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March 12, 2020

PLANT POWER QUALITY STUDY

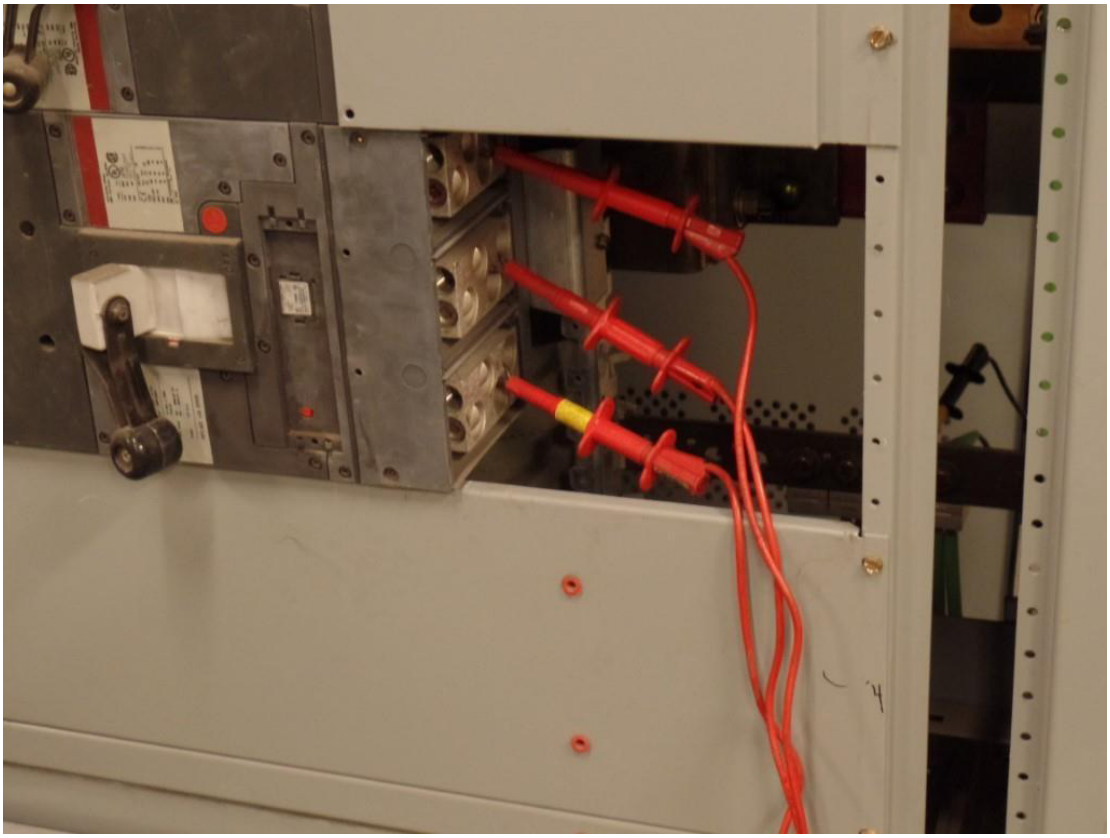
On Tuesday, February 18, 2020, I met with , Process Engineer II and , Lead Electrical Engineer from ., and , Plant Manager and , Assistant Plant Manager at at 5:00 AM at the Hilton Garden Inn Hotel in . I had been contracted by . to conduct a Power Quality Study of their plant electrical system.

We rode out to the plant and met in the conference room to discuss the problems the plant had been experiencing and what they wanted to monitor to investigate the causes for the problems. It was determined that almost all of the testing could be completed in the Main Electrical Power Room in the main building. I used a Dranetz Model 658 Power Quality Analyzer with a Dell computer for data storage and analysis.

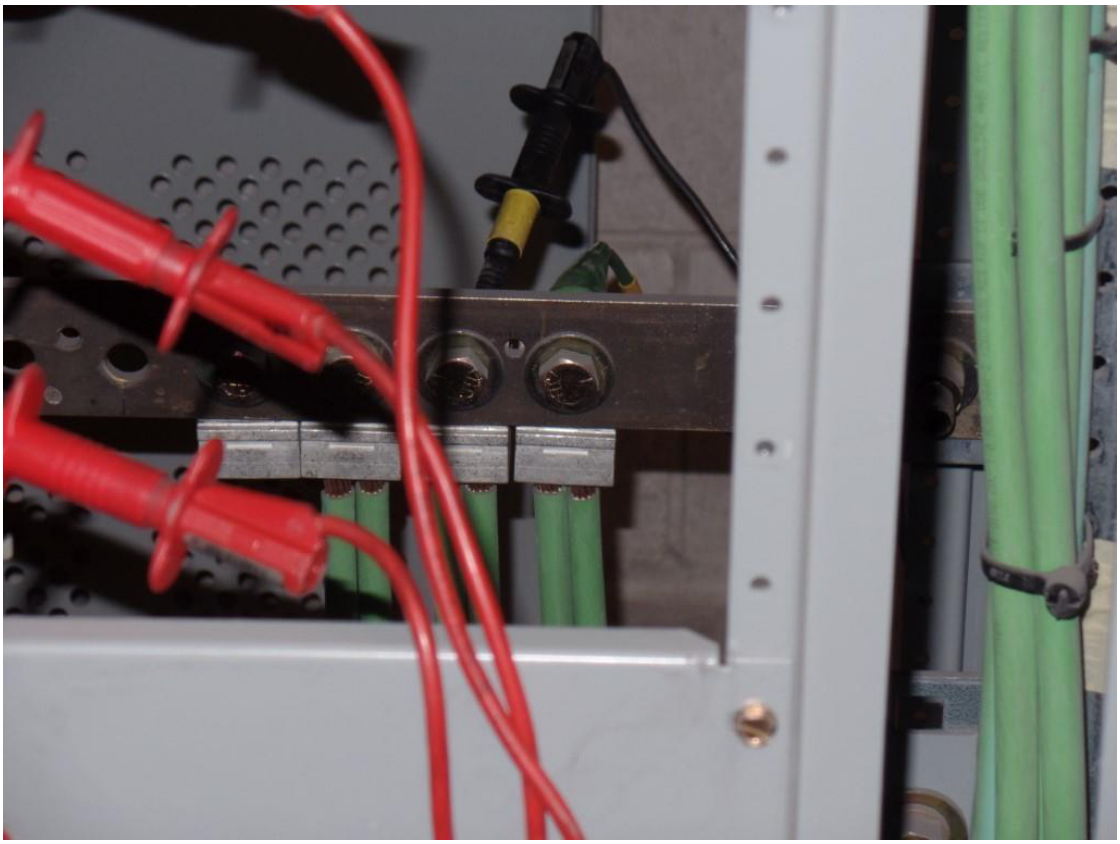
We began at the Main Service Entrance /Main Distribution Panel. This is a 480Y/277 Volt, 3 Ø, 4-Wire + Ground, Wye electrical panel, with a 4000 Amp Main Bus.

I connected the Dranetz to the spare breaker at the bottom of the row on the Main Distribution Panel.

Main Distribution Panel Test Setup



Electrical probes for each phase.



Neutral and Ground Lead connections

Current Clamp on Phase B

We set the Dranetz to monitor to voltage on Channel A from Phase A to Phase B, on Channel B from Phase B to Phase C, and on Channel C from Phase C to Phase A. Chart 1 shows the Summary of the readings for Channel A during the monitoring period which lasted for 2 minutes and 8 seconds before the Dranetz internal memory was full. The date was correct, but the time was not set properly. The actual time of the tests was from 08:11:30 to 08:13:38, Tuesday, February 18, 2020. There were 194 Events recorded during the monitoring period.

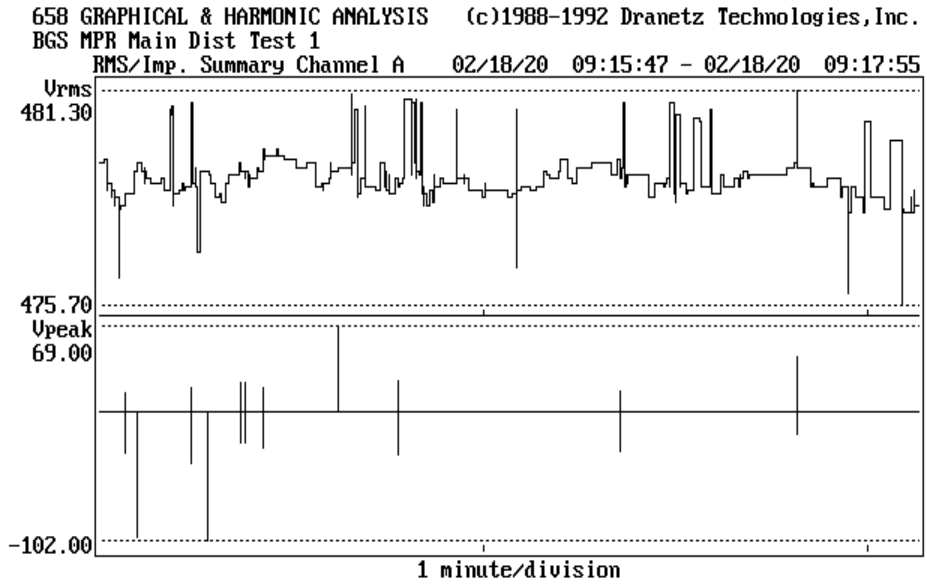


Chart 1

The chart shows the voltage fluctuating over a narrow range from 475.70 Vrms to 481.30 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 69.00 Vpeak Positive to 102.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic. If a sufficient number of these low-level, repetitive surge events flow down into the electrical distribution system and read motor windings, circuit boards, controls, computers, office equipment and other similar parts of the system, they have the capability to cause cumulative damage over time. The cumulative damage can result in the loss of processors, circuit boards, controls, drives, PLCs, motors, lighting, office equipment, control room monitoring equipment, and other critical equipment in the plant.

Chart 2 shows the Summary of the readings for Channel B.

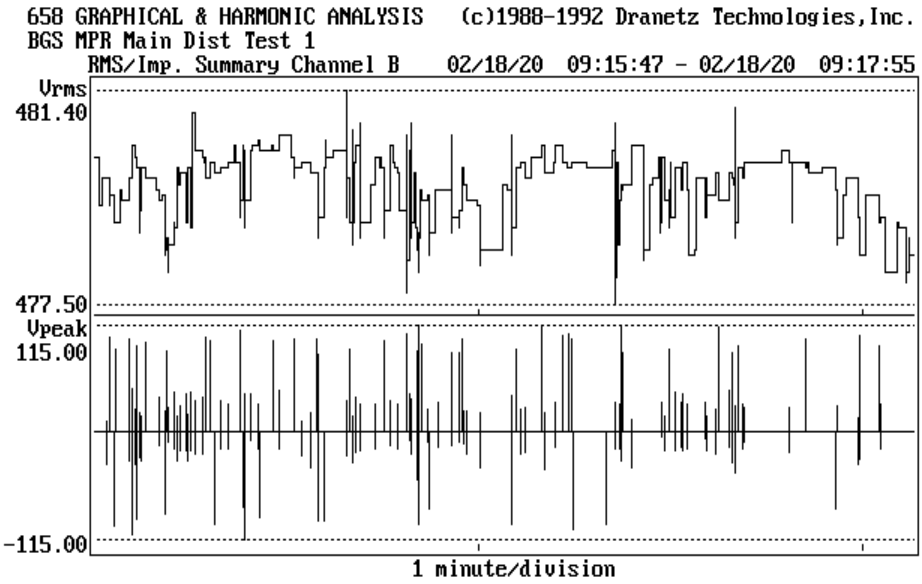


Chart 2

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 477.50 to 481.40 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. There is a noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 3 shows the Summary of the readings from Channel C.

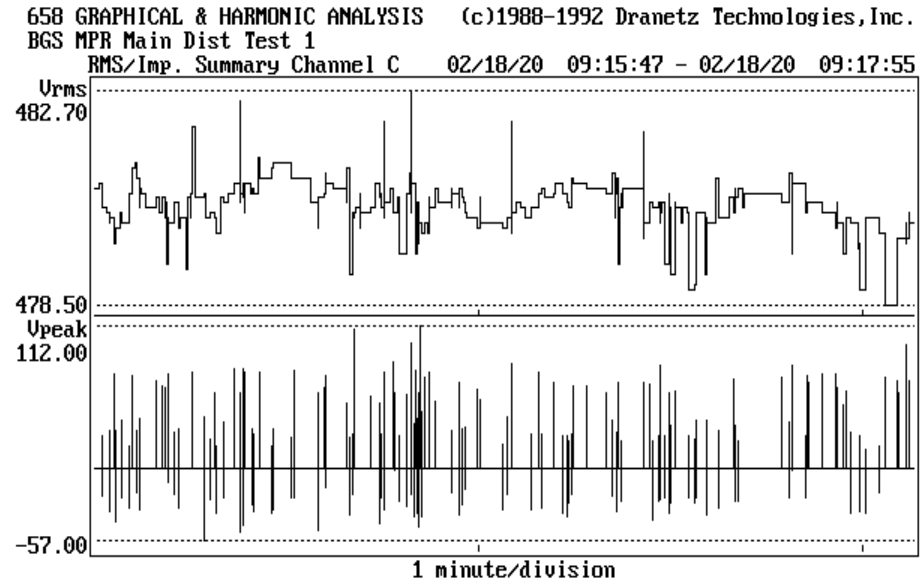


Chart 3

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 478.50 to 482.70 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. There is a further increase in the number of surge events

recorded on Phase C to Phase A mode over those recorded on Phase A to Phase B mode and Phase B to Phase C mode.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 4, is from Event #14 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

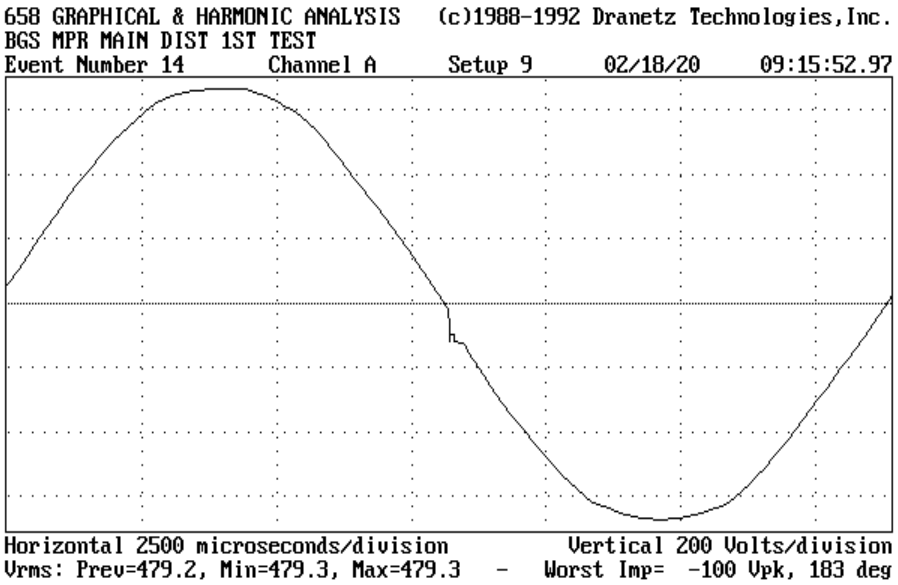


Chart 4

This event has a negative 100 Vpeak surge. As an individual event, it would have no negative impact on the electrical system or equipment. However, these surge events are occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 5 from Event #14 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

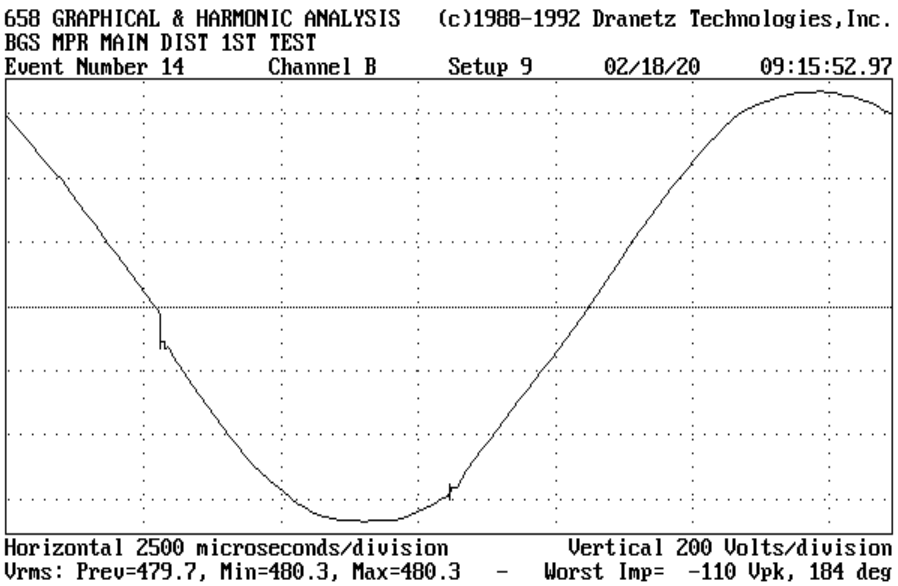


Chart 5

Chart 5 for event #14 shows two surges, the most severe is a negative 110 Vpeak, at 184°. The voltage is stable at 480.3 Vrms. There is a smaller surge at approximately 280°. Just as on Channel A Chart 5, this 110 Vpeak surge event is occurring repeatedly throughout the monitoring period. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A. The increase in numbers of surge events could be from an imbalance in the equipment loads up line at the mine which supplies the power to the / plant.

Chart 6 from Event #14 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

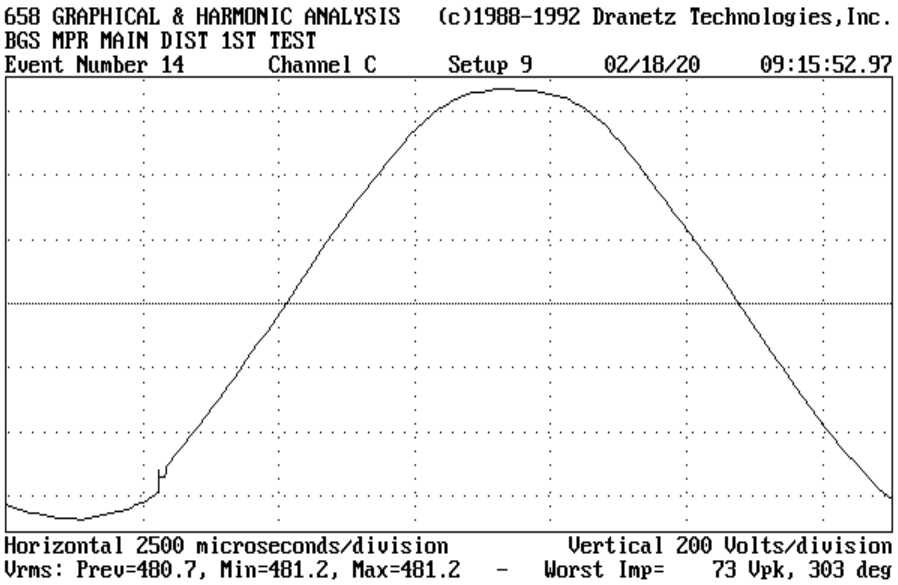


Chart 6

Chart 6 for Event #14 shows a 73 Vpeak surge at the 303° point on the wave form. The voltage holds steady at 481.2 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 115 Vpeak to a negative 115 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

A second test with the same setup was run to verify the original readings. Chart 7 shows the Summary of the readings for Channel A during the monitoring period which lasted for 1 minute and 59 seconds before the Dranetz internal memory was full. The time of the tests was from 09:48:53 to 09:50:52, Tuesday, February 18, 2020. There 206 Events recorded during the monitoring period.

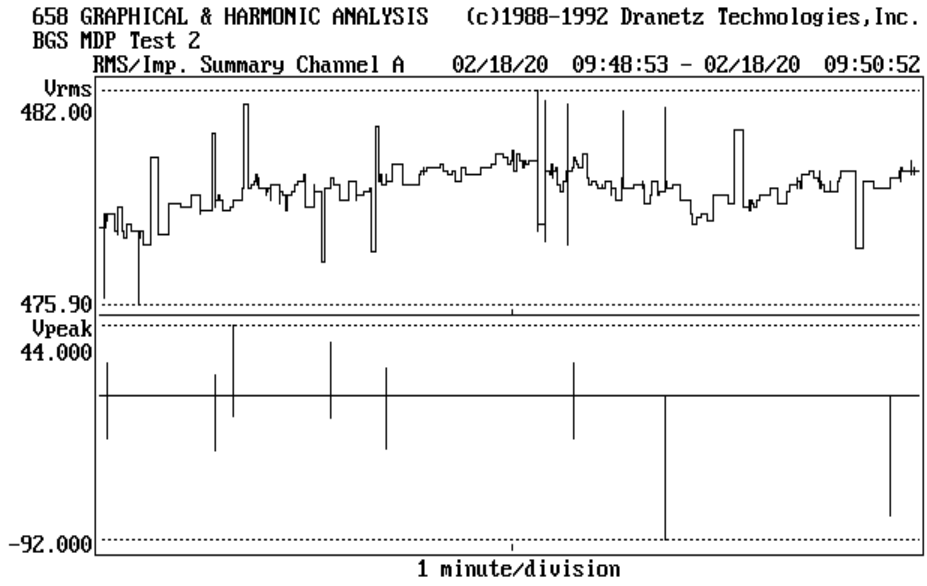


Chart 7

The chart shows the voltage fluctuating over a narrow range from 475.90 Vrms to 482.00 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 44.00 Vpeak Positive to 92.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic. This verifies the readings from the first test.

Chart 8 shows the Summary of the readings for Channel B.

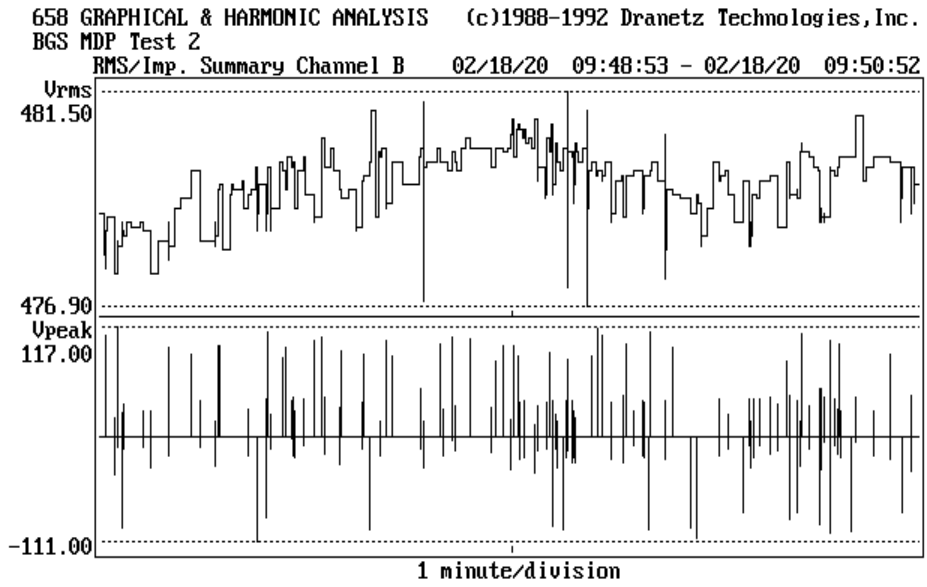


Chart 8

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 476.90 to 481.50 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events range from a positive 117.00 Vpeak to a negative 111.00 Vpeak. As in the first test, there is a noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 9 shows the Summary of the readings from Channel C.

