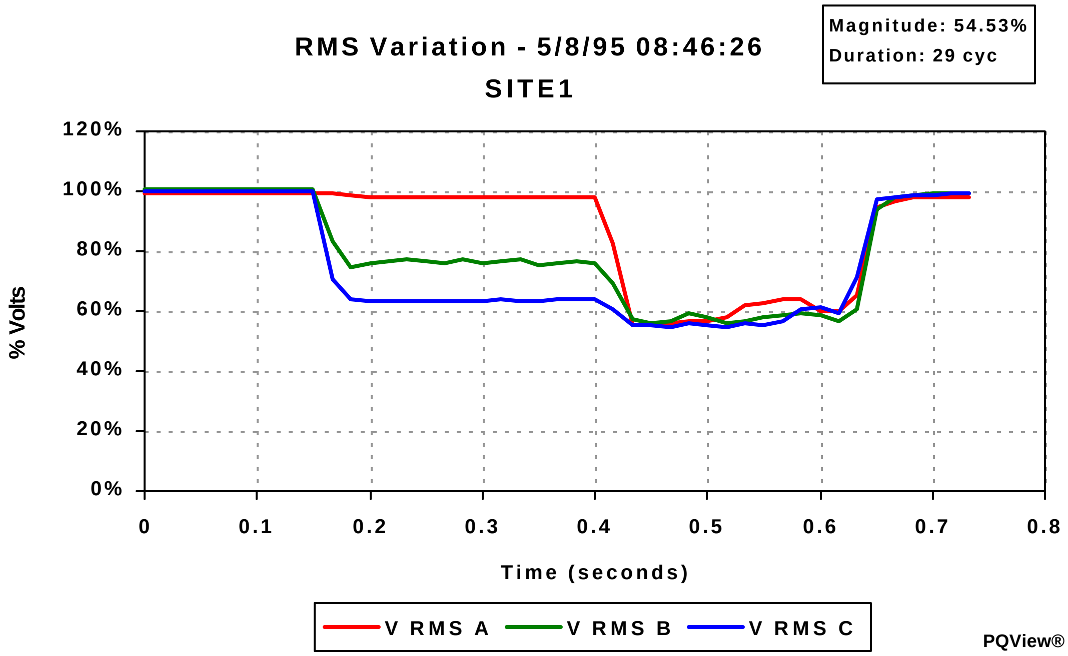

Figure 53: RMS Variation Voltage 5/8/95 08:46:26

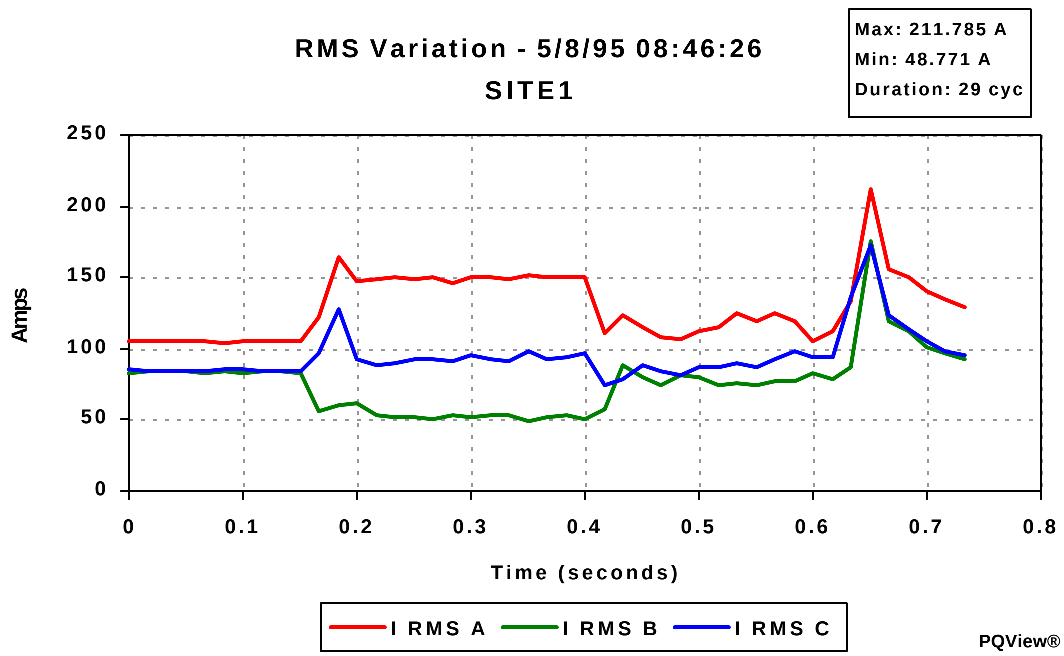

Figure 54: RMS Variation Current 5/8/95 08:46:26

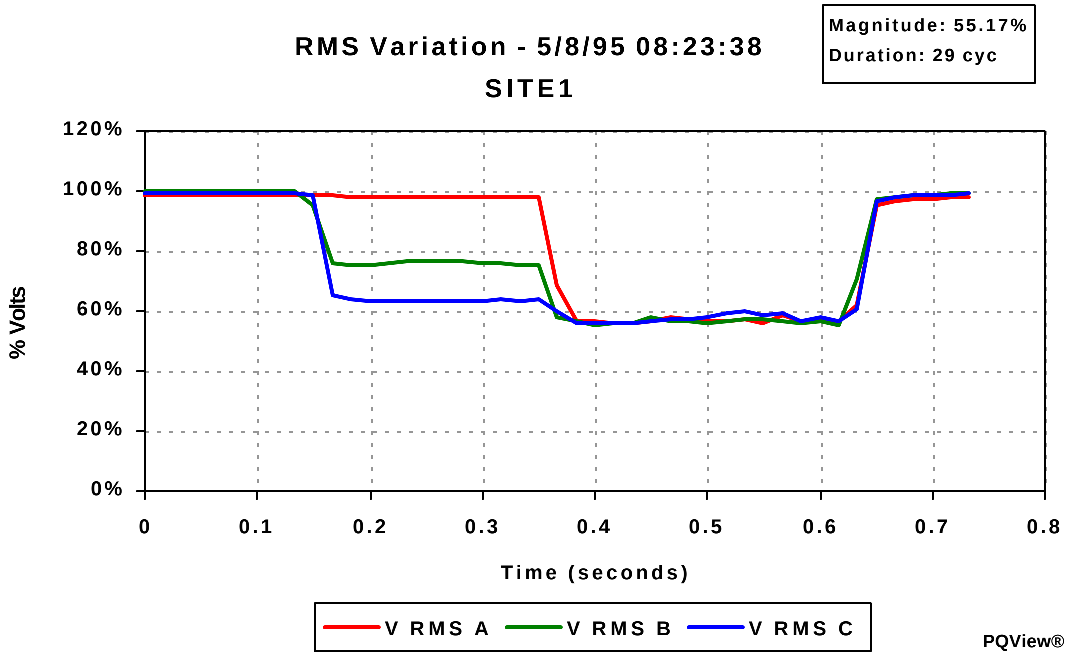

Figure 55: RMS Variation Voltage 5/8/95 08:23:38

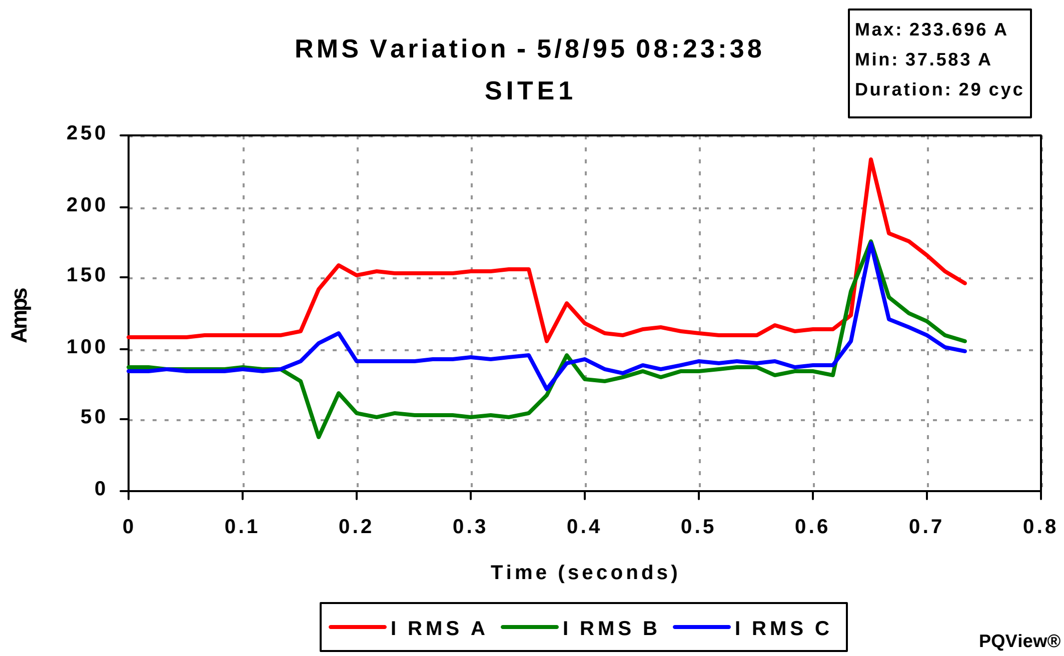

Figure 56: RMS Variation Current 5/8/95 08:23:38

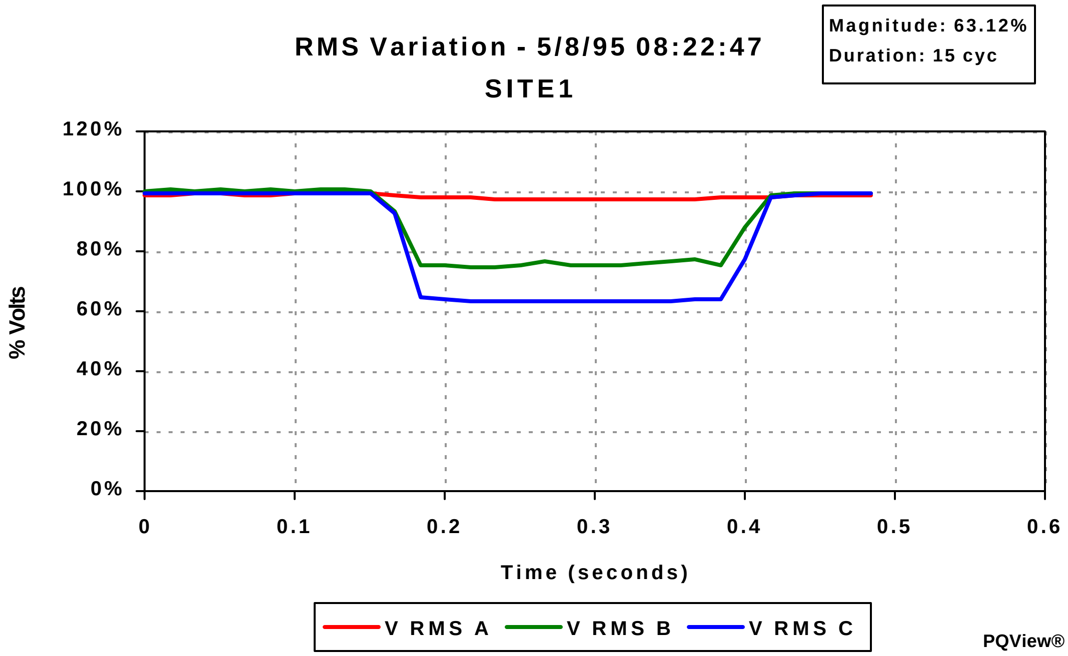

Figure 57: RMS Variation Voltage 5/8/95 08:22:47

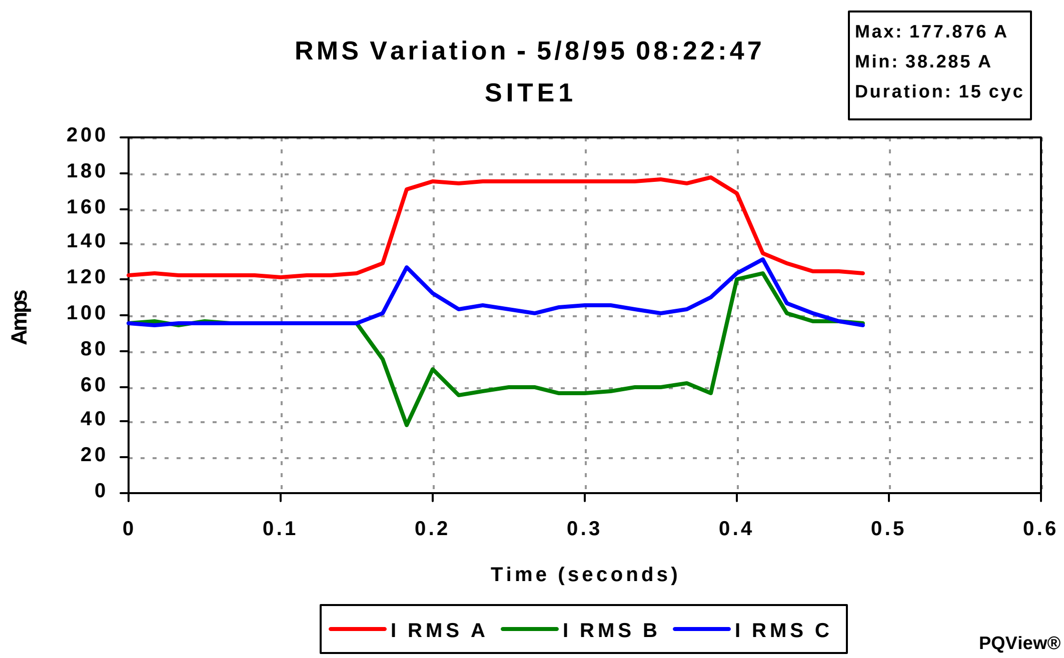

Figure 58: RMS Variation Current 5/8/95 08:22:47

1.12 Transient Overvoltages

Transient overvoltages can result from capacitor switching events on the utility system, from other switching events or lightning surges on the utility system, or from switching events within the facility. It is often difficult to determine the cause of transient overvoltages without detailed logs of switching times for equipment on the system and possible correlation with lightning events in the vicinity.

The following chart summarizes transient overvoltage performance by providing a histogram of transient overvoltages during the monitoring period. The height of each column represents the number of times that a transient overvoltage event was detected, while the histogram's label shows what was the absolute peak voltage magnitude of the transient. The absolute peak voltage, which is dependent on the transient magnitude and the point on the fundamental frequency voltage waveform at which the event occurs, is important for dielectric breakdown evaluation.

Only absolute peak magnitudes between 1.05 per unit and 4.0 per unit were included in this histogram. Additionally, only those events were evaluated that had principal switching frequencies between 220 Hz and 3000 Hz. A time filter was also applied that excluded events with durations longer than one cycle.