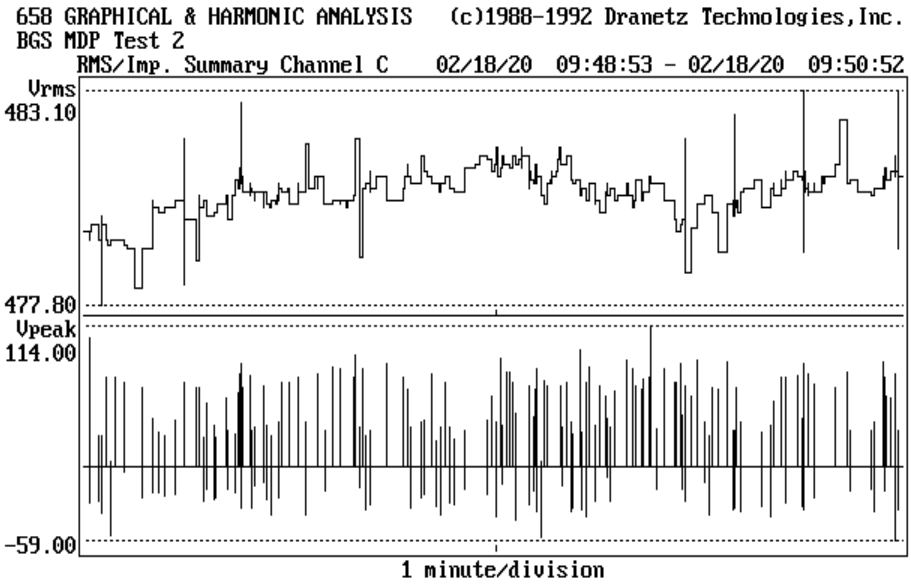


Chart 9

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 477.80 to 483.10 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events range from a positive 114.00 Vpeak to a negative 59.00 Vpeak. As with the first test, there is a further increase in the number of surge events recorded on Phase C to Phase A mode over those recorded on Phase A to Phase B mode and Phase B to Phase C mode.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 10, is from Event #3 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

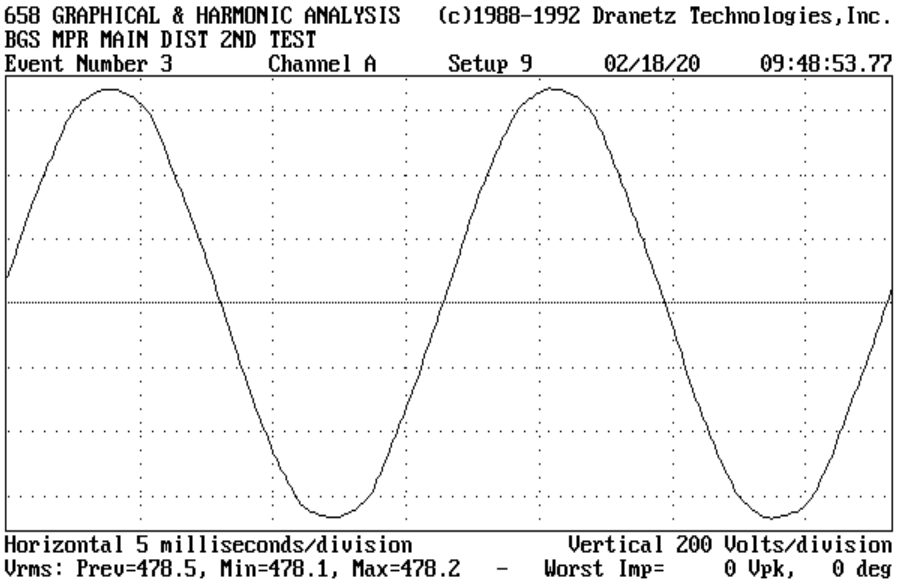


Chart 10

This event has no detectable surge activity. It is somewhat unusual on a 3 Ø, 3-Wire system for one phase to have no surge activity and the other two phases record surge activity. This may be the result of unbalanced loads or an unequal distribution of 1 Ø and 2 Ø loads on the mine equipment up line.

Chart 11 from Event #3 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

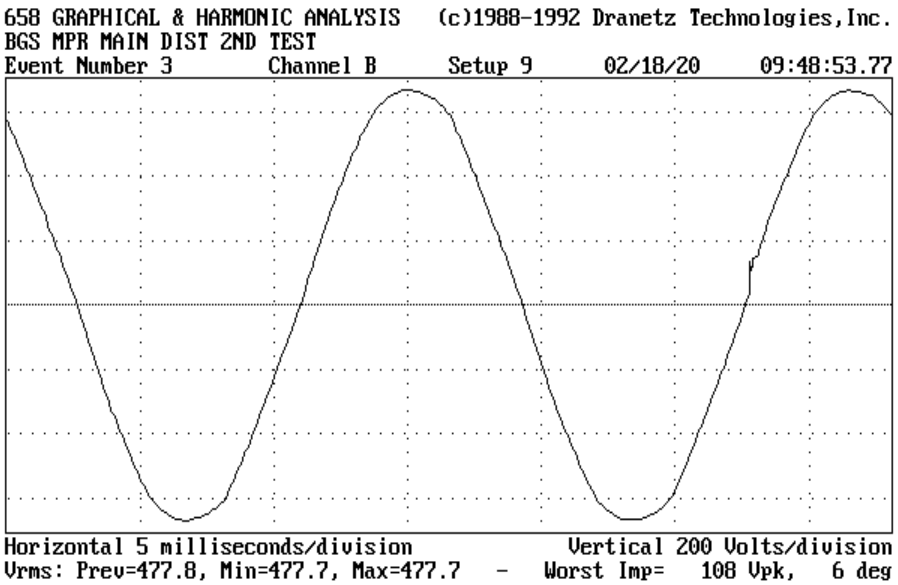


Chart 11

Chart 11 for event #3 shows a surge of 108 Vpeak, at 6°. The voltage is stable at 477.7 Vrms. This 108 Vpeak surge event is occurring repeatedly throughout the monitoring period. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A. The increase in numbers of surge events could be from an imbalance in the equipment loads up line at the mine which supplies the power to the plant.

Chart 12 from Event #3 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

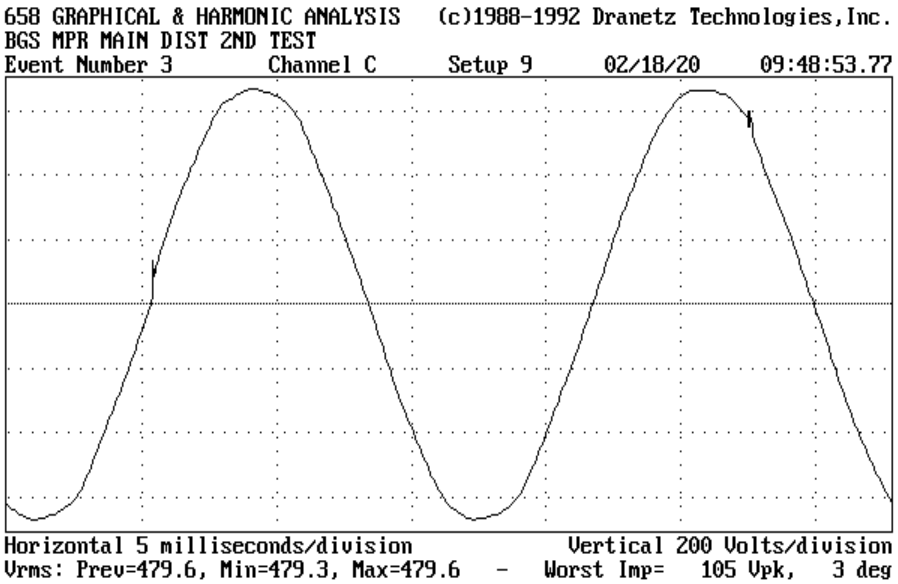


Chart 12

Chart 12 for Event #3 shows a 105 Vpeak surge at the 3° point on the wave form. There is a smaller surge event at approximately the 100° point of the following waveform. The voltage holds steady at 479.6 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 121 Vpeak to a negative 117 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

For the third test the Dranetz was again set to monitor to voltage on Channel A from Phase A to Phase B, on Channel B from Phase B to Phase C, and on Channel C from Phase C to Phase A. For this test Channel D recorded the Phase B current. At this point the clock on the Dranetz had been set to the correct time. Chart 13 shows the Summary of the readings for Channel A during the monitoring period which lasted for 7 minutes and 26 seconds before the Dranetz internal memory was full. The time of the tests was from 10:41:50 to 10:49:16, Tuesday, February 18, 2020. There were 288 events captured during the monitoring.

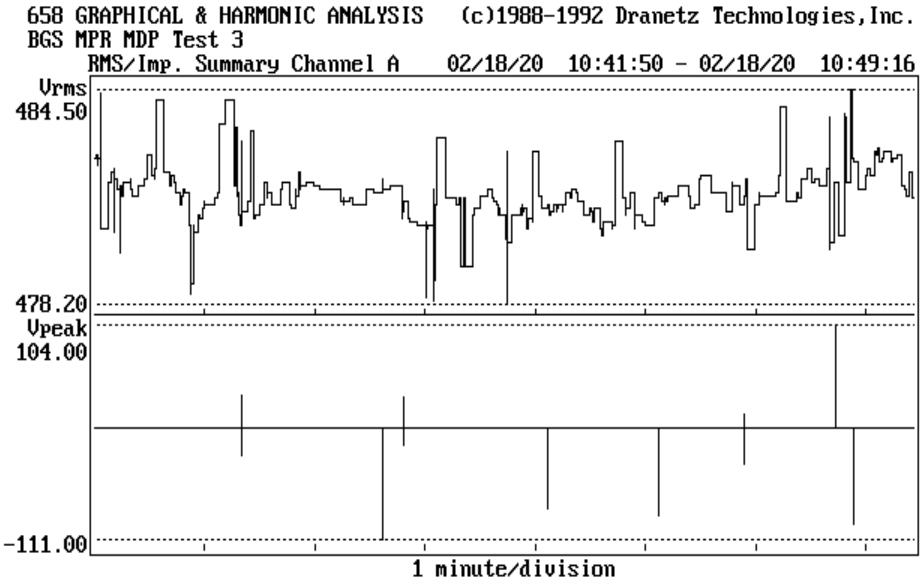


Chart 13

The chart shows the voltage fluctuating over a narrow range from 478.20 Vrms to 484.50 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 104.00 Vpeak Positive to 111.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 14 shows the Summary of the readings for Channel B.

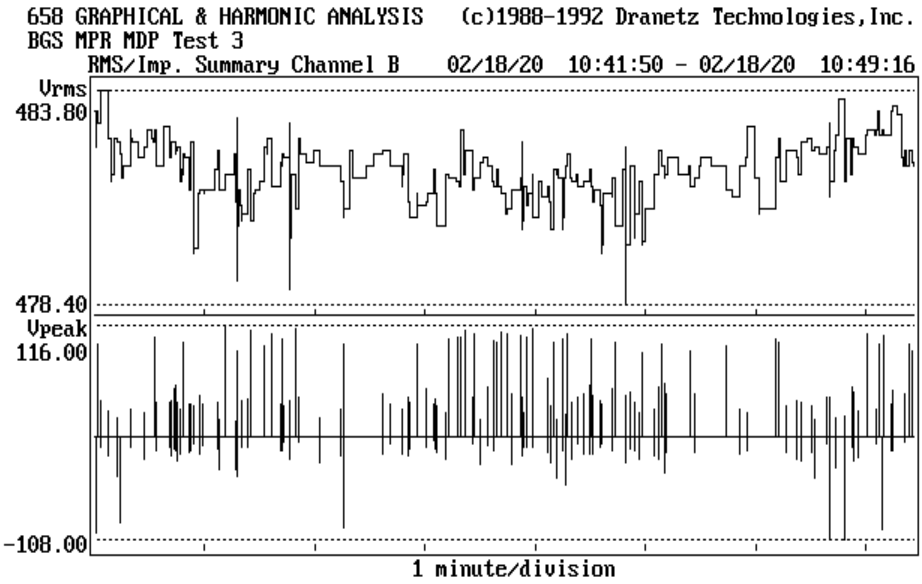


Chart 14

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 478.40 to 483.80 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 116.00 Vpeak to a negative 108.00 Vpeak. There is a very noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 15 shows the Summary of the readings from Channel C.

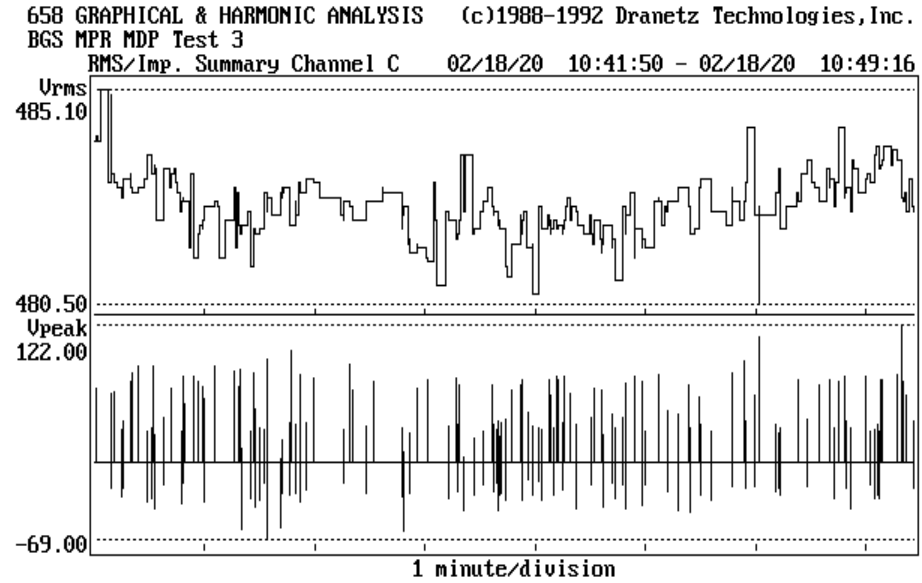


Chart 15

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 480.50 to 485.10 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage

surge events recorded during the same period. The surge events ranged from a positive 122.00 Vpeak to a negative 69.00 Vpeak. There is a further increase in the number of surge events.

Chart 16 shows the Summary of the current readings from Phase A.

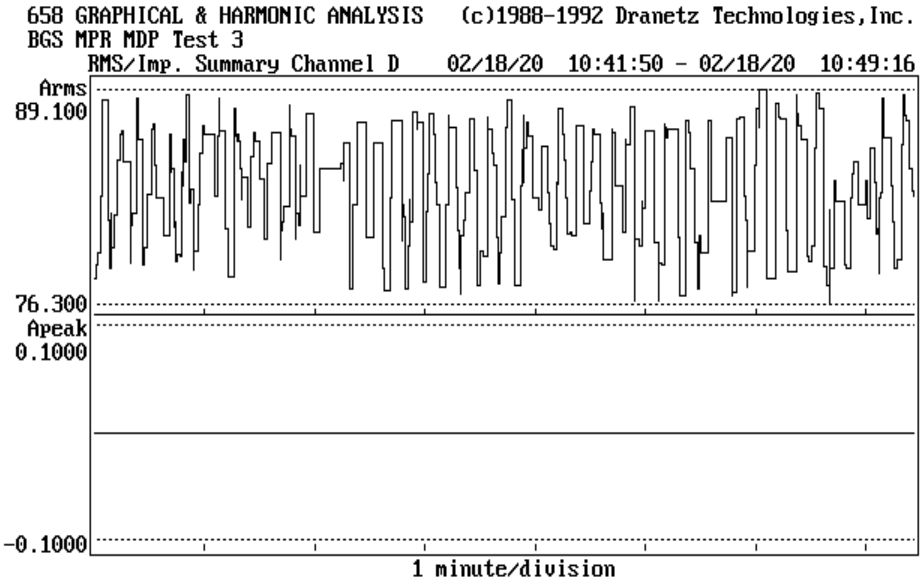


Chart 16

The current on Phase A fluctuates mildly from 76.300 Arms to 89.100 Arms and there were no recorded surge current events. This is an indication that the voltage surge events captured at this point are originating up line from the monitoring point rather than from the down line plant equipment.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 17, is from Event #258 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

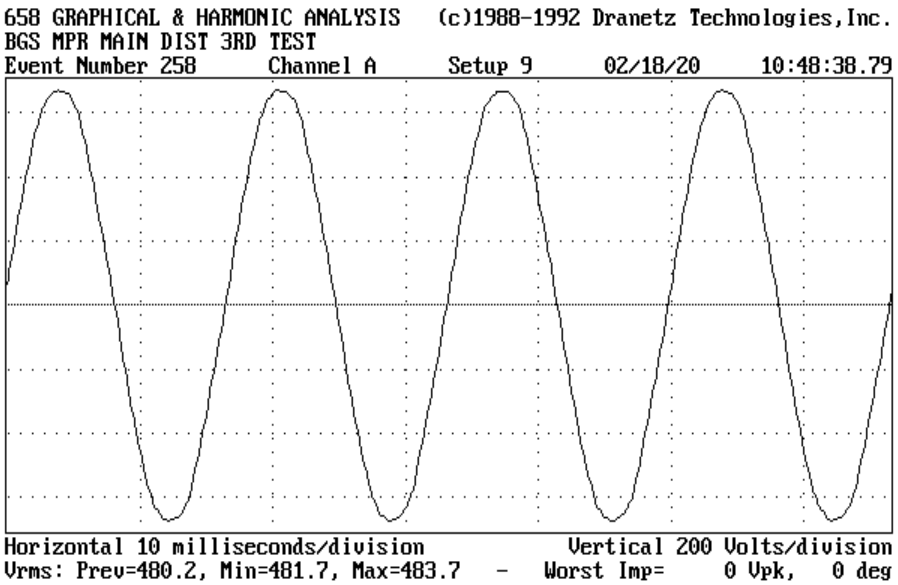


Chart 17

As with Test 2, this event had no surge activity recorded on Channel A. However, Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 18 from Event #258 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

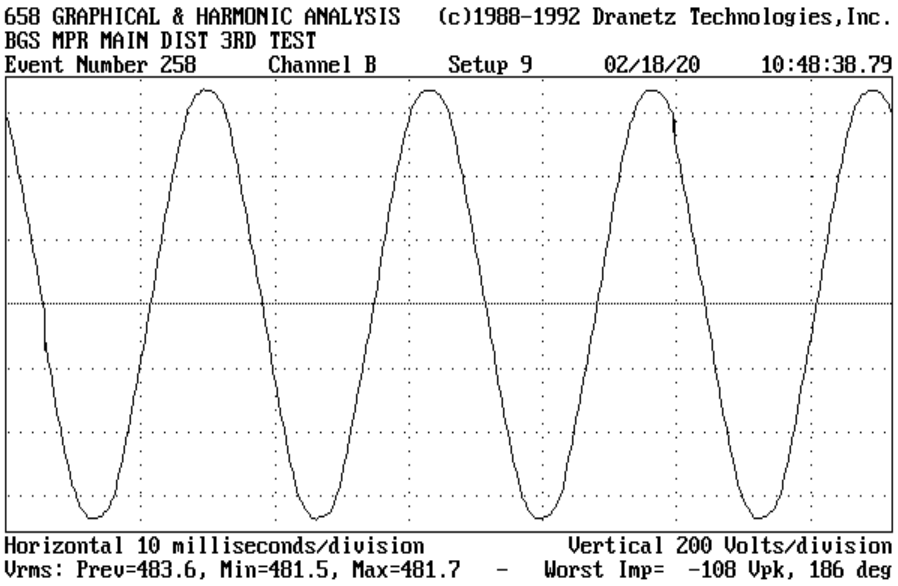


Chart 18

Chart 18 for event #258 shows a negative 110 Vpeak surge, at 184°. The voltage is stable at 481.73 Vrms. This surge event is occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 19 from Event #258 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

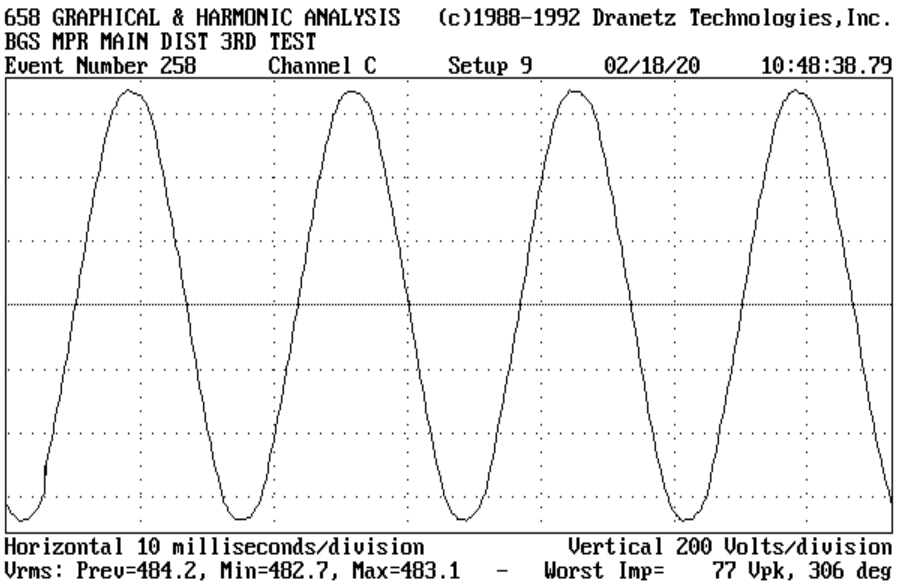


Chart 19

Chart 19 for Event #258 shows a 77 Vpeak surge at the 306° point on the wave form. The voltage holds steady at 482.7 to 483.1 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 122 Vpeak to a negative 111 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 20 is from Event #258 and shows the current on Phase B.

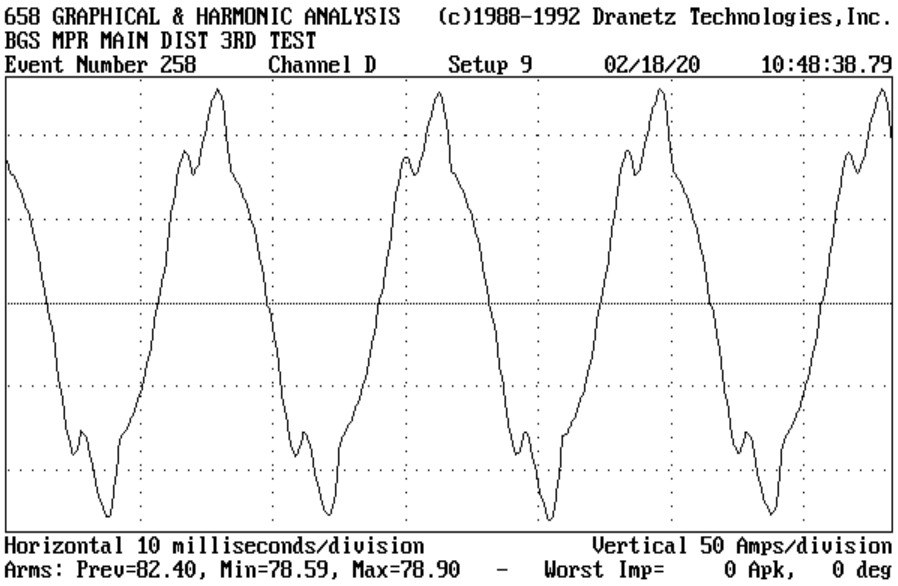


Chart 20

Chart 20 of Event #258 on Channel D shows the current on Phase B. The current is 78.59 to 78.90 Amps with no surge current reported. The distortion on the waveform is typical current harmonic distortion from the way the VFDs, bridge rectifiers and switch-mode power supplies are converting power from AC to DC.

Chart 21 is the Harmonic Analysis of Chart 20.

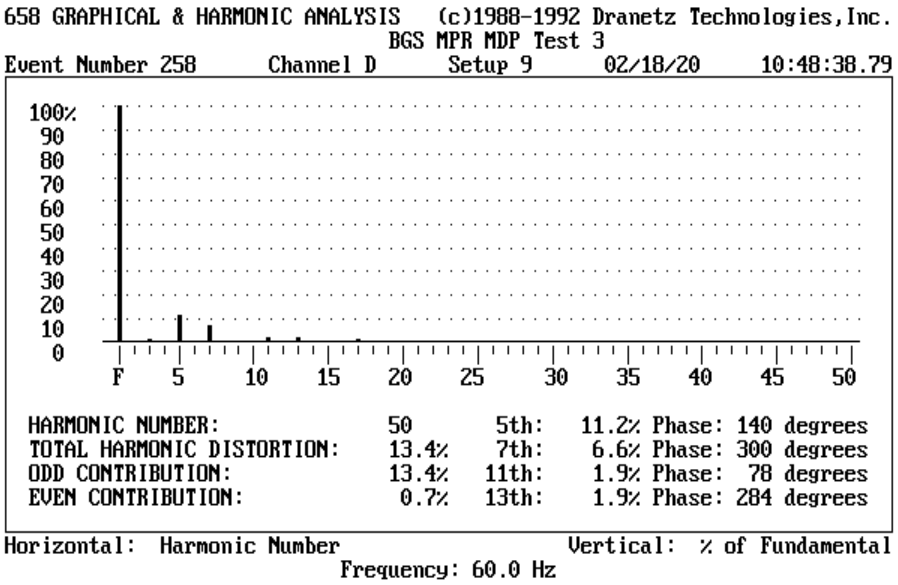


Chart 21

The harmonic levels for the current are in excess of the IEEE Standard 519-1992 limits of Total Harmonic Distortion (THD) of 5% and Individual Voltage Distortion (IVD) of 3%. Harmonic current limits are not actively enforced and are usually investigated only if voltage is distorted. It is common to have harmonic currents in excess of the IEEE 519-1992 limits without problems. Any problems will often be noticed in excessive voltage distortion first. Other than the surge events, the voltage waveforms display virtually no harmonic distortion.

A fourth test with the almost the same setup, except Channel D was measuring the current on Phase C, was run to verify the Test 3 readings. Chart 22 shows the Summary of the readings for Channel A during the monitoring period which lasted for 2 minutes and 14 seconds before the Dranetz internal memory was full. The time of the tests was from 12:15:57 to 12:18:11, Tuesday, February 18, 2020. There were 190 Events recorded during the monitoring period. The charts are mislabeled as Test 2. They are from Test 4.

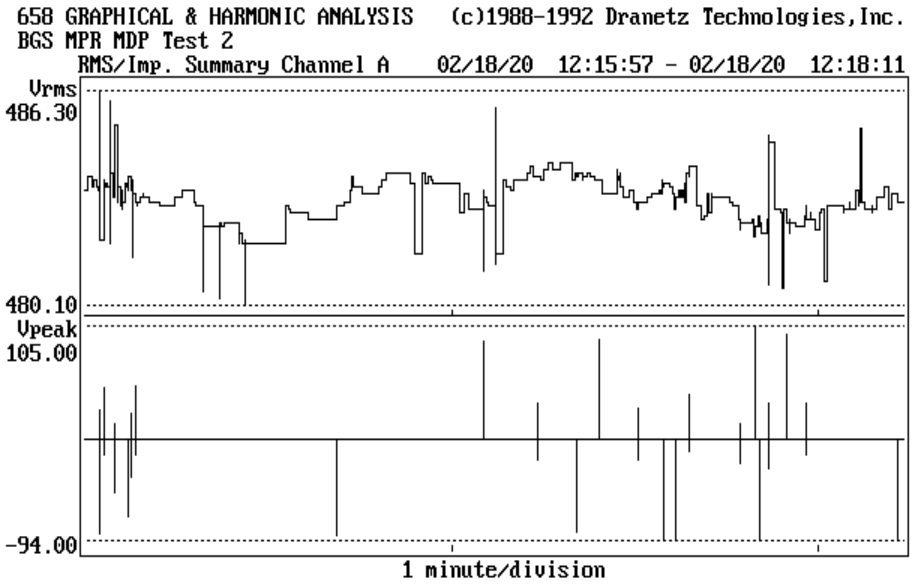


Chart 22

The chart shows the voltage fluctuating over a narrow range from 480.10 Vrms to 486.30 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 105.00 Vpeak Positive to 94.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic. This verifies the readings from the first test.

Chart 23 shows the Summary of the readings for Channel B.

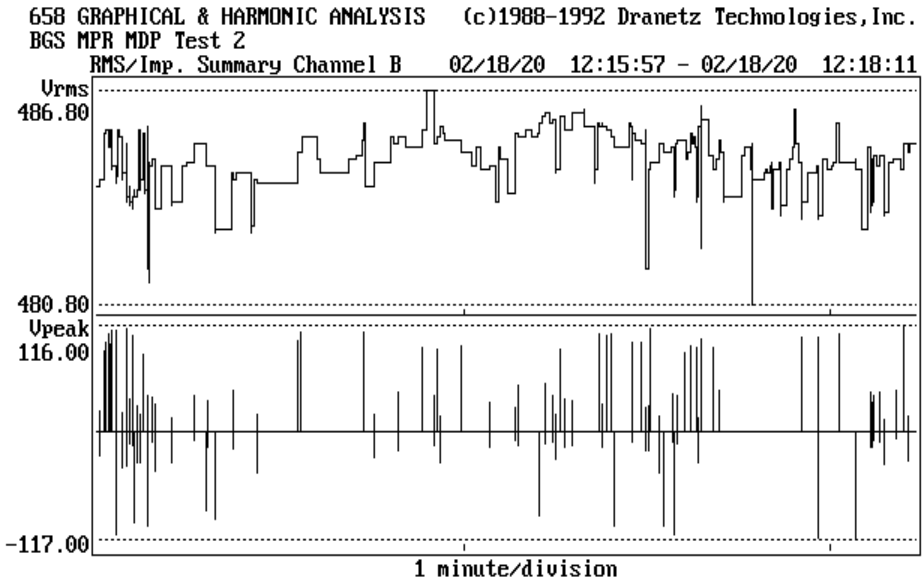


Chart 23

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 480.80 to 486.80 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events range from a positive 116.00 Vpeak to a negative 117.00 Vpeak. As in the first test, there is a noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 24 shows the Summary of the readings from Channel C.

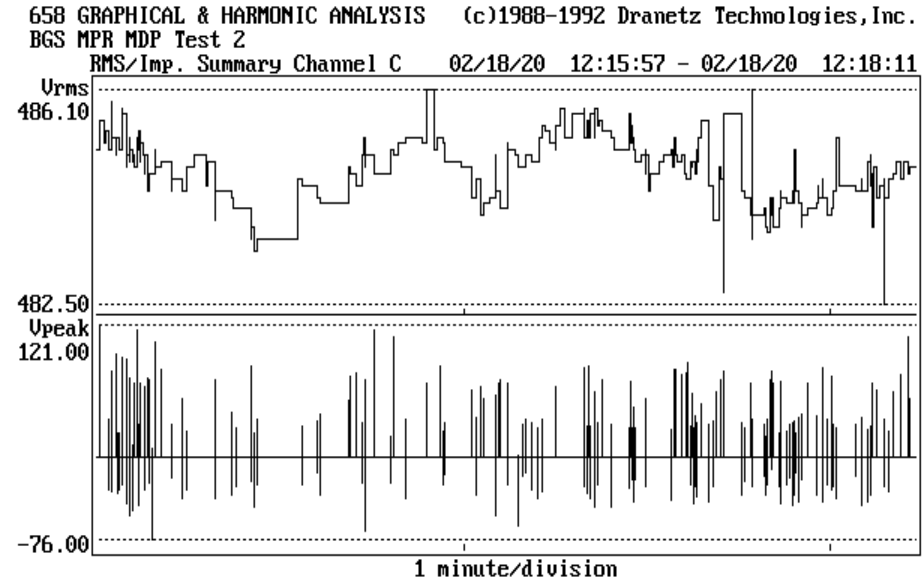


Chart 24

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 482.50 to 486.10 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events range from a positive 121.00 Vpeak to a negative 76.00 Vpeak. As with the first test, there is a further increase in the number of surge events recorded on Phase C to Phase A mode over those recorded on Phase A to Phase B mode and Phase B to Phase C mode.

Chart 25 shows Channel D with the Summary of the current on Phase C.

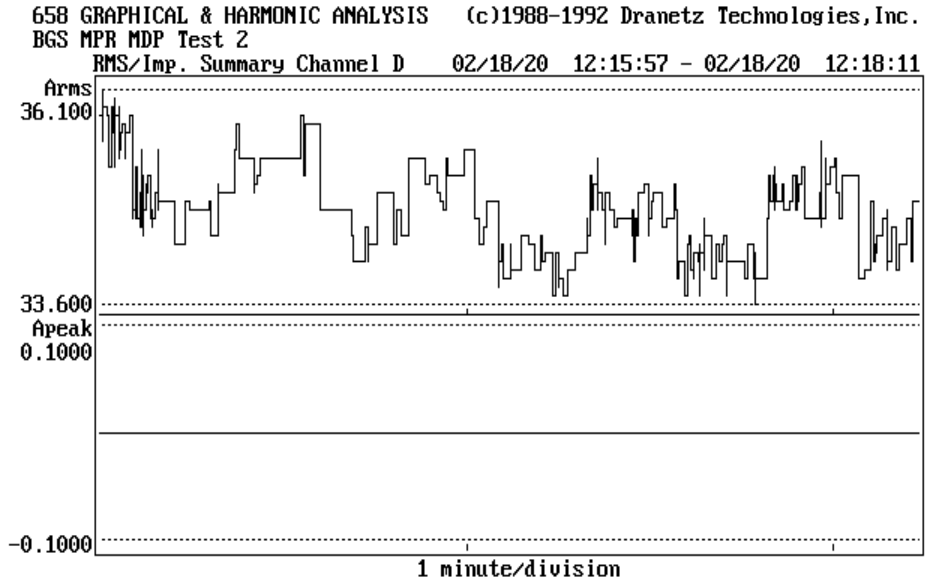


Chart 25

Chart 25 displays the Summary of the current on Phase C during the monitoring period. The Amperage ranges from 33.600 to 36.100 Amps. Although there are multiple changes in current during the 2 minutes and 14 seconds of the monitoring period, the amplitude of the changes is very small. There are no surge current events reported curing the monitoring period. The fact that there are no current spikes reported indicates that the voltage surge events are being generated up line in the supply power system. If the voltage surge events were originating from switching down line from the Main Distribution Panel, there should be surge current events to coincide with the voltage surge events.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 26, is from Event #101 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

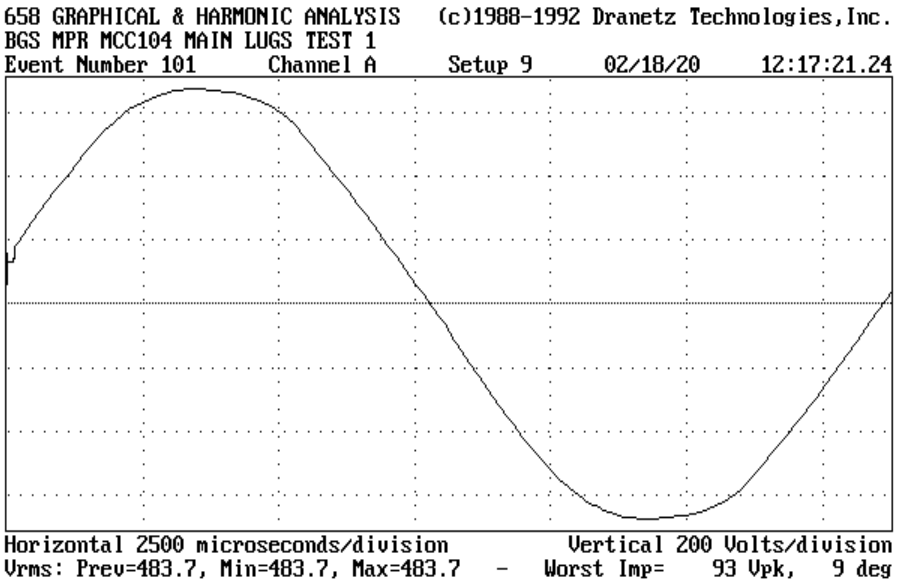


Chart 26

Chart 26 for event #101 shows a surge of negative 93 Vpeak, at 9°. This 93 Vpeak surge event is occurring repeatedly throughout the monitoring period. The voltage is stable at 483.7 Vrms.

Chart 27 from Event #101 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

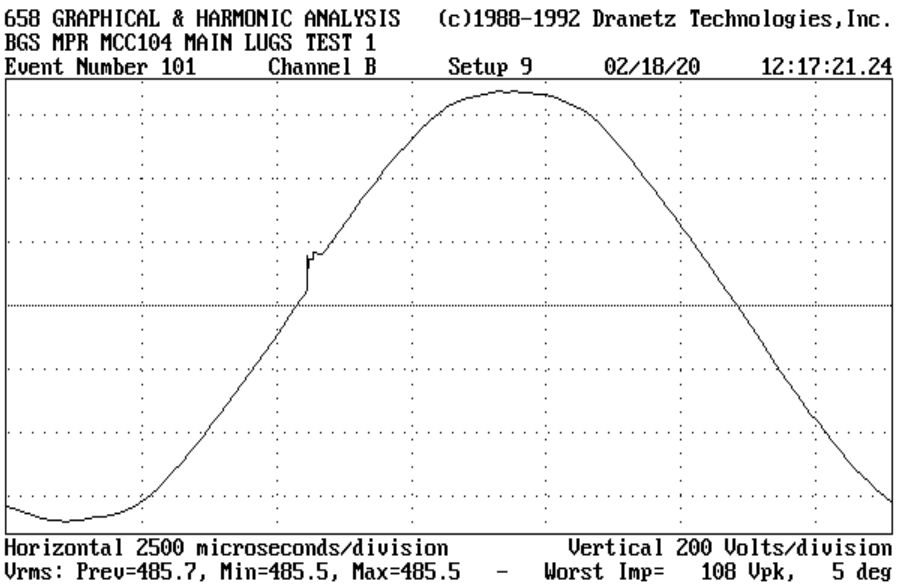


Chart 27

Chart 27 for event #101 shows a surge of 108 Vpeak, at 5°. The voltage is stable at 485.5 to 485.7 Vrms. This 108 Vpeak surge event is occurring repeatedly throughout the monitoring period. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of

surge events on Channel B over those on Channel A. The increase in numbers of surge events could be from an imbalance in the equipment loads up line at the mine which supplies the power to the plant.

Chart 28 from Event #101 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

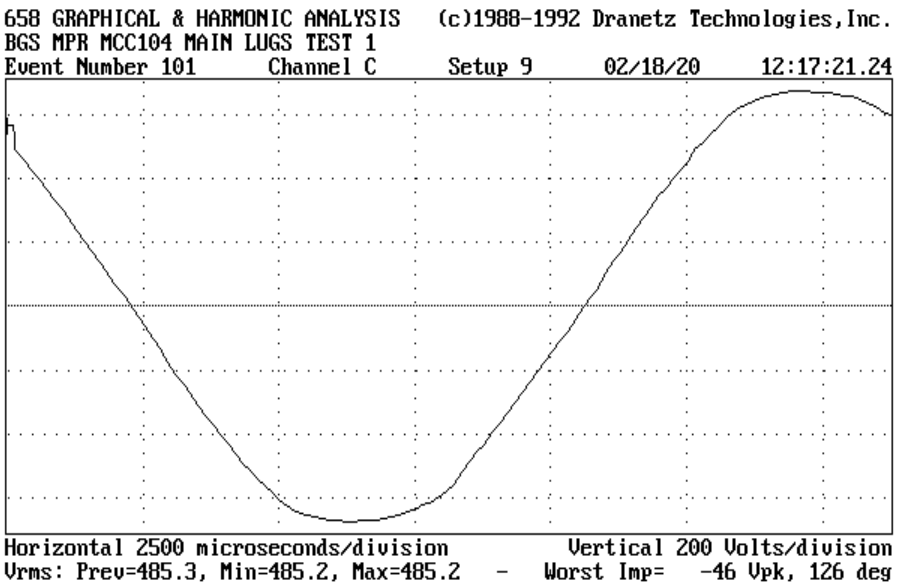


Chart 28

Chart 28 for Event #101 shows a negative 46 Vpeak surge at the 126° point on the wave form. The voltage holds steady at 485.2 to 485.3 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 121 Vpeak to a negative 117 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 29 shows the current on Phase C during Event #101.

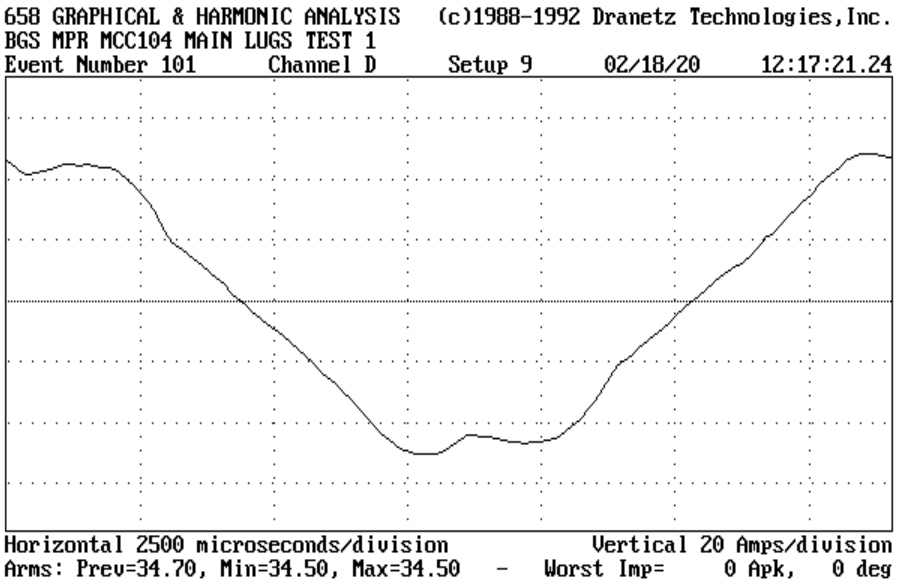


Chart 29

Chart 29 shows the current on Phase C during Event #101. The current is stable at 34.50 to 34.70 Amps and no surge current events were reported.

Chart 30 is the Harmonic reading for the image on Chart 29.

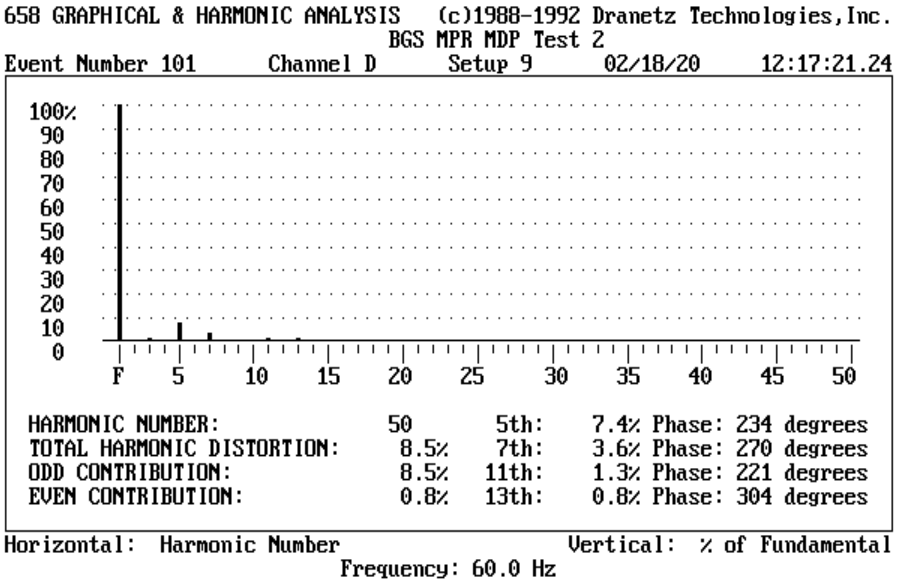
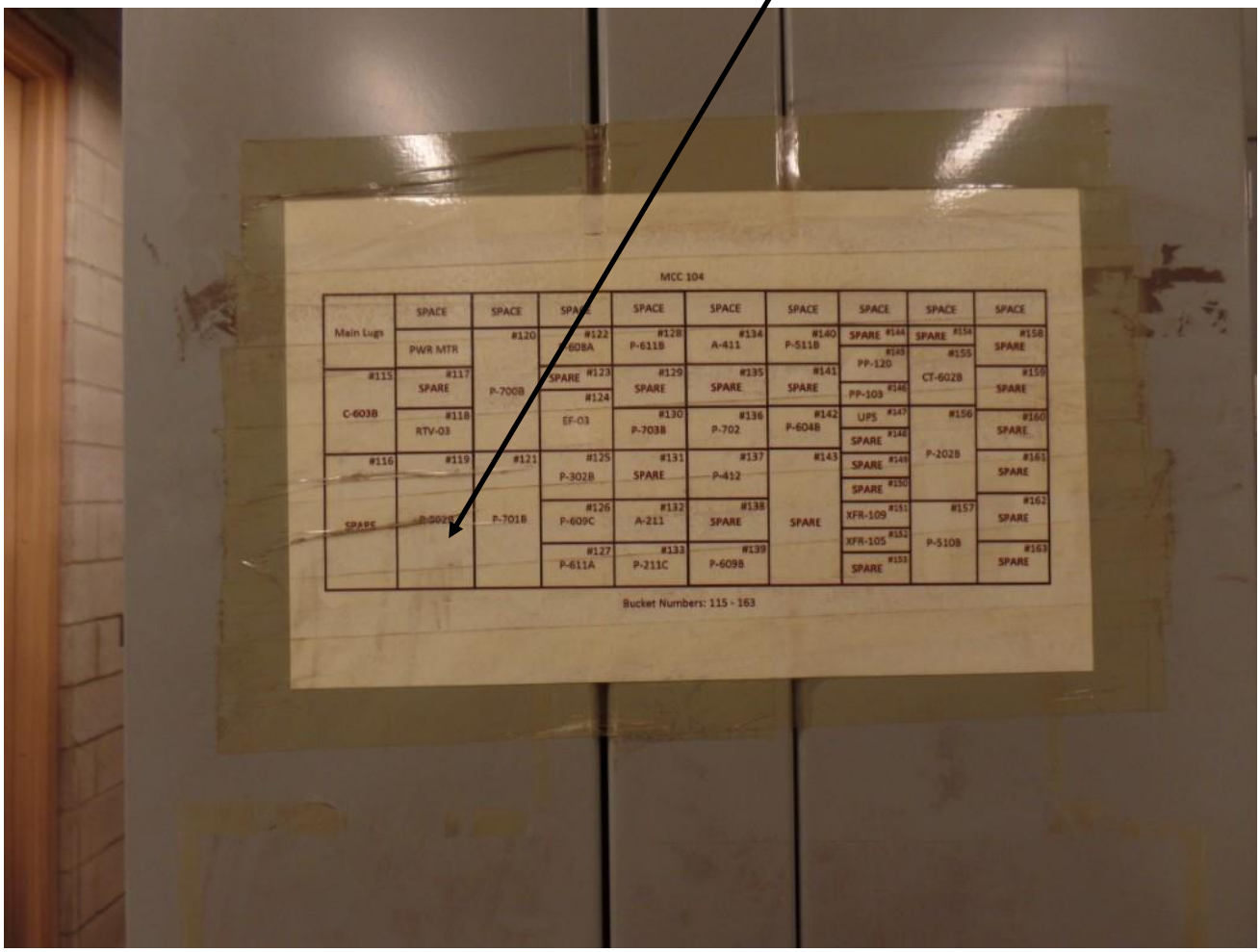


Chart 30

Chart 30 shows the Harmonic distribution for the current waveform on Chart 29. The harmonic levels (8.5% THD and 7.4% highest IHD) are slightly above the IEEE 519-1992 recommended maximum voltage harmonic levels of 5% THD and 3% IHD. The distortion is typical for non-linear loads such as VFDs and other electronic controls within manufacturing plants. It is not a problem until the distortion causes significant distortion on the voltage waveforms. Since there is al most no distortion on the voltage waveforms except the surge events, this does not rise to the level requiring action at this time.