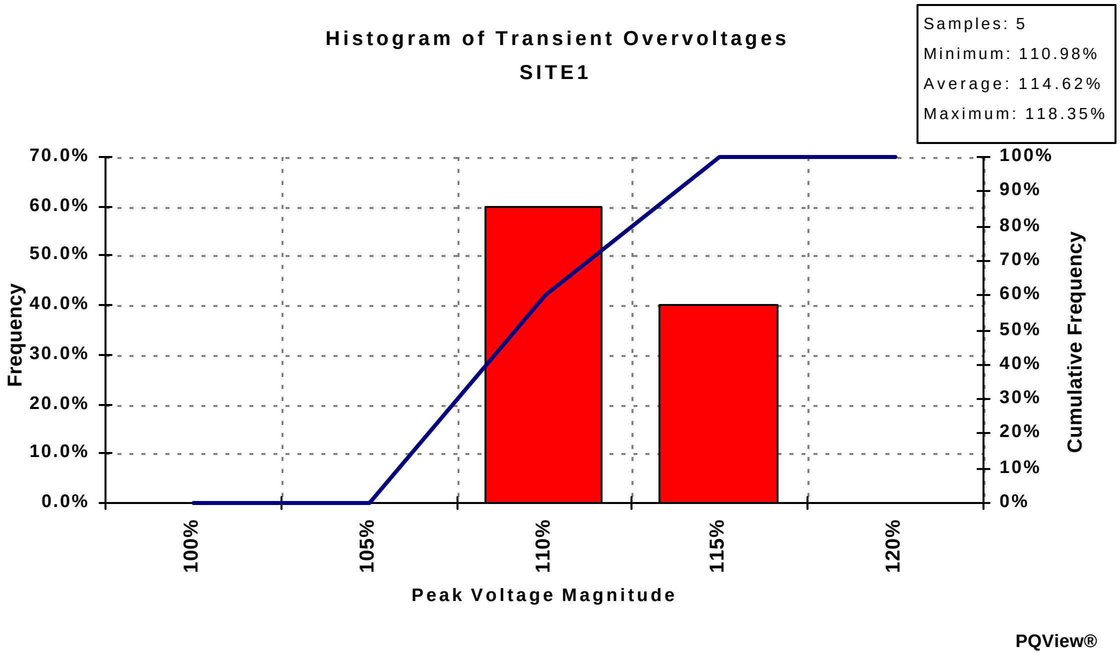

Figure 59: Histogram of Transient Overvoltages

1.13 Compliance with Planning Limit Default

This section of the report presents summary tables that evaluate compliance with planning limits.

1.13.1 RMS Voltage Compliance

The steady-state rms voltage must remain within the range of 90.00% to 110.00%, and must comply with this limit 95.00% of the time.

Table 11: Statistics of RMS Voltage Compliance

Min	CP05	Avg	CP95	Max	Percent Below	Percent Above	Compliance
93.10%	94.84%	98.60%	100.62%	101.07%	0.00%	0.00%	100.00%

1.13.2 Voltage Unbalance Compliance

The ratio of the negative-sequence voltage to the positive-sequence voltage must remain less than 2.00%, and must comply with this limit 95.00% of the time.

Table 12: Statistics of Voltage Unbalance Compliance

Min	CP05	Avg	CP95	Max	Percent Above	Compliance
0.18%	0.34%	0.59%	0.86%	7.65%	0.07%	99.93%

1.13.3 Voltage THD Compliance

The total harmonic voltage distortion (THD-V) must remain less than 5.00%, and must comply with this limit 95.00% of the time.

Table 13: Statistics of Voltage THD Compliance

Min	CP05	Avg	CP95	Max	Percent Above	Compliance
0.00%	0.34%	0.58%	0.79%	19.81%	0.07%	99.93%

1.13.4 Voltage Harmonics Compliance

Each harmonic component has limits that differ with frequency, and must comply with its limit for at least 95.00% of the time.

Table 14: Statistics of Voltage Harmonics Compliance

Harmonic	Min	CP05	Avg	CP95	Max	Percent Above	Compliance
3	0.00%	0.13%	0.33%	0.50%	7.28%	0.07%	99.93%
5	0.00%	0.10%	0.37%	0.64%	4.11%	0.07%	99.93%
7	0.00%	0.00%	0.07%	0.23%	2.81%	0.00%	100.00%

1.13.5 95.00% Power Frequency (Hz) Compliance

The system frequency must remain within the range of 59.4 to 60.6 Hz, and must comply with this limit 95.00% of the time.

Table 15: Statistics of 95.00% Power Frequency (Hz) Compliance

Min	CP05	Avg	CP95	Max	Percent Below	Percent Above	Compliance
59.86	59.99	60.01	60.02	60.04	0.00%	0.00%	100.00%

1.13.6 100.00% Power Frequency (Hz) Compliance

The system frequency must remain within the range of 56.4 to 62.4 Hz, and must comply with this limit 100.00% of the time.

Table 16: Statistics of 100.00% Power Frequency (Hz) Compliance

Min	CP05	Avg	CP95	Max	Percent Below	Percent Above	Compliance
59.86	59.99	60.01	60.02	60.04	0.00%	0.00%	100.00%