The next area of study was the power at both the input and output of VFD 5147, Pump 502B, on MCC 104. This VFD is near the Main Lugs of the MCC.



MCC 104 panel Schedule Riser Diagram

MCC 104 End View

MCC 104 – 10 vertical columns

We were not able to test on the main lugs coming into the VFD in front of the Line Reactor. All the terminals were insulated and would have required shutting down the active drive and making alterations to the connections. This was ruled out as too invasive. We ran the first test on the output power from the VFD to the motor. This was to measure how the VFD Rectifiers converting the 480 AC to DC voltage were impacting the outgoing AC voltage waveform The Dranetz was connected with Channel A monitoring the Phase A to Phase B voltage, Channel B monitoring the Phase B to Phase C voltage, Channel C monitoring the Phase C to Phase A voltage, and Channel D monitoring the Phase A current. The monitoring period was 2 seconds before the Dranetz memory was full. The monitoring period was from 12:58:05 to 12:58:07, on Tuesday, February 18, 2020. There were 8 Events recorded during that 2 second period.

Chart 31 displays the Channel A, Phase A to Phase B voltage waveform.

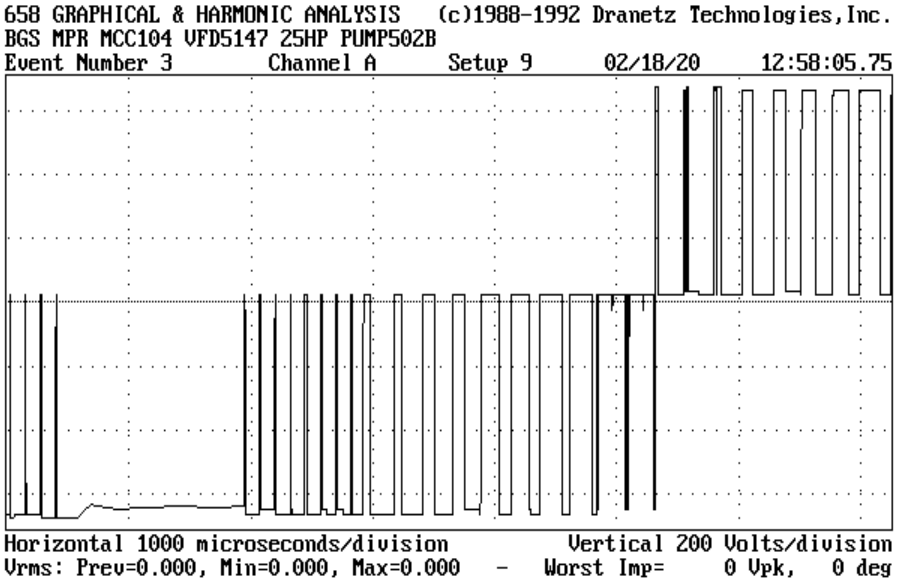


Chart 31

Chart 31 shows the Phase A to Phase B voltage waveform at the output lugs of the VFD, going to the motor. The drive is producing a Pulse-Width-Modulation waveform to the motor. This is an alternative way of producing controlled voltage to the motor in the form of pulses of voltage at 700 Vpeak with varying widths Near the 0° point the pulse is a very short duration, but still 700 Vpeak. There is a relatively wide gap before the next pulse, which is slightly longer in duration and also 700 Vpeak. The next gap is slightly shorter in duration and then the next pulse is slightly longer in duration than the previous pulse. Each pulse in approximately 700 Vpeak which represents the peak of the 480 Vrms waveform. As you proceed toward the 90° point, the pulses get wider and the gaps between pulses get narrower, until at 90° you have a wide pulse of 700 Vpeak. It then reverses, with the pulses getting narrower and the gaps getting wider, until it reaches the 180° point and crosses over to the negative and repeats the process back to the 360°/0° point. Motors that are designed to run with PWM waveforms can be more precisely controlled, but they must be high-quality motors with higher than normal insulation withstand capabilities to survive the pulsing which is normally accompanied by surge pulses from the almost instantaneous rise to full voltage and current at the start of the PWM pulse and again at the collapsing electrical field at the end of the PWM. These are extremely short duration surge events, but they can be up to 2000 volts, two time per pulse. This PWM waveform appears to be 76 pulses per cycle which could produce 152 surges per cycle. At the time of this test the drive was under only a light load and only a few small surge events were noticed. As the load increases, the current associated with each pulse increases and the accompanying surge event will also increase.

Chart 32 displays the voltage waveform from Channel B.

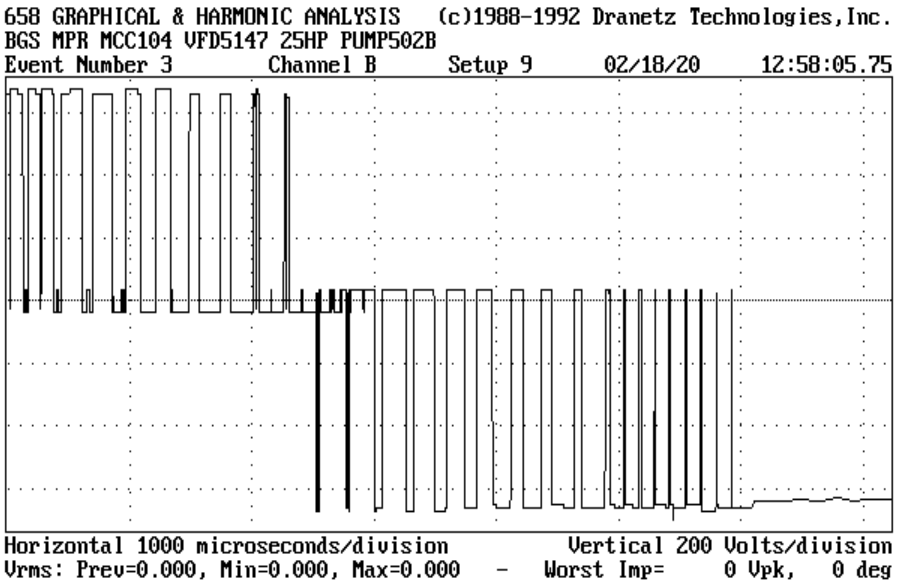


Chart 32

Chart 32 shows the same level of PWM pulse activity being generated by the VFD Rectifiers. Notice on this chart that a few ringing surge events are visible at the zero line on several of the positive PWM pulses and a few of the negative PWM pulses in addition to one at the bottom of one of the negative PWM pulses.

Chart 33 displays the voltage waveform from Channel D.

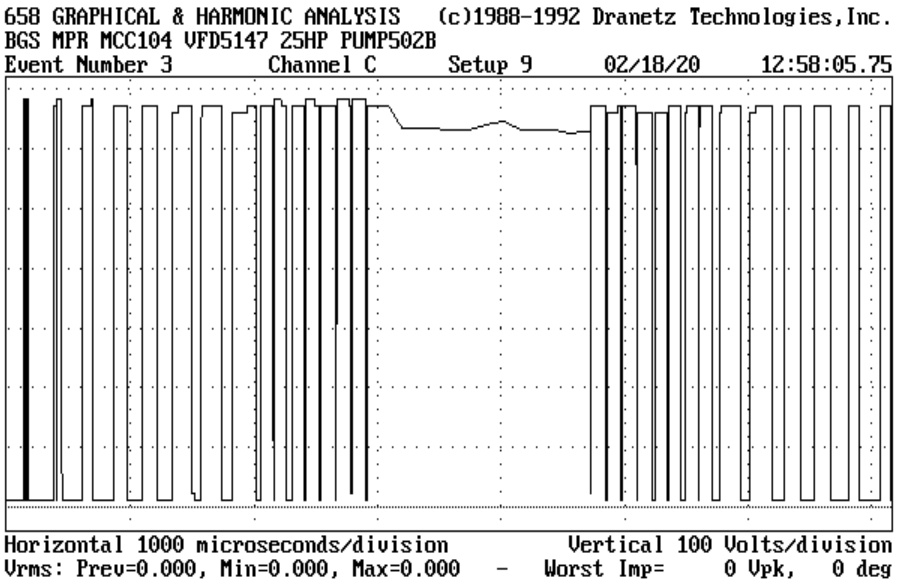


Chart 33

Chart 33 shows the Phase C to Phase A 700 Vpeak PWM voltage waveform. There is only one small surge event at the top of one of the PWM pulses. As the load on the VFD increases, and the current increases, so too will the ringing surges increase. Under 50 to 60 % load on the VFD there would be ringing surge events on each PWM pulse. That would be 32,832,000 ringing surge events per hour.

Chart 34 displays the current on Channel D.

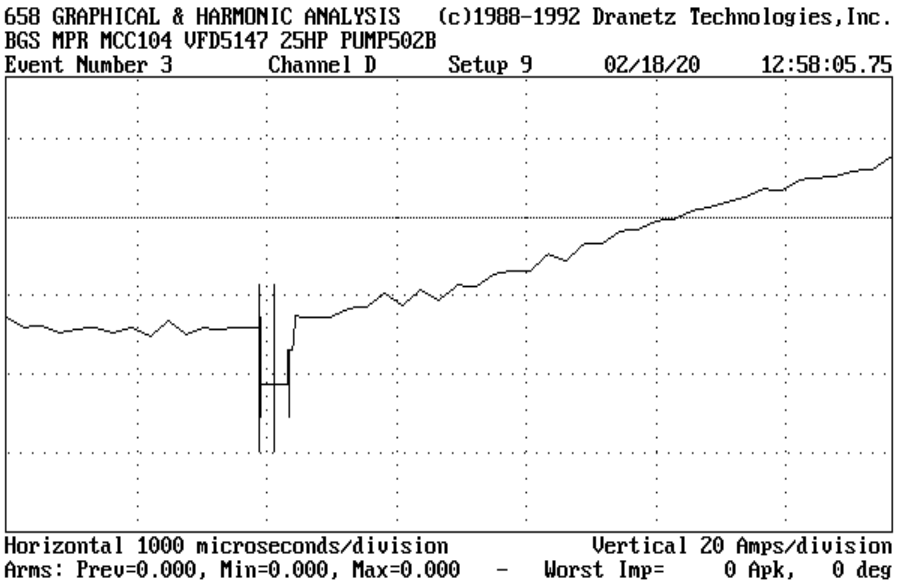


Chart 34

Chart 34 shows the current on Phase B during Event #3. The Dranetz is unable to determine a frequency or voltage from the voltage waveform or a current from the current waveform, so without a starting point it is unable to measure the obvious surge event on the current waveform. Notice that it coincides with the ringing surge events on chart 32.

We ran the second test on the input power to the VFD, after the Line Reactor. This was to measure how the VFD Rectifiers converting the 480 AC to DC voltage were impacting the incoming AC voltage waveform. The Dranetz was connected with Channel A monitoring the Phase A to Phase B voltage, Channel B monitoring the Phase B to Phase C voltage, Channel C monitoring the Phase C to Phase A voltage, and Channel D monitoring the Phase A current. The monitoring period was 2 seconds before the Dranetz memory was full. The monitoring period was from 13:38:27 to 13:38:29, on Tuesday, February 18, 2020. There were 8 Events recorded during that 2 second period.

Chart 35 displays the Channel A, Phase A to Phase B voltage waveform.

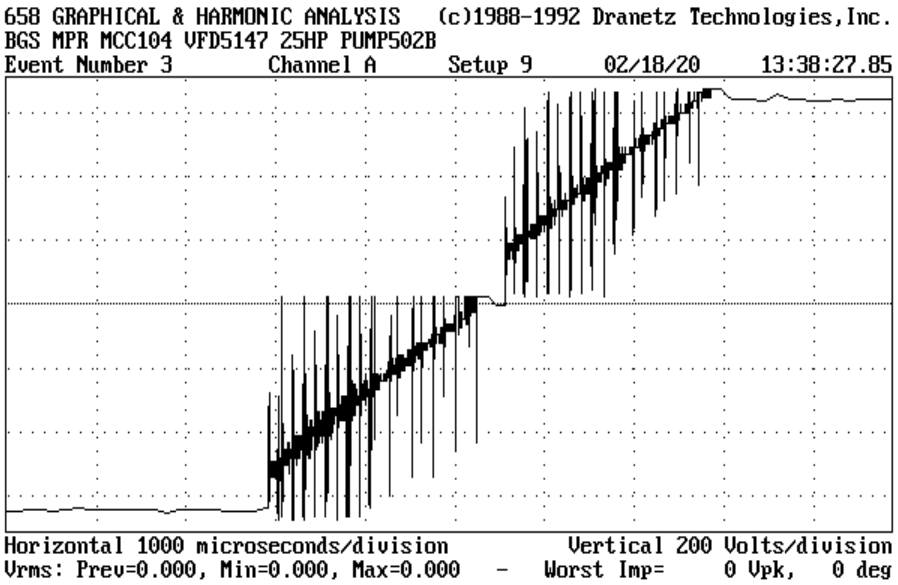


Chart 35

Chart 35 shows the Phase A to Phase B voltage waveform at the input lugs of the VFD, after the Line Reactor. The drive rectifiers are producing severe surge activity back onto the incoming line. This surge activity is currently being absorbed by the Line Reactor. Without the Line Reactor, this level of surge activity would not only cause malfunctions and damage to the control circuits within the VFD, it would also cause major disruptions and damage to the other equipment on MCC 104.

Chart 36 displays the voltage waveform from Channel B.

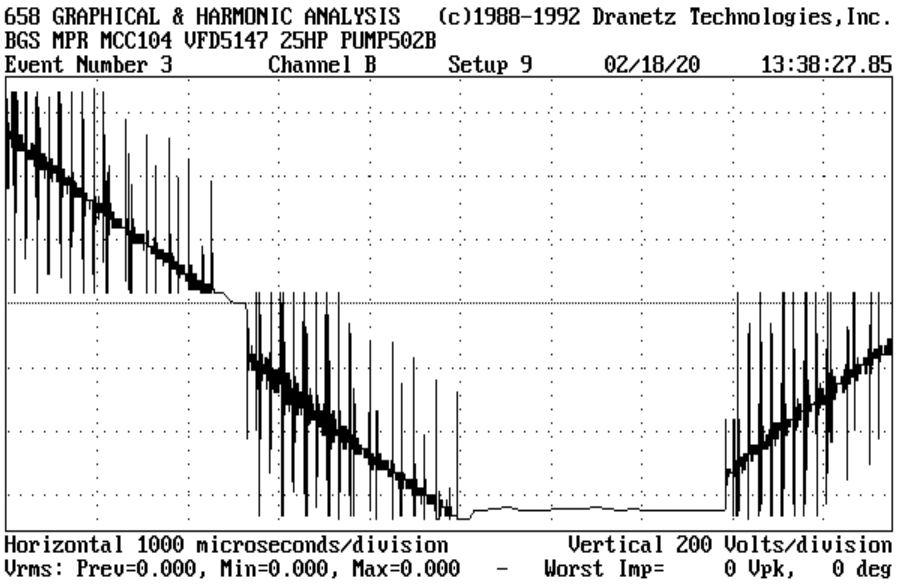


Chart 36

Chart 36 shows the same level of surge activity being generated by the VFD Rectifiers before it is filtered by the Line Reactor. There is no voltage level indicated or surge event recorded because the Dranetz cannot recognize this as a waveform due to the number and amplitude of the distorting surge events.

Chart 37 displays the voltage waveform from Channel C.

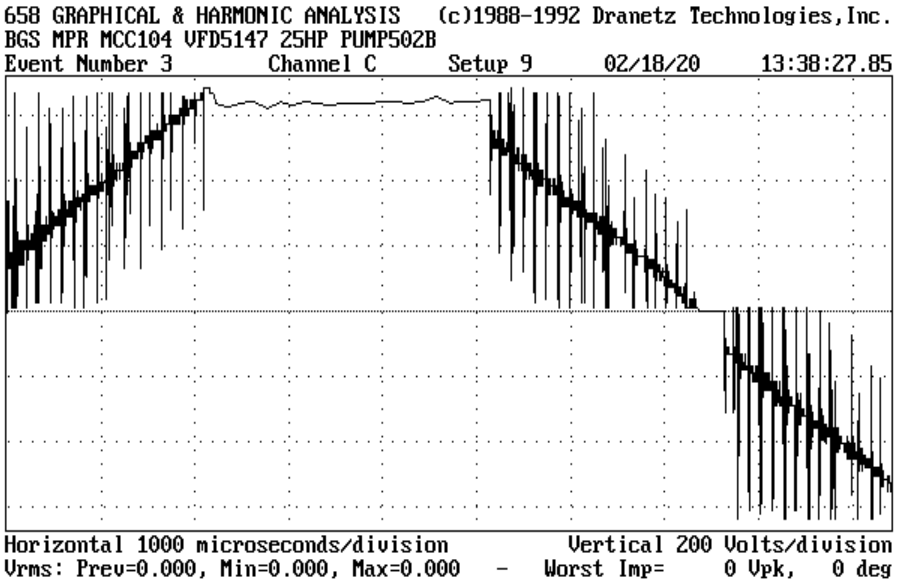


Chart 37

Chart 37 shows the voltage waveform for the Phase C to Phase A 480 Vrms voltage. The number and amplitude of the surge events prevent the Dranetz from determining the voltage or frequency.

Chart 38 displays the current on Channel D.

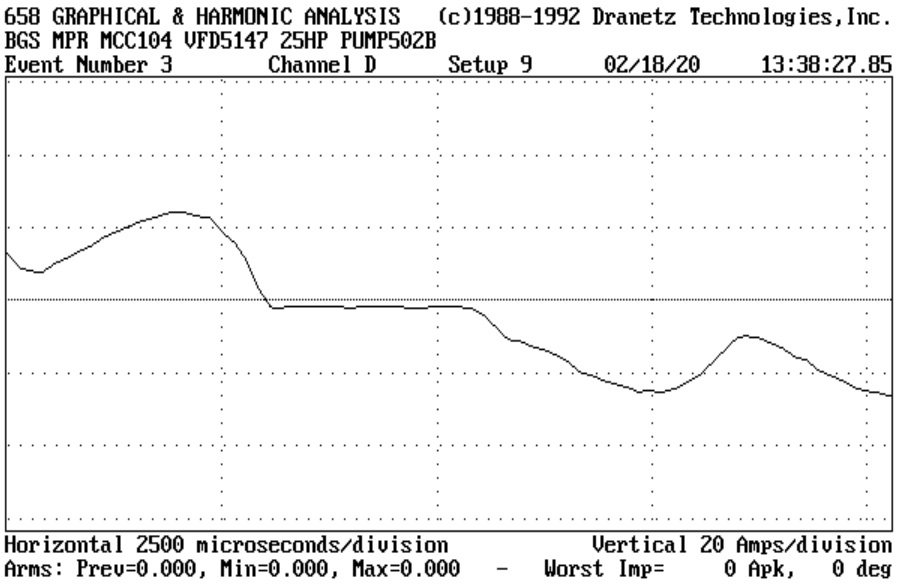


Chart 38

Chart 38 shows the current on Phase A during Event #3. The VFD is drawing current in pulses to convert the AC voltage to DC voltage. It is then inverting the DC voltage to AC voltage and outputting it in pulses as a Pulse-Width Modulated waveform. This is creating the multiple surge events on the incoming AC voltage waveform.

A third test on VFD 5147 was conducted on the output of the step-down 480 V to 120 V, 1 Ø, 2-Wire + Ground transformer for the control voltage to the VFD electronic circuits. The Dranetz was set up with Channel A recording the Phase to Neutral voltage, Channel B recording the Phase to Ground voltage, Channel C recording the Neutral to Ground voltage and Channel D recording the Phase current. The test period ran from 14:32:56 to 14:47:57, on Tuesday, February 18, 2020. There were 3 Events recorded during the monitoring period.

Chart 39 displays the Channel A recording for Event #1.

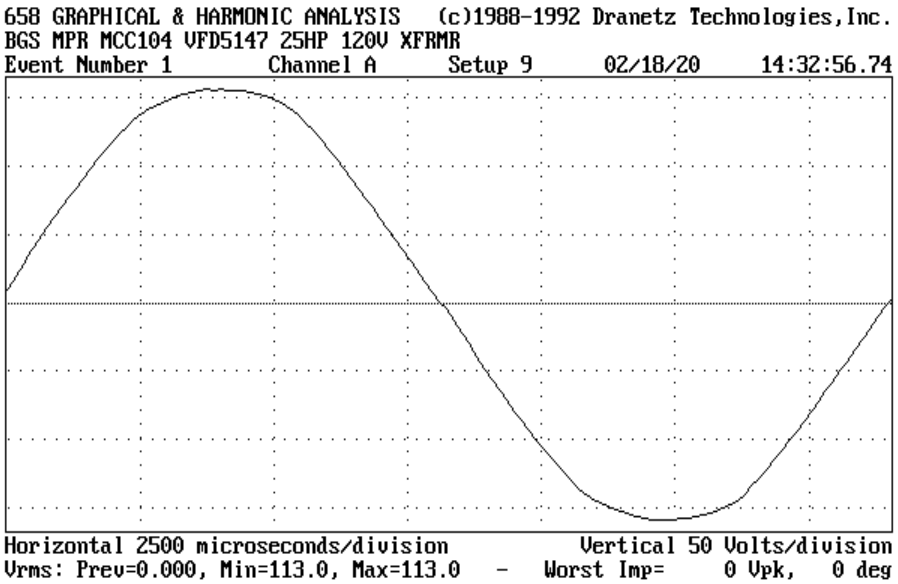


Chart 39

Chart 39 shows the Phase to Neutral voltage waveform on the transformer output. The voltage is 113.00 Vrms and there are no surge events recorded. At this time, the VFD was running on light load and drawing very little current on the 480 Vrms power. The Line Reactor was able to remove almost all of the surge events being generated by the VFD Rectifiers and absorb most of the low-level surge events present of the MCC main bus from the Main Distribution Panel up line.

As the loads increase on the VFD, all of the surge events will increase and the amount of surge that gets to the 120 Vrms control voltage level will also increase. This low-level surge activity will contribute to cumulative damage to the sensitive control circuits and components of the VFD, and can lead to resets, reboots, shutdowns, lost processors, circuit boards, complete drives and most importantly, downtime for the plant.

Chart 40 displays the Phase to Ground voltage from Channel B.

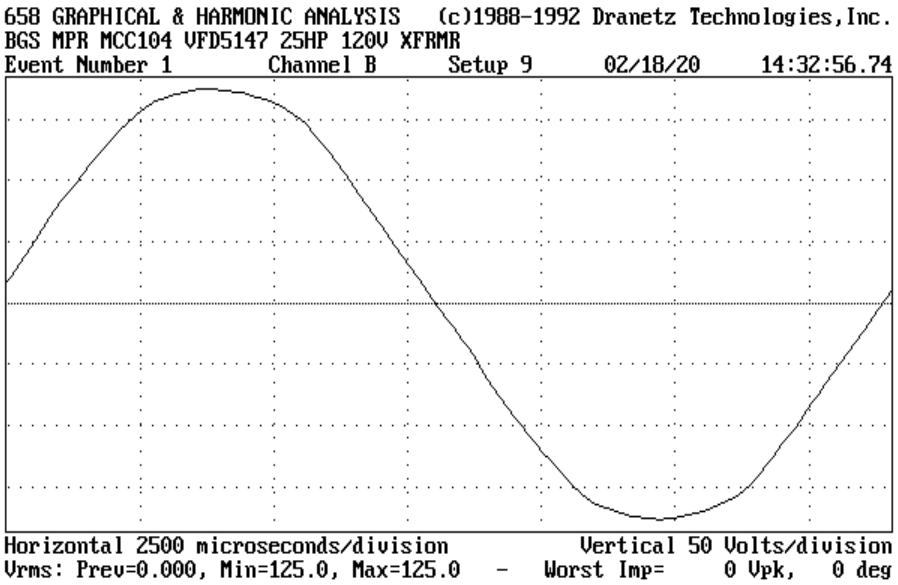


Chart 40

Chart 40 shows the Phase to Ground voltage waveform from Channel B. This is the same Event #3, at the same time as the Channel A, Phase to Neutral monitoring on Chart 39 above. Notice that the Phase to Ground voltage is reading 125.0 Vrms, where the Phase to Neutral voltage on Chart 39 was 113.0 Vrms. The two voltages should be the same. This is a new service from the transformer and the Neutral and Ground should be bonded. If the Neutral and Ground were properly bonded, it would not be possible for them to be 12 Vrms apart. This should be checked and, if not bonded, this should be corrected. It will stabilize the voltage output of the transformer and provide an improved voltage level for the electronic controls.

Chart 41 displays the Neutral to Ground voltage on Channel C.

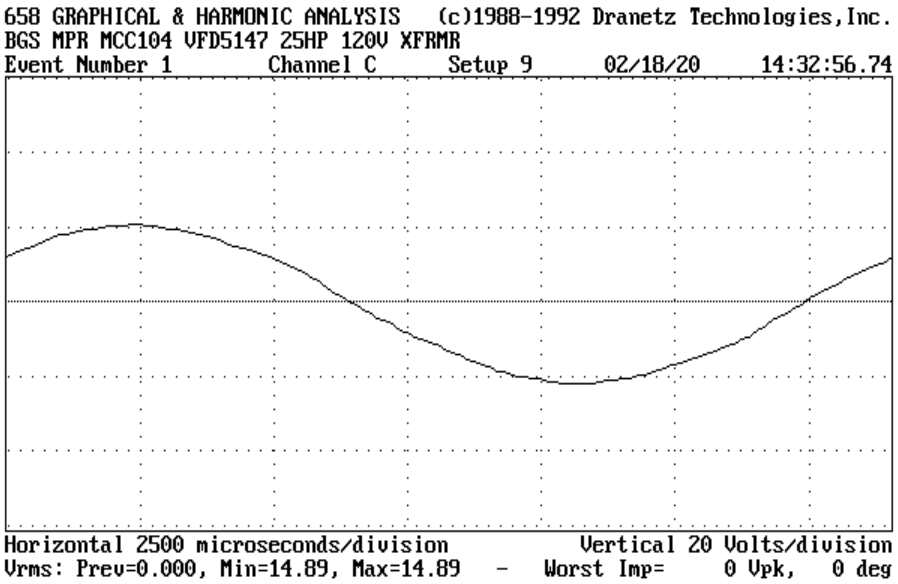


Chart 41

Chart 41 shows the Neutral to Ground voltage from Channel D. The 14.89 Vrms is a clear indicator that the Neutral and Ground are not bonded at the output of this step-down transformer. When this is properly bonded, both the Phase to Neutral and Phase to Ground voltages should be at 120 Vrms, and the Neutral to Ground voltage should be 0 Vrms.

Chart 42 display the current on the Phase lead from Channel D.

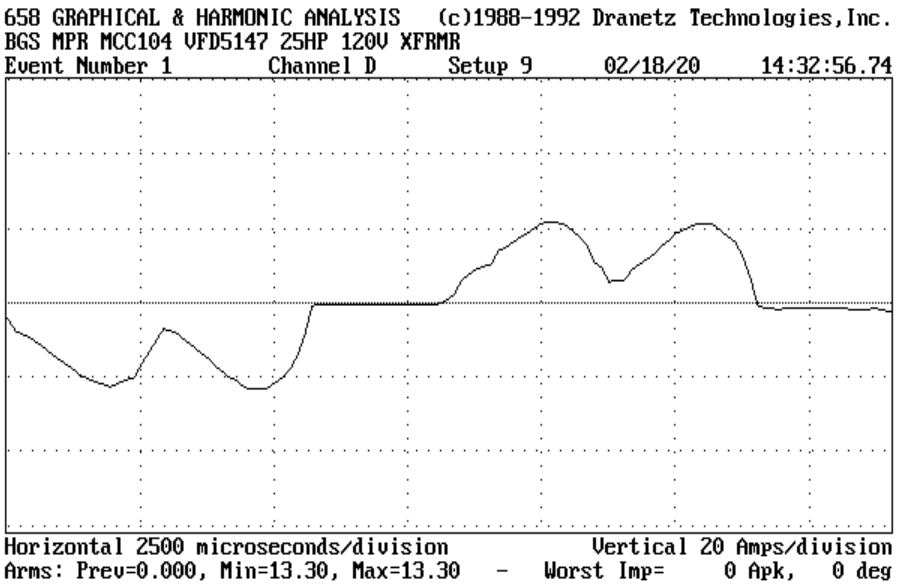


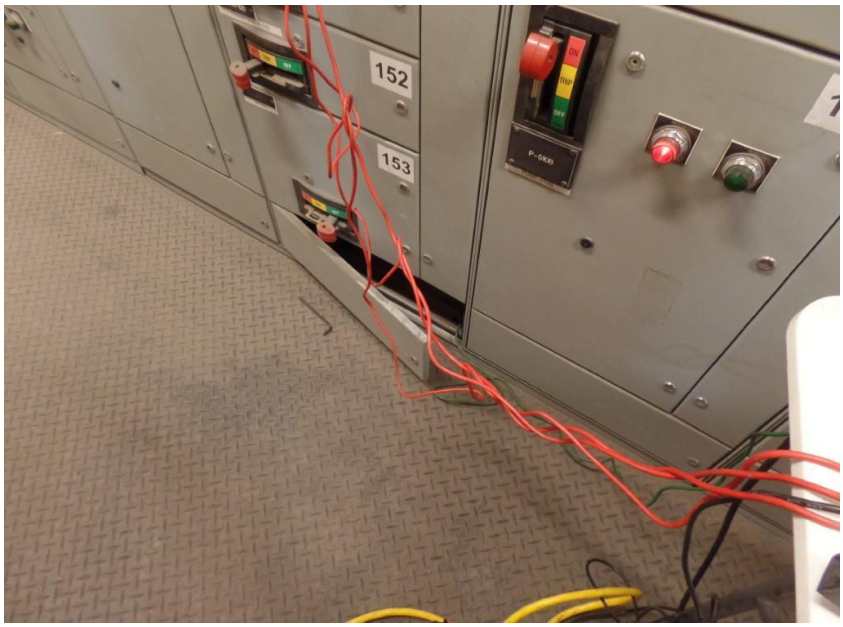
Chart 42

Chart 42 shows the current on the Phase Lead at 13.30 Arms with no surge current events. Notice that the 13.30 Arms pulses are peaking at just over 20 Vpeak, both positive and negative. Any increase in loads on this system will increase the peaks of these pulses which will become sufficient to produce voltage surge events on the control voltage, producing cumulative damage over time to the control circuits. In addition, lightning has been an ongoing problem for the plant. The control voltage circuits are not protected from potential damage from a lightning event. Staged protection ending with a series wired surge protective device at the output of the step-down transformer is critical at this point to provide a final stage of elimination for the remaining lightning surge event on the system.

The next test on MCC 104 was at the disconnect for the Main UPS. This is the critical power for the Control Room circuits and the PLC cabinets.

UPS Disconnect Switch

Voltage Probes on UPS Disconnect



Ground Probe connection for UPS Disconnect Switch

The Dranetz was connected to the UPS Disconnect Switch with Channel A monitoring the Phase A to Phase B voltage, Channel B monitoring the Phase B to Phase C voltage, Channel C monitoring the Phase C to Phase A voltage. We were unable to access the cable to place the current probe on a phase lead for Channel D. Chart 43 shows the Summary of the readings for Channel A during the monitoring period which lasted for 1 minute and 18 seconds before the Dranetz internal memory was full. The time of the tests was from 15:27:04 to 15:28:22, Tuesday, February 18, 2020. There were 197 events captured during the monitoring.

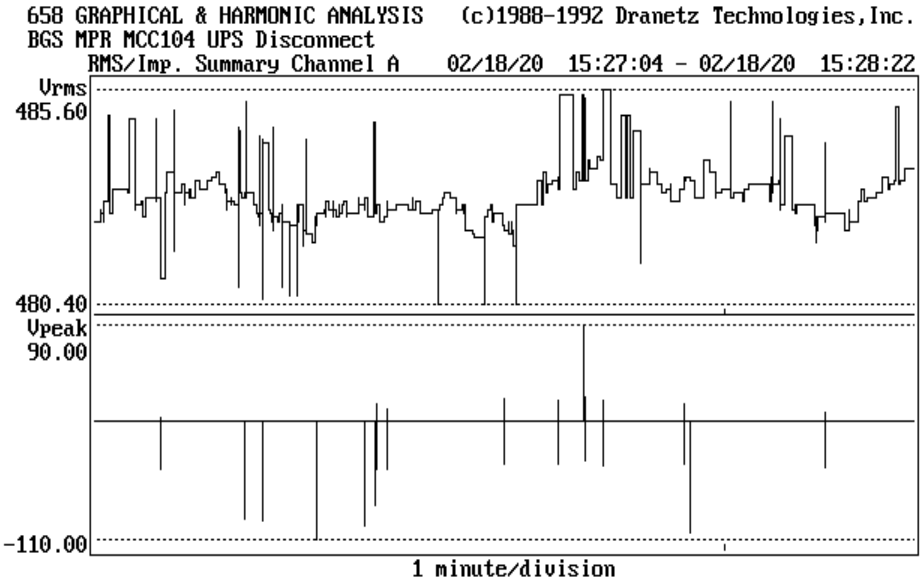


Chart 43

The chart shows the voltage fluctuating over a narrow range from 480.40 Vrms to 485.60 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 90.00 Vpeak Positive to 110.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 44 shows the Summary of the readings for Channel B.

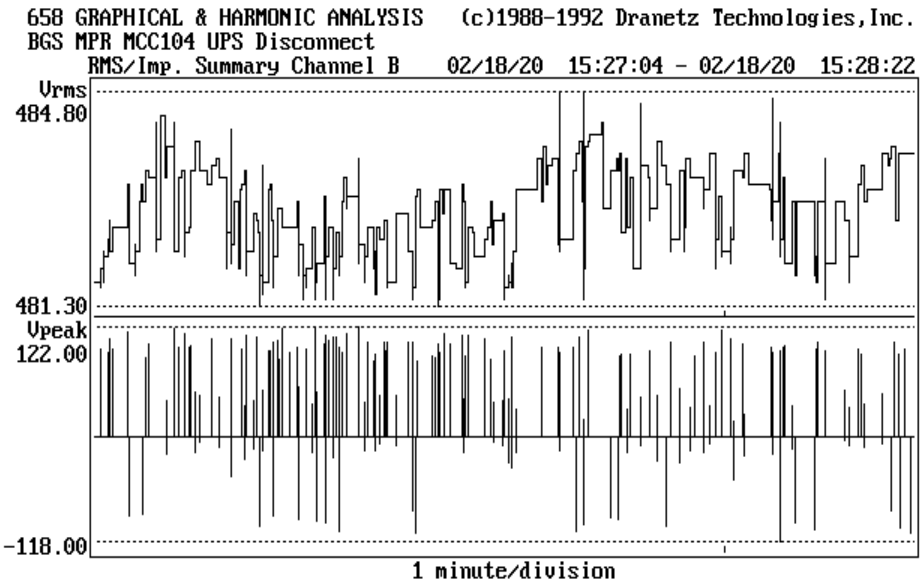


Chart 44

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 481.30 to 484.80 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 122.00 Vpeak to a negative 118.00 Vpeak. There is a very noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 45 shows the Summary of the readings from Channel C.

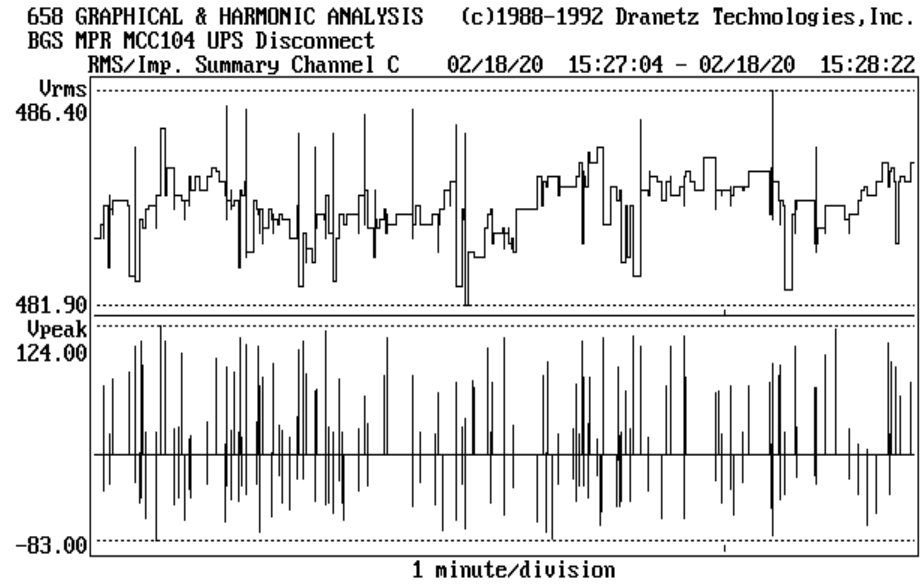


Chart 45

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 481.90 to 486.40 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 124.00 Vpeak to a negative 83.00 Vpeak. There is a further increase in the number of surge events.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 46, is from Event #62 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

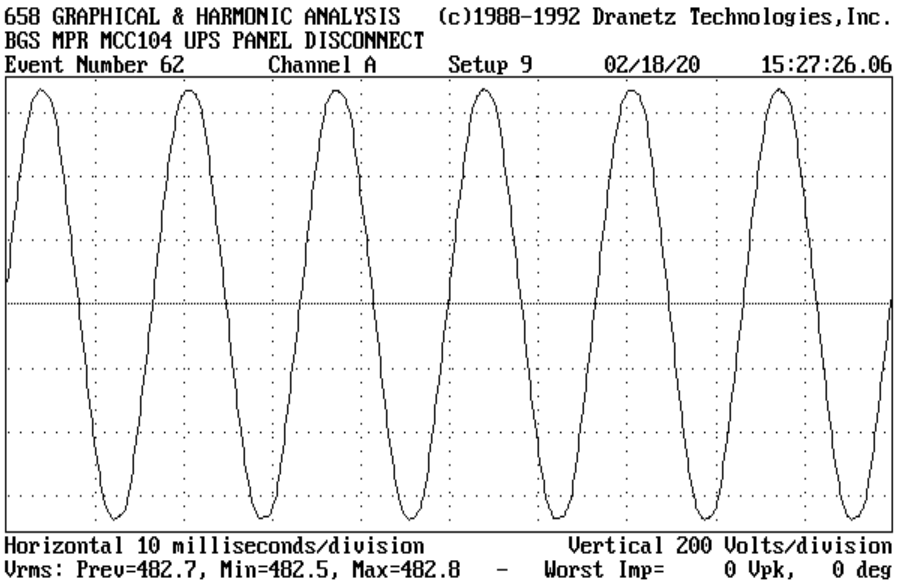


Chart 46

As with some of the previous tests, this event had no surge activity recorded on Channel A. However, Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.
Chart 47 from Event #62 shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

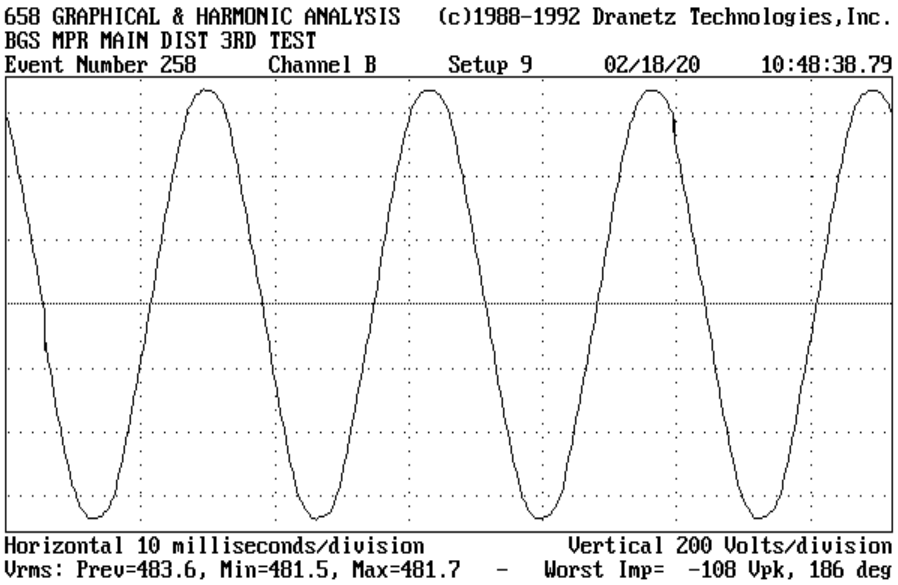


Chart 47

Chart 47 for event #62 shows a negative 1080 Vpeak surge, at 186°. The voltage is stable at 481.5 to 481.7 Vrms. This surge event is occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 48 from Event #62 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

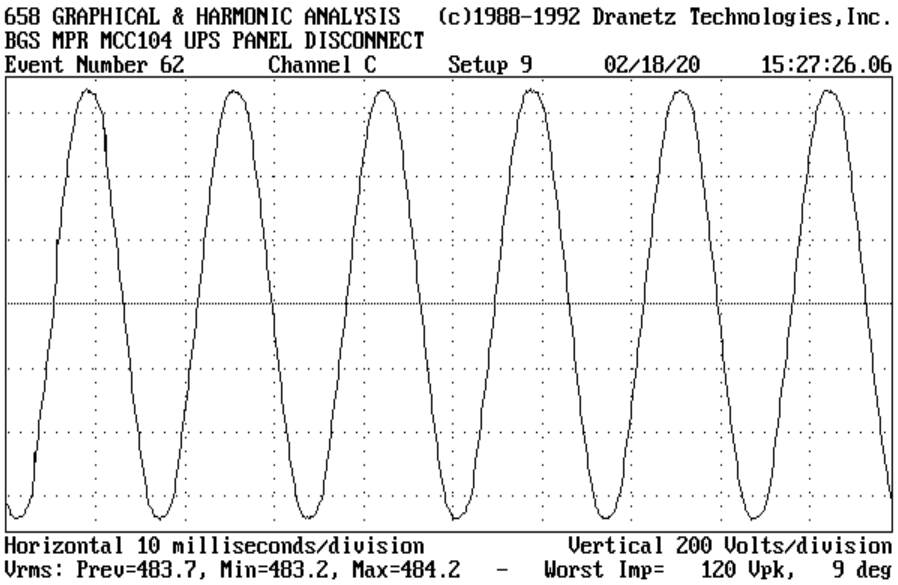


Chart 48

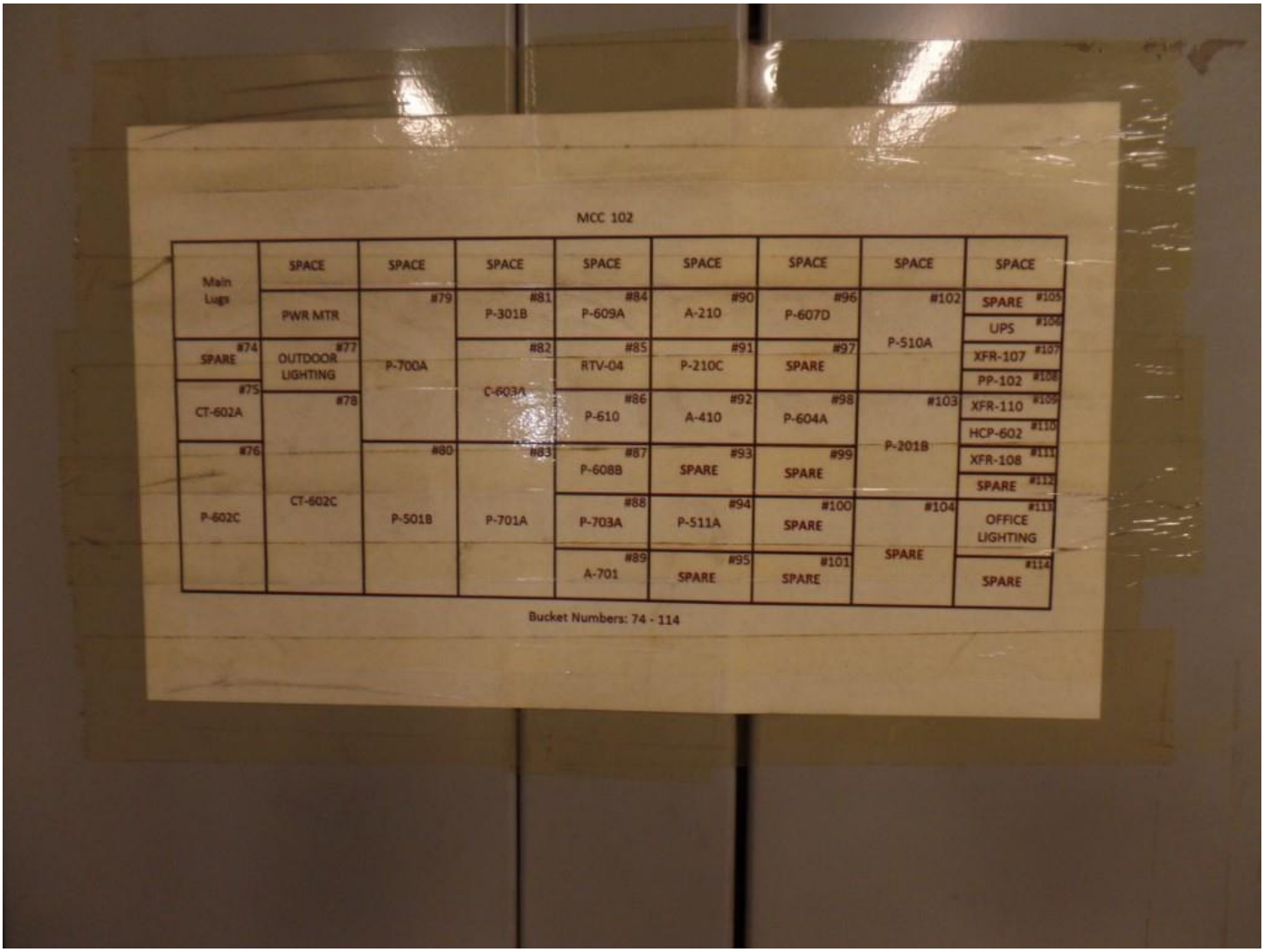
Chart 48 for Event #62 shows a 120 Vpeak surge at the 9° point on the wave form. The voltage holds steady at 483.2 to 484.2 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 124 Vpeak to a negative 118 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system. In this case, the Main UPS providing continuous, regulated power for the Control Room equipment and PLC cabinets. Plant operations depend on this equipment to run continuously, with no breaks in power. Any failures in the UPS control circuits can be catastrophic for the plant and the personnel.

At the conclusion of the testing of the UPS Disconnect Switch, the Dranetz probes were removed and the Plant Electrician was closing the Disconnect Switch cover to secure the location when the disconnect switch for the UPS power tripped off. The Plant Electrician had his hand on the switch and immediately pushed it back to the ON position. There was a 1 second loss of power to the Main UPS. Under normal conditions, the Main UPS should be able to provide battery power seamlessly to the equipment downline with no interruption in service. This did not happen. The Main UPS failed to support the downline equipment during the 1 second outage. It appears that the Main UPS batteries have failed and should be replaced. I recommended that this be done as soon as possible to get the Main UPS back in service. A service technician should at least check the Main UPS to see if it is still serviceable.

The next area to be tested was the MCC 102. We connected to VFD 6023, Pump 602C.

MCC 102



MCC f102 Panel Schedule Riser Diagram

View from end of MCC 102

Dranetz connected to VFD 6023 Pump 602C

Name Plates and Display Window VFD 6023

Dranetz Probe connections

For the test on VFD 6023 Pump 602C, the Dranetz was again set to monitor to voltage on Channel A from Phase A to Phase B, on Channel B from Phase B to Phase C, and on Channel C from Phase C to Phase A. For this test Channel D recorded the Phase A current. Chart 49 shows the Summary of the readings for Channel A during the monitoring period which lasted for 45 seconds before the Dranetz internal memory was full. The time of the tests was from 16:16:01 to 16:16:46, Tuesday, February 18, 2020. There were 144 events captured during the monitoring.

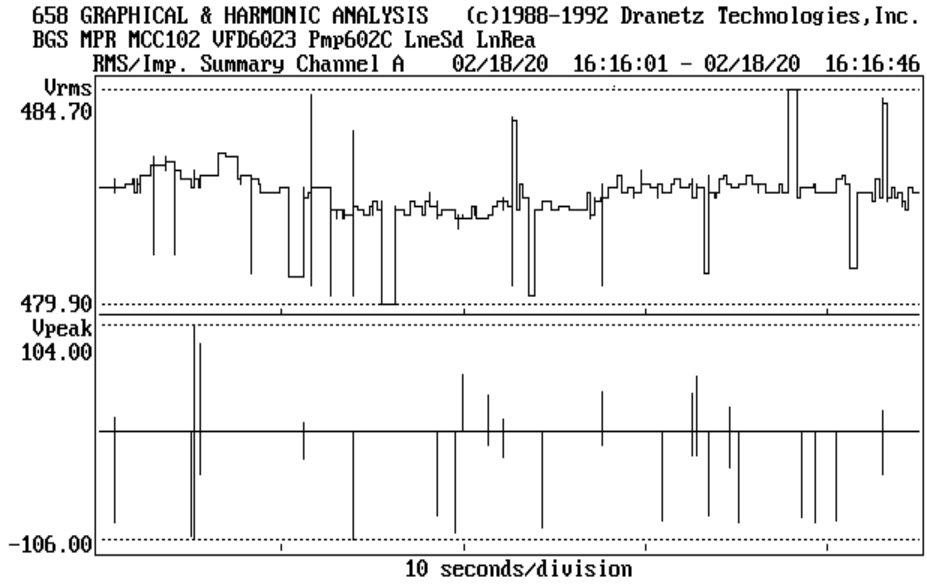


Chart 49

The chart shows the voltage fluctuating over a narrow range from 479.90 Vrms to 484.70 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 104.00 Vpeak Positive to 106.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 50 shows the Summary of the readings for Channel B.

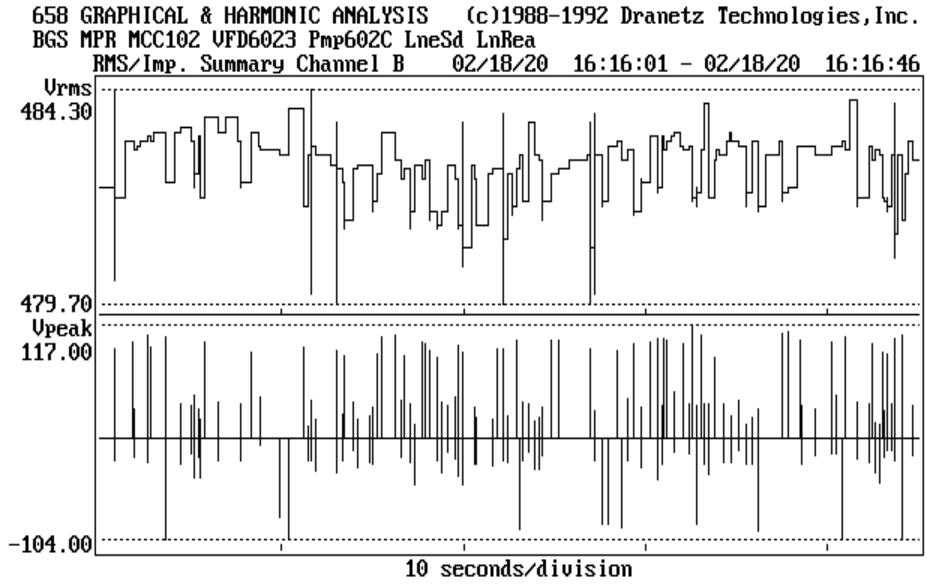


Chart 50

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 479.70 to 484.30 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 117.00 Vpeak to a negative 104.00 Vpeak. There is a very noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 51 shows the Summary of the readings from Channel C.

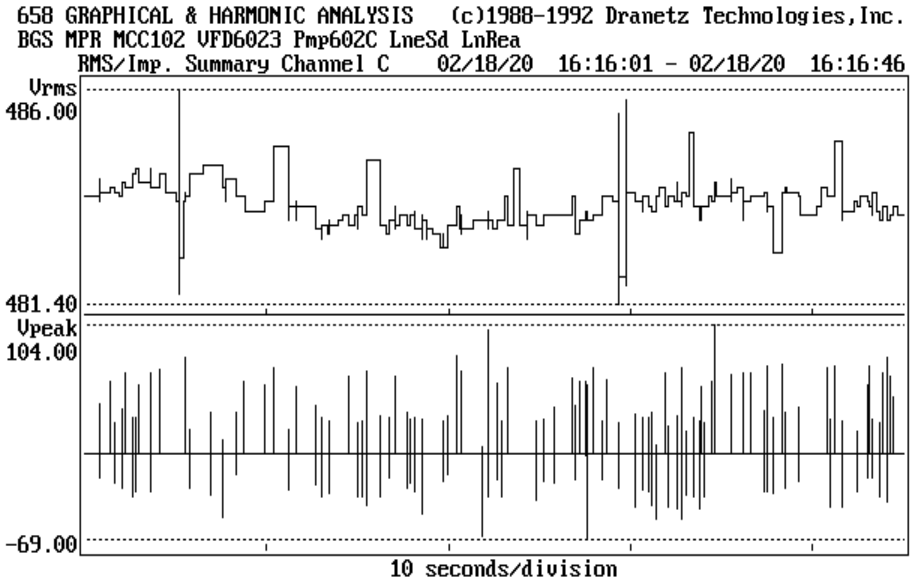


Chart 51

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 481.40 to 486.00 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 104.00 Vpeak to a negative 69.00 Vpeak. There is a further increase in the number of surge events.

Chart 52 shows the Summary of the current readings from Phase A.

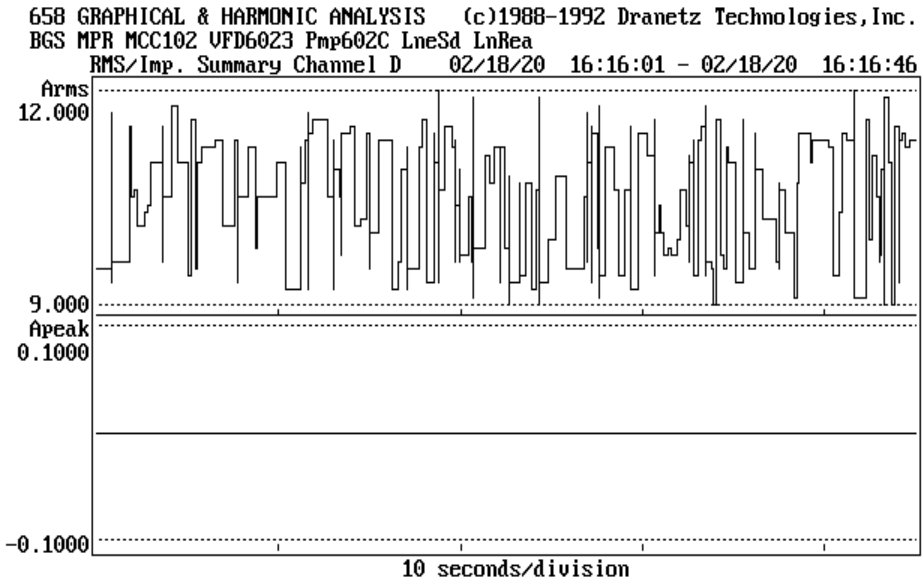


Chart 52

The current on Phase A fluctuates mildly from 9.000 Arms to 12.000 Arms and there were no recorded surge current events. This is an indication that the voltage surge events captured at this point are originating up line from the monitoring point rather than from the down line plant equipment. The VFD and motor were very lightly loaded at the time of the test.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 53, is from Event #99 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

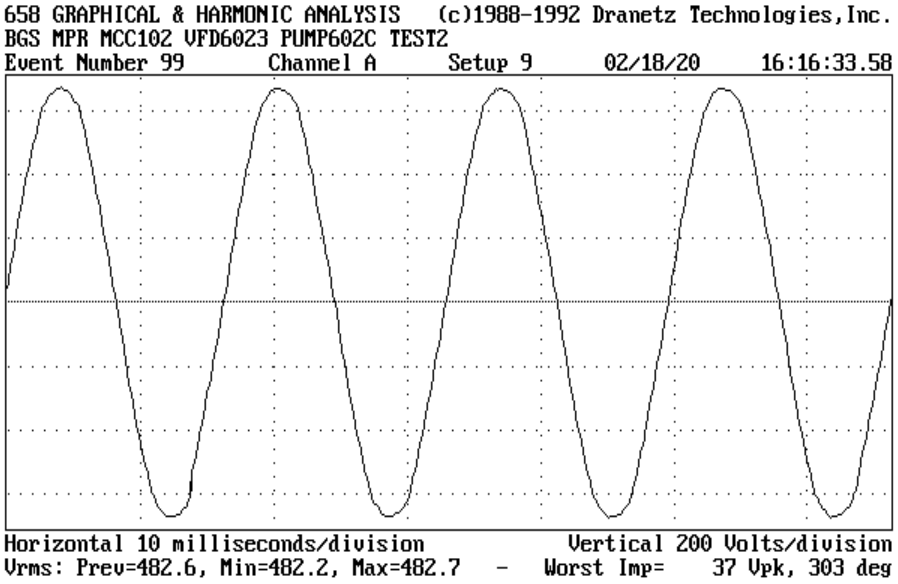


Chart 53

This chart shows the voltage waveform on Phase A to Phase B mode on Channel A. The voltage is stable at 482.2 to 482.7 Vrms. There is a 37 Vpeak surge event at 303°, just after the low point of the first cycle. Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment. Chart 54 from Event #99 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

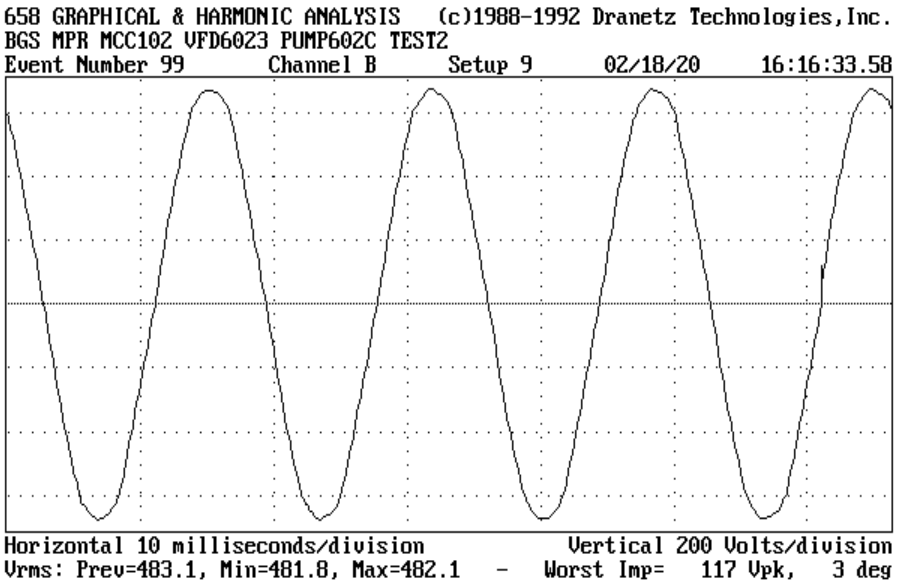


Chart 54

Chart 54 for event #99 shows a positive 117 Vpeak surge, at 3°. The voltage is stable at 481.8 to 482.1 Vrms. This surge event is occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 55 from Event #99 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

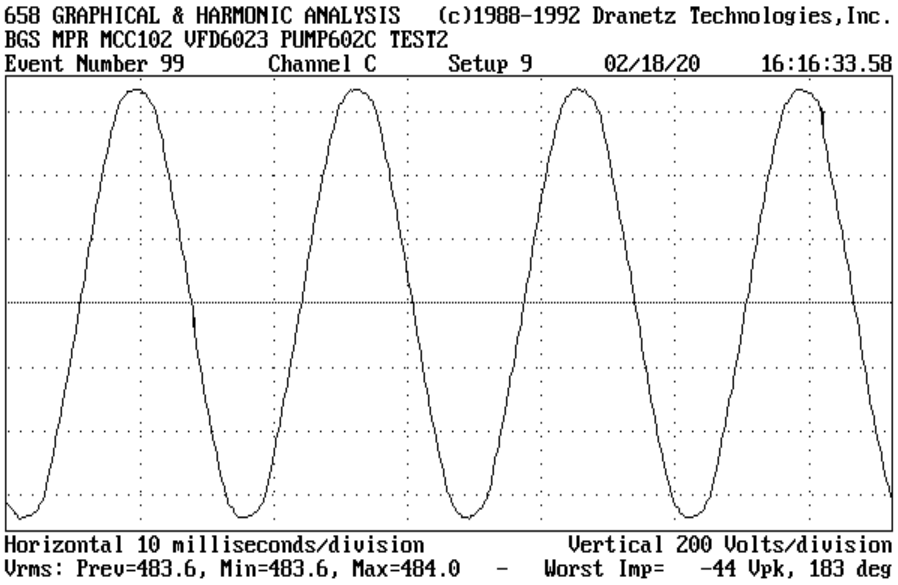


Chart 55

Chart 55 for Event #99 shows a negative 44 Vpeak surge at the 183° point on the wave form. The voltage holds steady at 483.6 to 484.0 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 122 Vpeak to a negative 111 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 56 is from Event #99 and shows the current on Phase A.

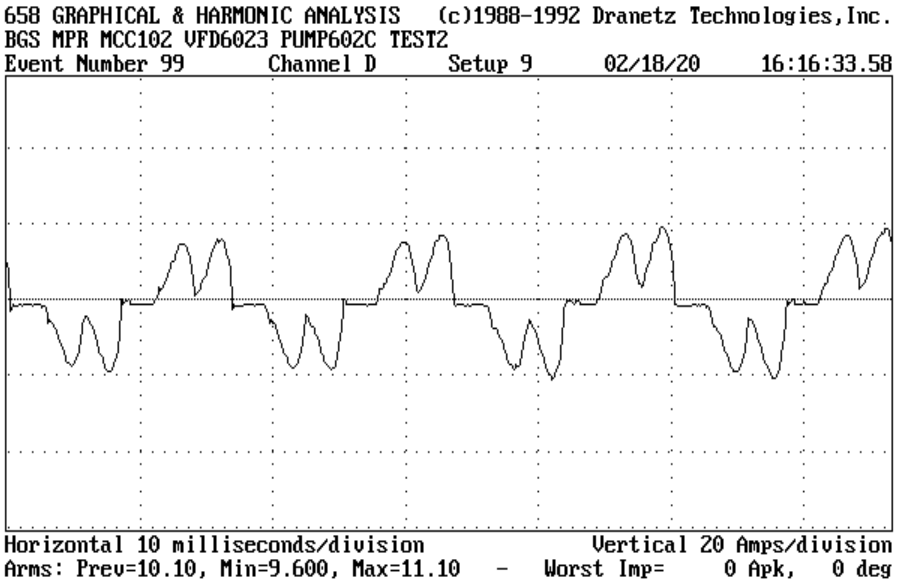


Chart 56

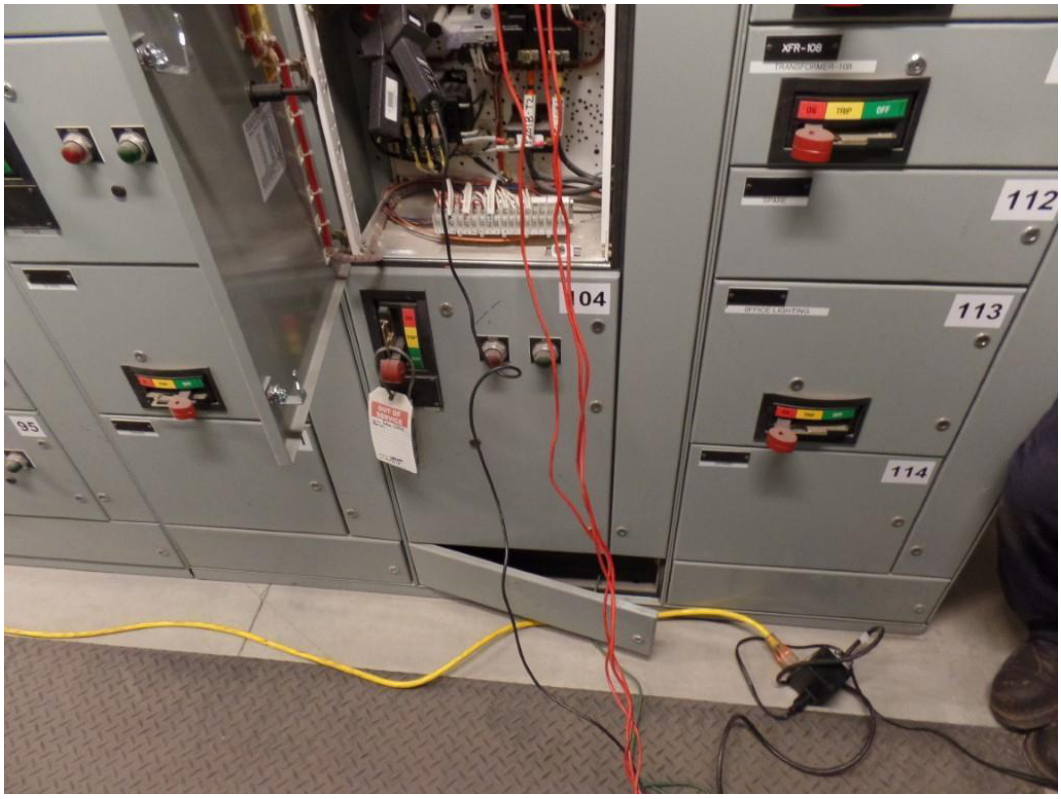
Chart 56 of Event #99 on Channel D shows the current on Phase A. The current is 9.600 to 11.10 Amps with no surge current reported. The distortion on the waveform is typical current harmonic distortion from the way the VFD is converting power from AC to DC by drawing current in pulses four times per cycle. That rate equals 864,000 times per hour. Notice the peaks of the current pulses are at 20 Apeak.

We moved to the other end of MCC 102, to pump 201B. This is a standard disconnect with a starter for the constant speed motor. The Dranetz was connected with Channel A monitoring the Phase A to Phase B voltage, Channel B monitoring the Phase B to Phase C voltage, Channel D monitoring the Phase C to Phase A voltage, and Channel D monitoring the current on Phase A. The monitoring period was from 08:33:41 to 08:34:16 for a total of 35 seconds, on Wednesday, February 19, 2020. There were 116 events recorded during the 35 seconds of the monitoring period.

Test setup monitoring Pump 201B

Pump 201B Disconnect Switch

Voltage and current clamp connections for monitoring Pump 201B



Ground connection for Pump 201B monitoring

Chart 57 displays the Summary of the voltage events on Channel A, Phase A to Phase B.

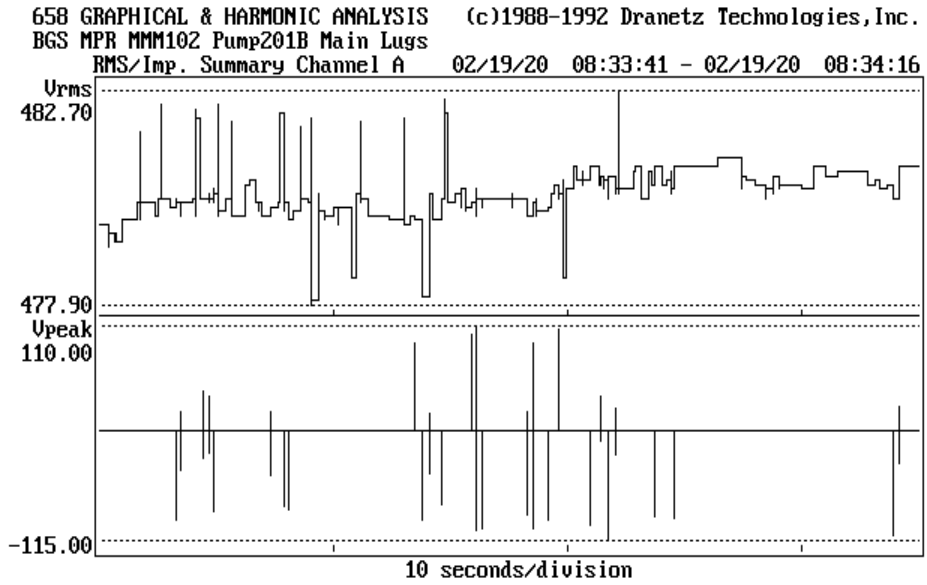


Chart 57

The chart shows the voltage fluctuating over a narrow range from 477.90 Vrms to 482.70 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 110.00 Vpeak Positive to 115.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 58 shows the Summary of the readings for Channel B.

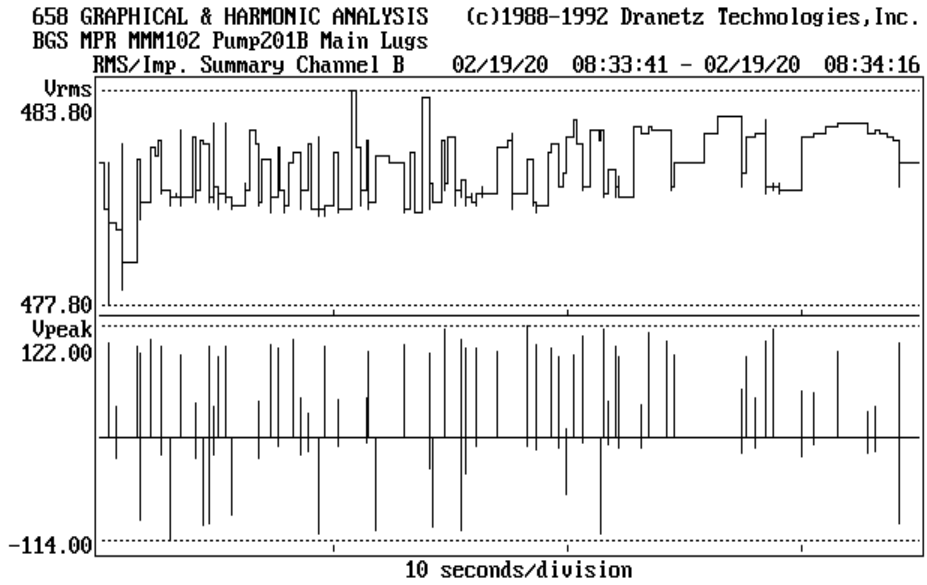


Chart 58

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 477.8 to 483.80 Vrms during the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 122.00 Vpeak to a negative 114.00 Vpeak. There is a very noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 59 shows the Summary of the readings from Channel C.

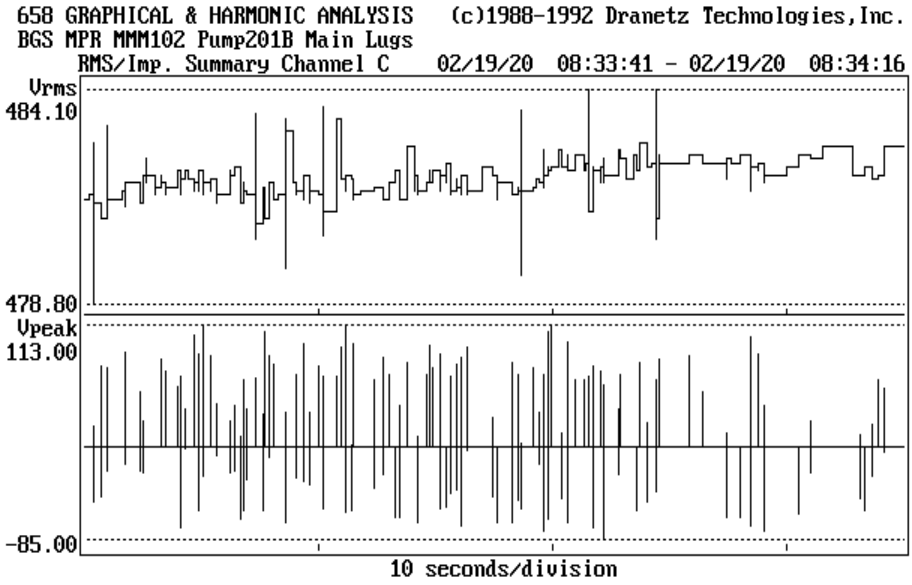


Chart 59

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 478.80 to 484.10 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 113.00 Vpeak to a negative 85.00 Vpeak. There is a further increase in the number of surge events.

Chart 60 shows the Summary of the current readings from Phase A.

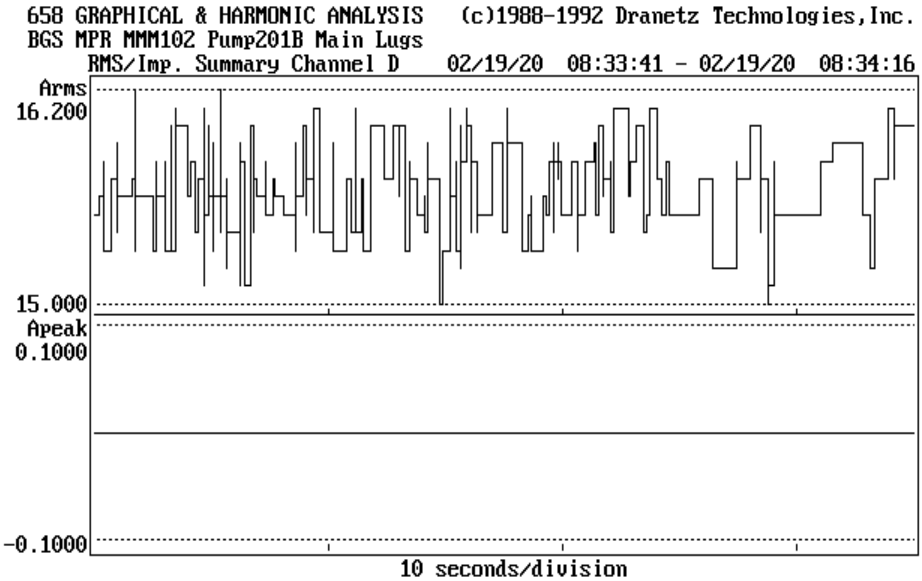


Chart 60

The current on Phase A fluctuates mildly from 15.000 Arms to 16.200 Arms and there were no recorded surge current events. This is an indication that the voltage surge events captured at this point are originating up line from the monitoring point rather than from the down line plant equipment.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 61, is from Event #69 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

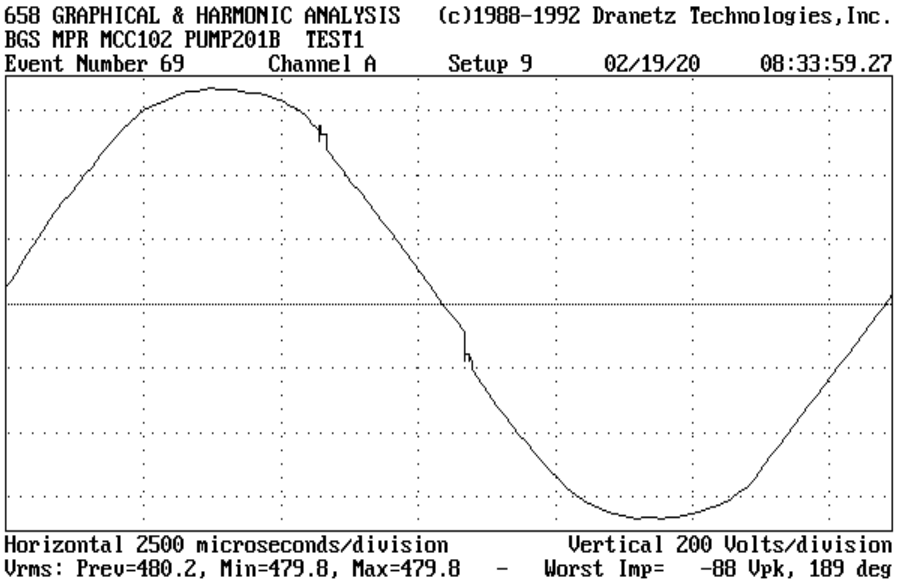


Chart 61

This chart displays the voltage surge events on Channel A for Phase A to Phase B. The voltage is stable at 479.8 Vrms. There is a negative 88 Vpeak surge event at 189°, and a smaller surge event at around 120°. Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 62 from Event #69 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

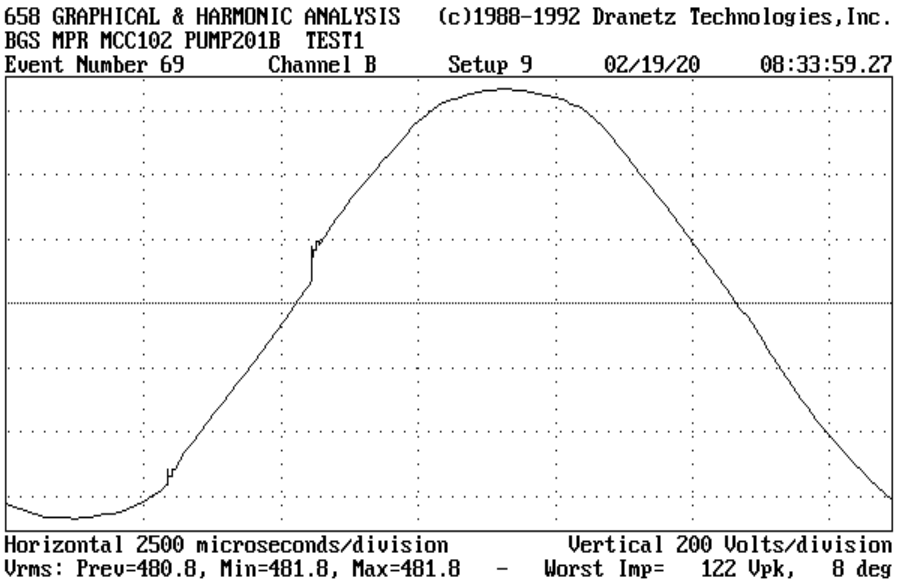


Chart 62

Chart 62 for event #69 shows a negative 122 Vpeak surge, at 8°. There is a second, smaller surge at approximately the 290° point. The voltage is stable at 481.8 Vrms. These surge events are occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 63 from Event #69 and shows the readings from Channel C on the 480 Vrms Phase C to Phase A mode.

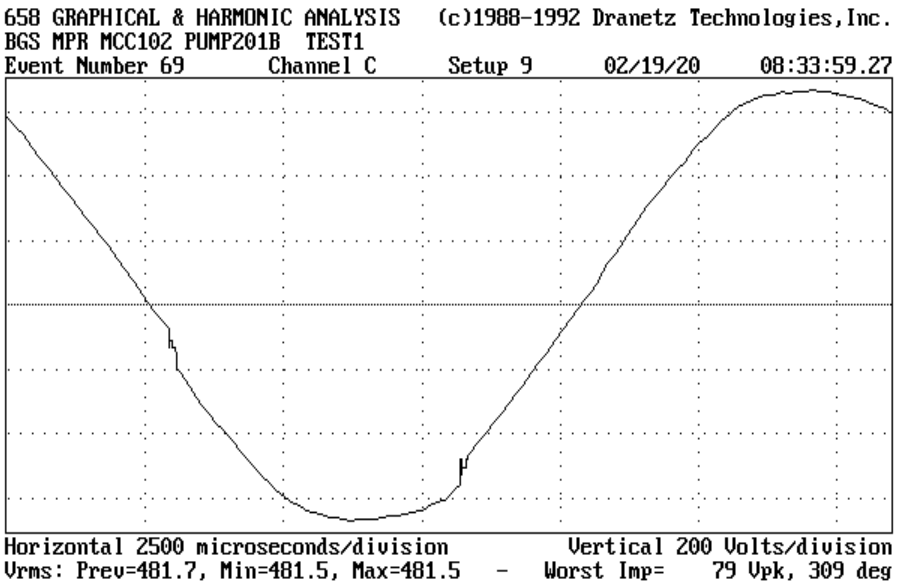


Chart 63

Chart 63 for Event #69 shows a 79 Vpeak surge at the 309° point on the wave form, with an almost equal surge at approximately the 190° point. The voltage holds steady at 481.5 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 122 Vpeak to a negative 115 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 64 is from Event #69 and shows the current on Phase B.

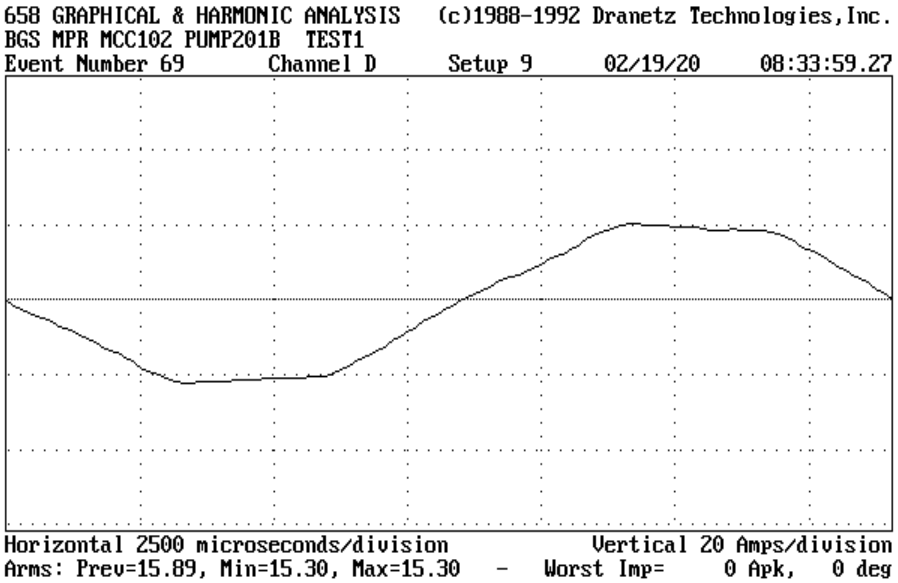
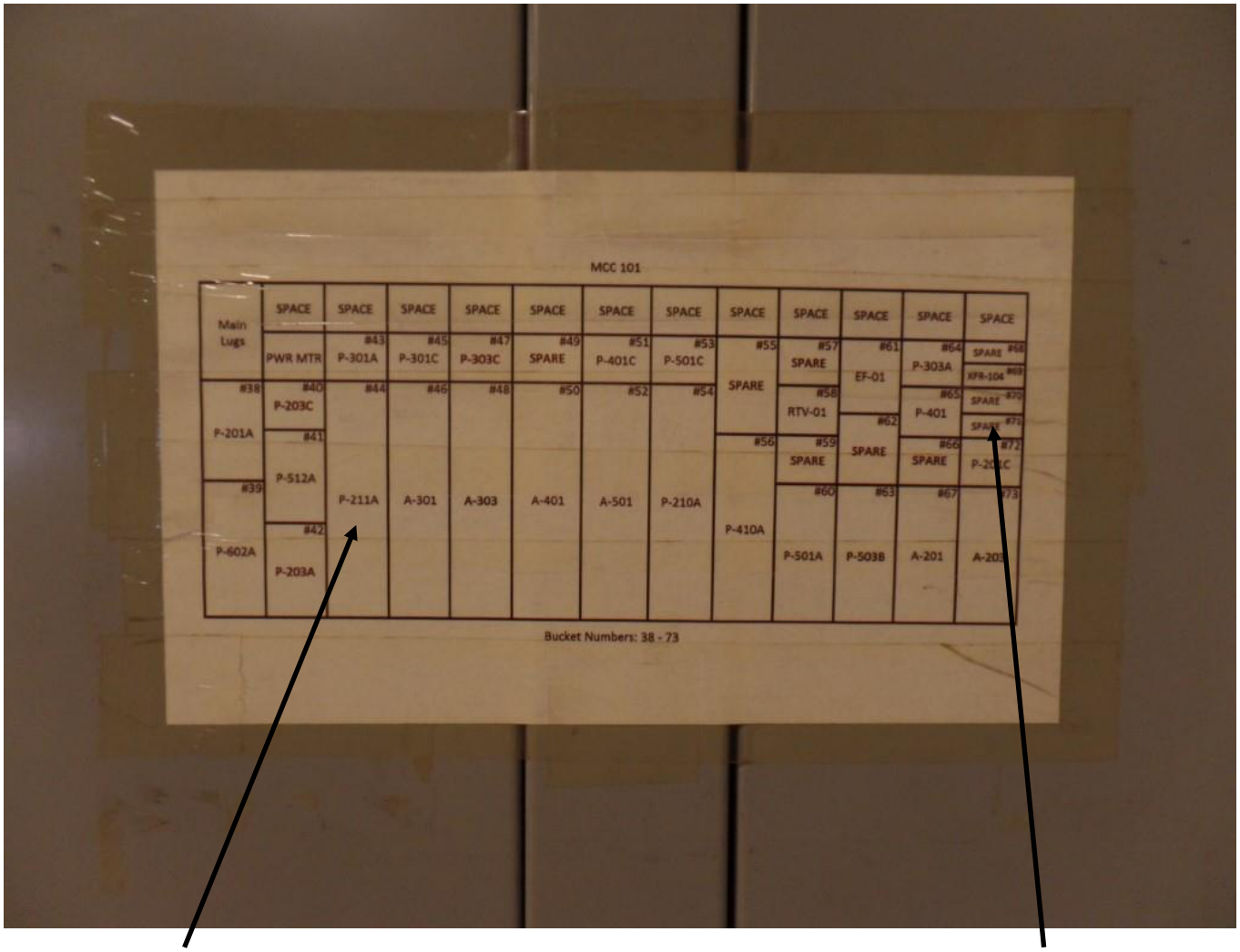


Chart 64

Chart 64 of Event #69 on Channel D shows the current on Phase B. The current is 15.89 to 15.30 Amps with no surge current reported. The distortion on the waveform is slight, and typical distortion from the way the standard constant running motors operate on AC power.

The next test location was MCC 101.

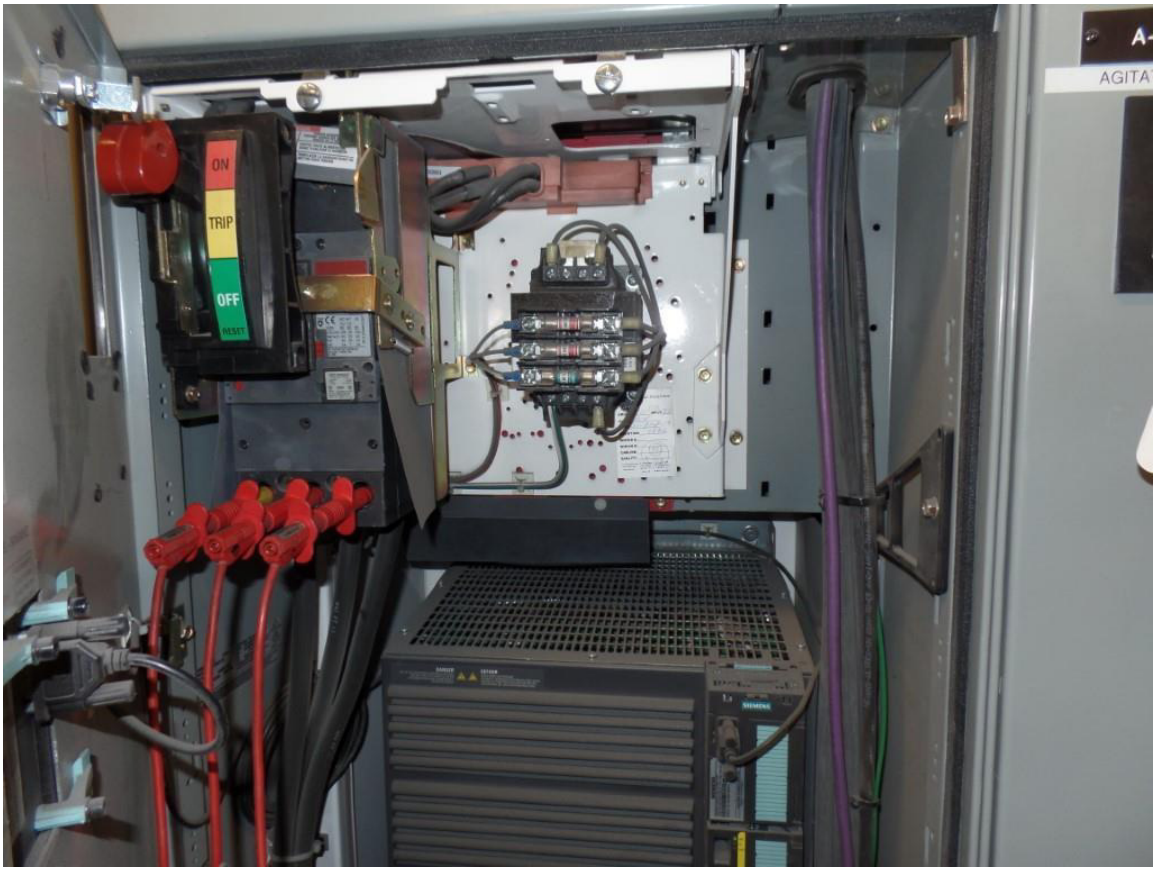
MCC 101 Name Plates



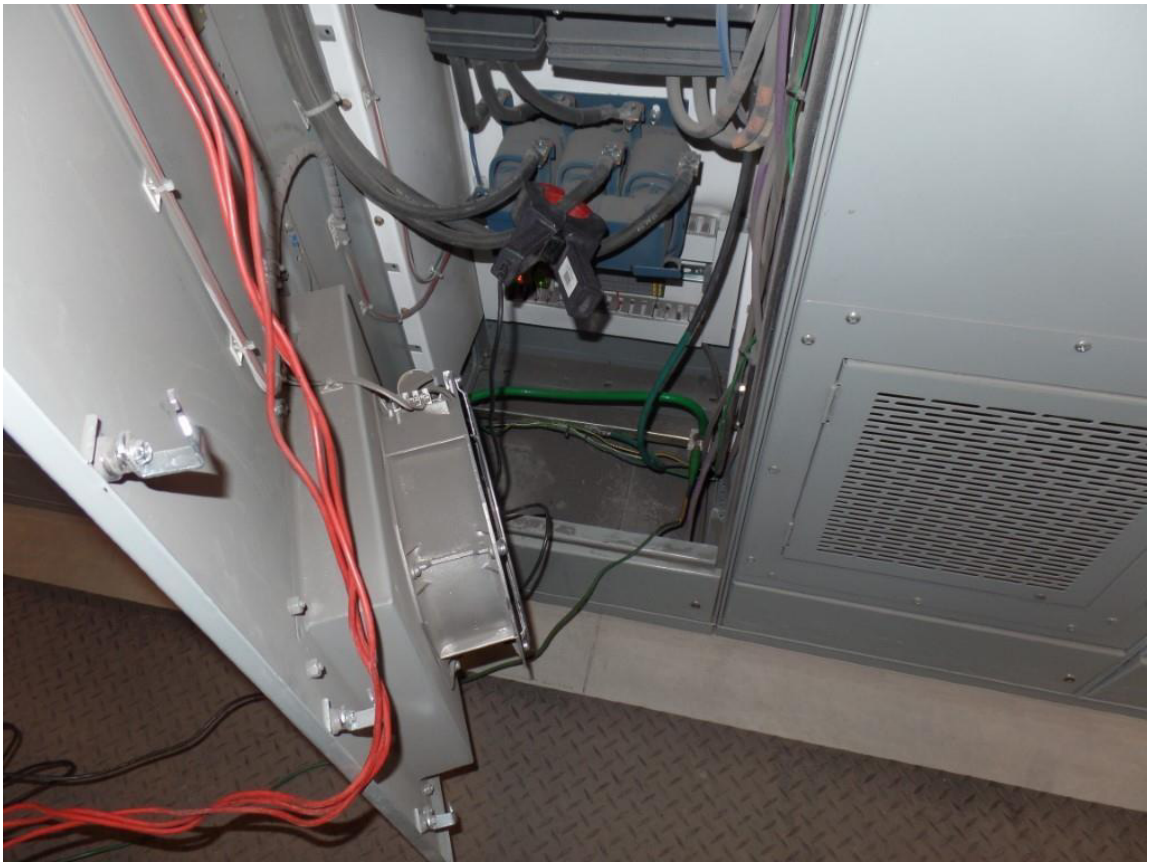
VFD 2057A MCC 101 Panel Schedule Riser Diagram Spare Can 71

MCC 101 Full View from Right End

VFD 2057A Pump 211A Name Plates and Display Screen



VFD 2057A Pump 211A Voltage Probe Connections



VFD 2057A Pump 211A Current Clamp Connection

For the test on VFD 2057A Pump 211A, the Dranetz was again set to monitor to voltage on Channel A from Phase A to Phase B, on Channel B from Phase B to Phase C, and on Channel C from Phase C to Phase A. For this test Channel D recorded the Phase A current. Chart 65 shows the Summary of the readings for Channel A during the monitoring period which lasted for 4 minutes and 57 seconds before the Dranetz internal memory was full. The time of the tests was from 09:01:37 to 09:06:24, Wednesday, February 19, 2020. There were 323 events captured during the monitoring.

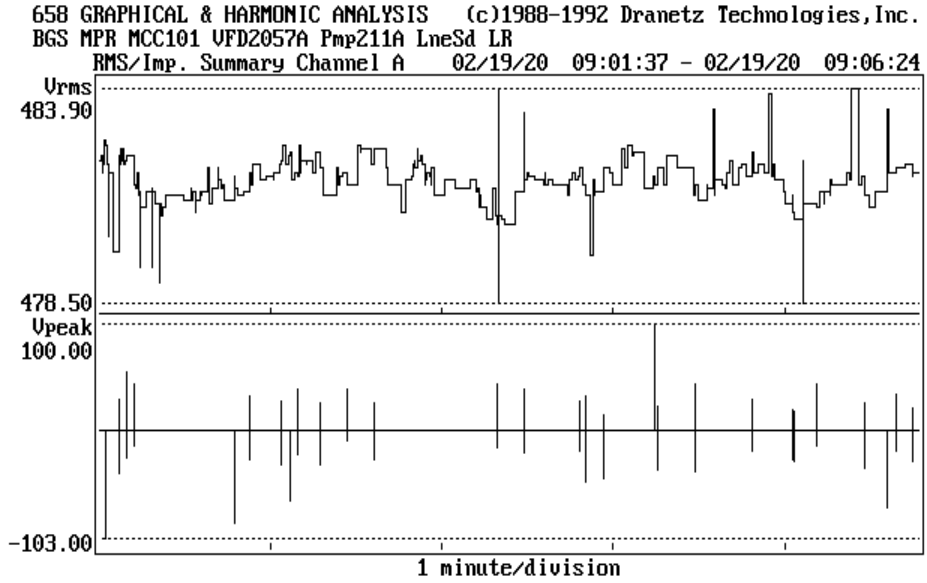


Chart 65

The chart shows the voltage fluctuating over a narrow range from 478.50 Vrms to 483.90 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 100.00 Vpeak Positive to 103.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 66 shows the Summary of the readings for Channel B.

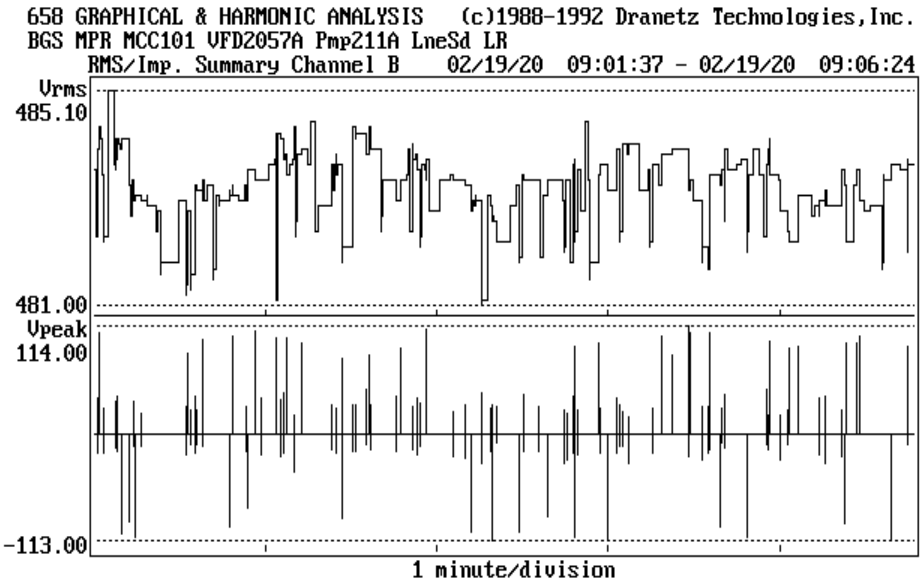


Chart 66

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 481.00 to 485.10 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 114.00 Vpeak to a negative 113.00 Vpeak. There is a very noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 67 shows the Summary of the readings from Channel C.

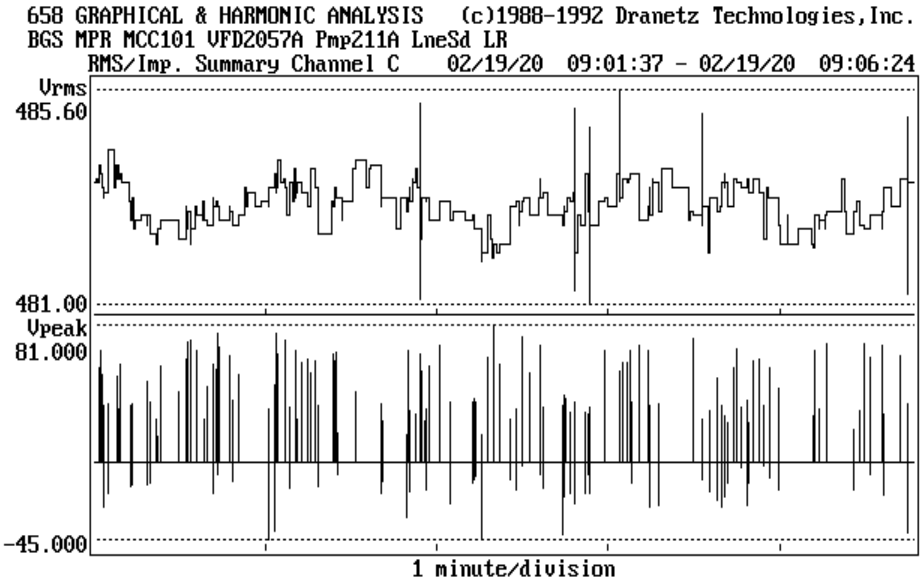


Chart 67

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 481.00 to 485.60 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 81.00 Vpeak to a negative 45.00 Vpeak. There is a further increase in the number of surge events.

Chart 68 shows the Summary of the current readings from Phase A.

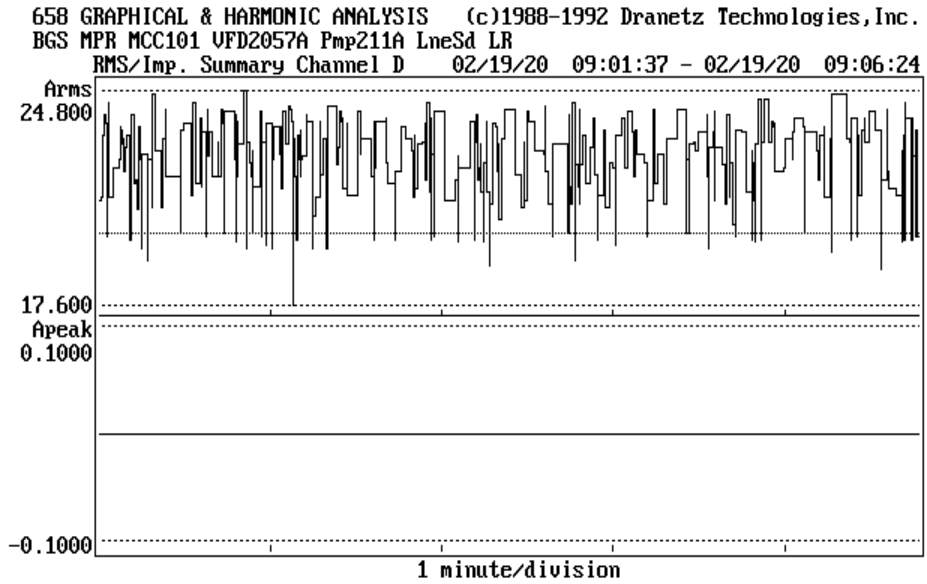


Chart 68

The current on Phase A fluctuates mildly from 17.600 Arms to 24.800 Arms and there were no recorded surge current events. This low but rapid current fluctuation is a result of the VFD drawing current in pulses several times per cycle to convert the AC voltage to DC voltage within the VFD. The VFD and motor were very lightly loaded at the time of the test.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 69, is from Event #88 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

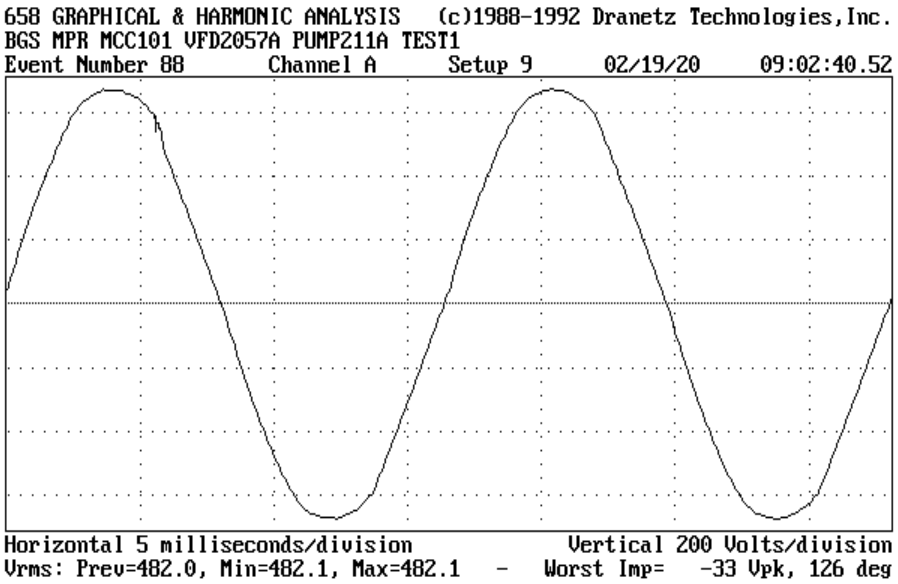


Chart 69

This chart shows the voltage waveform on Phase A to Phase B mode on Channel A. The voltage is stable at 482.1 Vrms. There is a negative 33 Vpeak surge event at 126°, just after the high point of the first cycle. Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 70 from Event #88 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

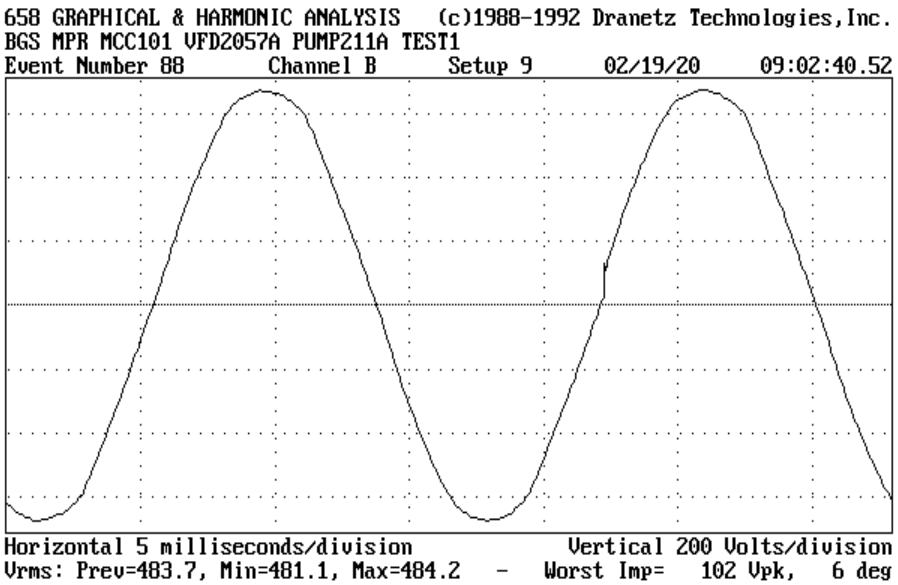


Chart 70

Chart 70 for event #88 shows a positive 102 Vpeak surge, at 6°. The voltage is stable at 481.18 to 484.2 Vrms. This surge event is occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 71 from Event #88 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

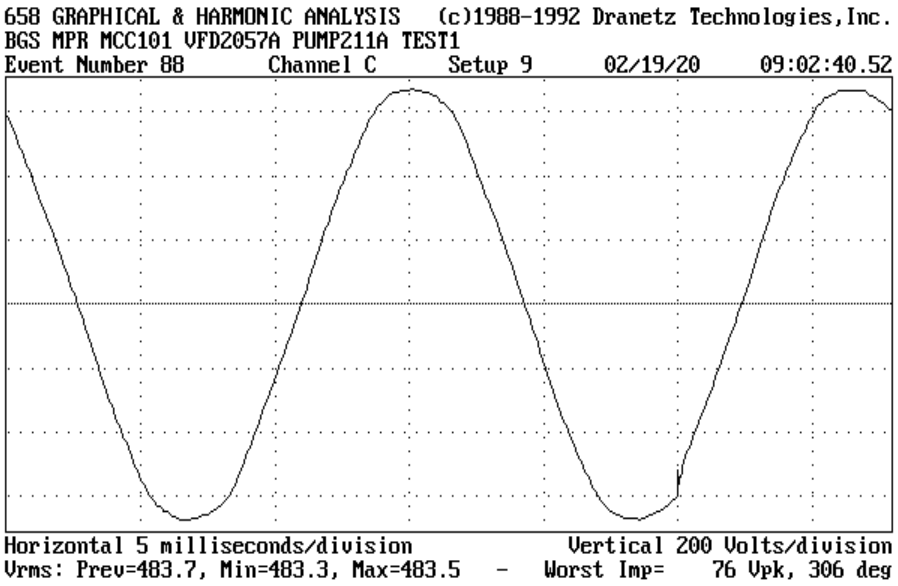


Chart 71

Chart 71 for Event #88 shows a positive 76 Vpeak surge at the 306° point on the wave form. The voltage holds steady at 483.3 to 483.5 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 114 Vpeak to a negative 113 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 72 is from Event #88 and shows the current on Phase A.

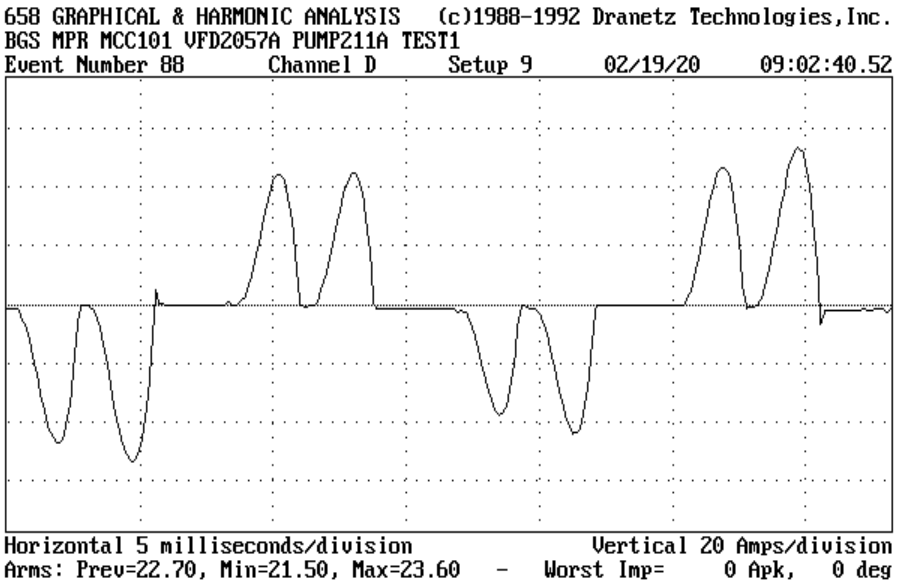


Chart 72

Chart 72 of Event #88 on Channel D shows the current on Phase A. The current is 21.50 to 23.60 Amps with no surge current reported. The distortion on the waveform is typical current harmonic distortion from the way the VFD is converting power from AC to DC by drawing current in pulses four times per cycle. That rate equals 864,000 times per hour. Notice the peaks of the current pulses are up to approximately 52 Apeak.

The next test was also on MCC 101, on the Spare Breaker in Can 71. The Dranetz was again set to monitor to voltage on Channel A from Phase A to Phase B, on Channel B from Phase B to Phase C, and on Channel C from Phase C to Phase A.

Spare Disconnect in Can #71

Spare Disconnect in Can #71 Voltage Probe Connections

Test Set =up on Spare Disconnect in Can #71

Chart 73 shows the Summary of the readings for Channel A during the monitoring period which lasted for 2 minutes and 37 seconds before the Dranetz internal memory was full. The time of the tests was from 10:17:51 to 10:2:28, Wednesday, February 19, 2020. There were 191 events captured during the monitoring.

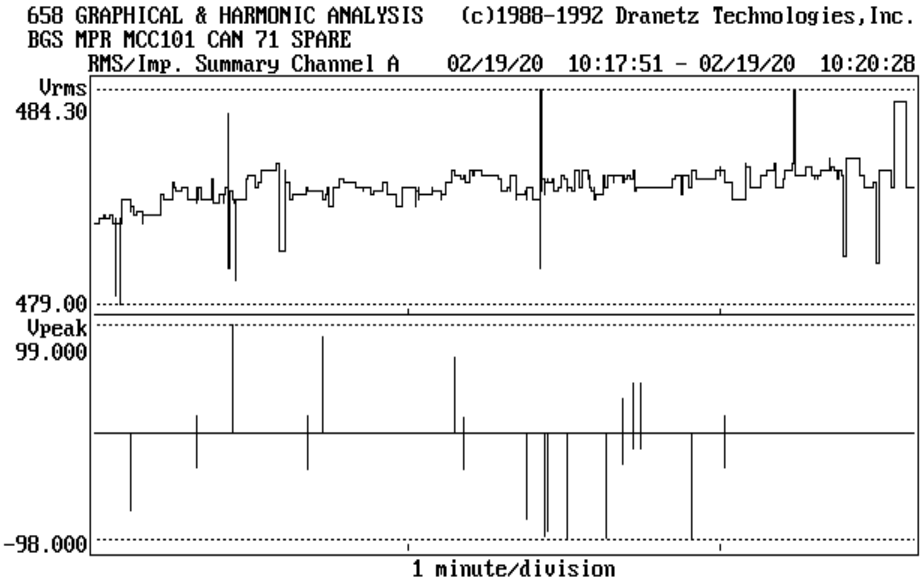


Chart 73

The chart shows the voltage fluctuating over a narrow range from 479.00 Vrms to 484.30 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 99.00 Vpeak Positive to 98.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 74 shows the Summary of the readings for Channel B.

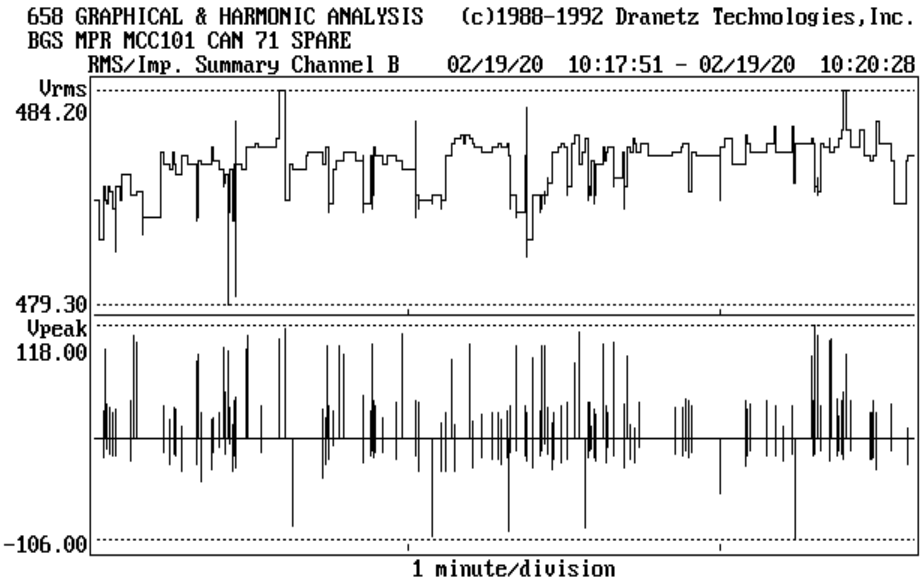


Chart 74

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 479.30 to 484.20 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 118.00 Vpeak to a negative 106.00 Vpeak. There is a very noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 75 shows the Summary of the readings from Channel C.

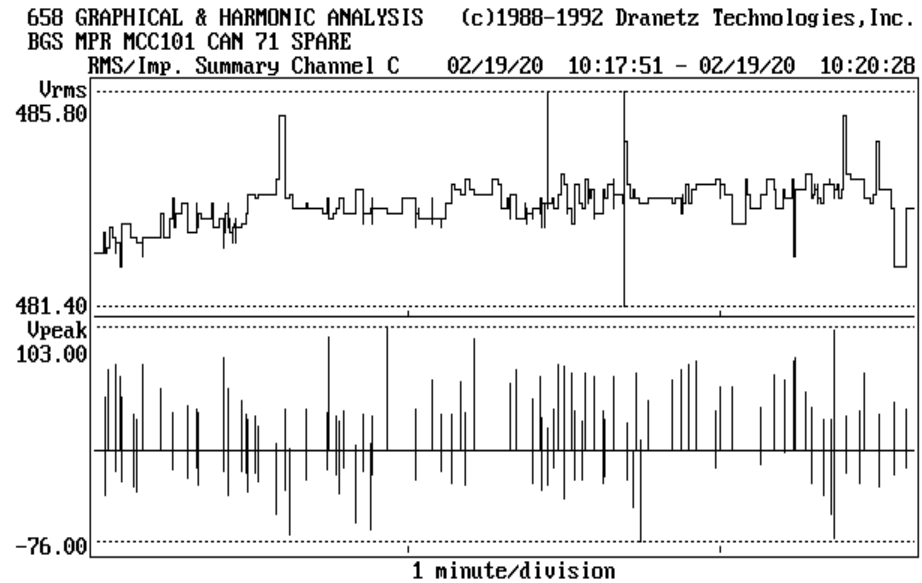


Chart 75

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 481.40 to 485.80 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 103.00 Vpeak to a negative 76.00 Vpeak. There is a further increase in the number of surge events.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 76, is from Event #101 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

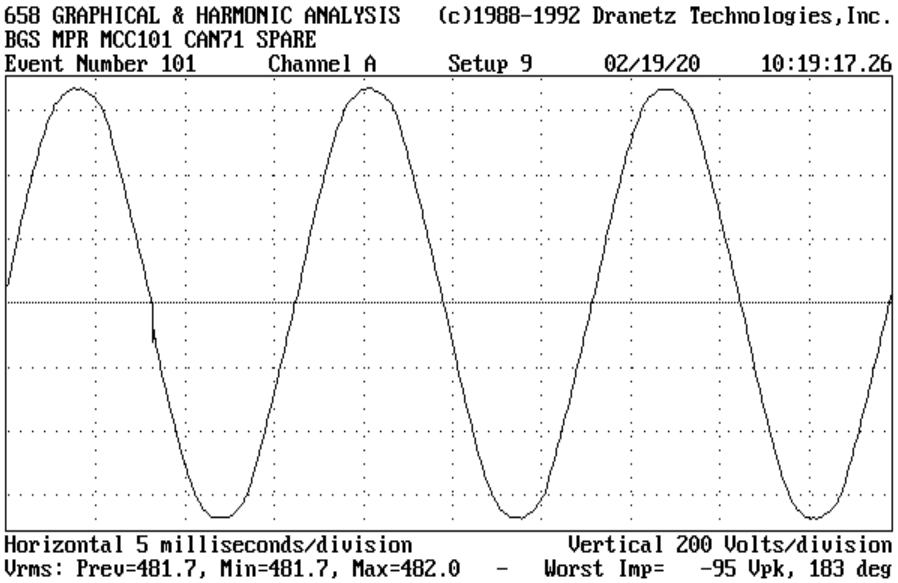


Chart 76

This chart shows the voltage waveform on Phase A to Phase B mode on Channel A. The voltage is stable at 481.7 to 482.0 Vrms. There is a negative 95 Vpeak surge event at 183°, just after the zero crossing on the first cycle. Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 77 from Event #101 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

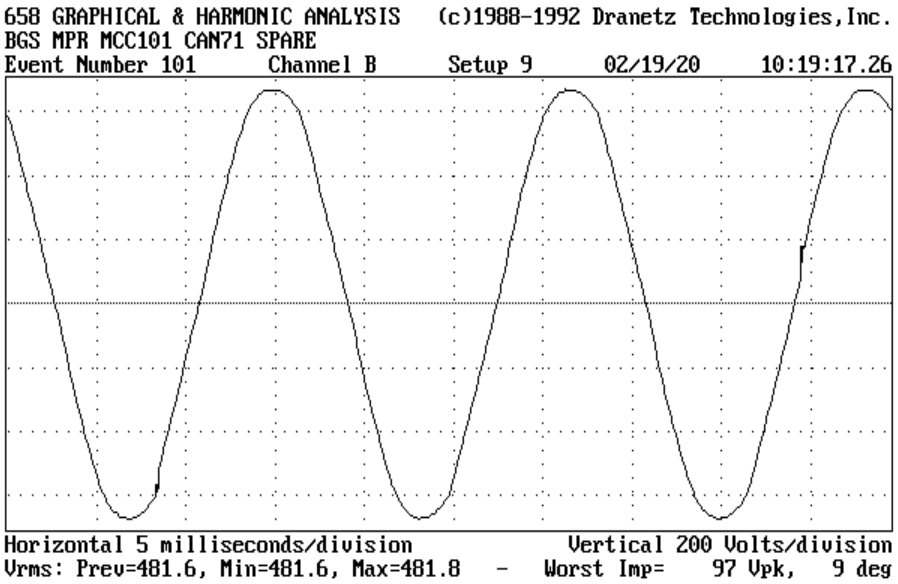


Chart 77

Chart 77 for event #101 shows a positive 97 Vpeak surge, at 9°. The voltage is stable at 481.6 to 481.8 Vrms. This surge event is occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 78 from Event #101 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

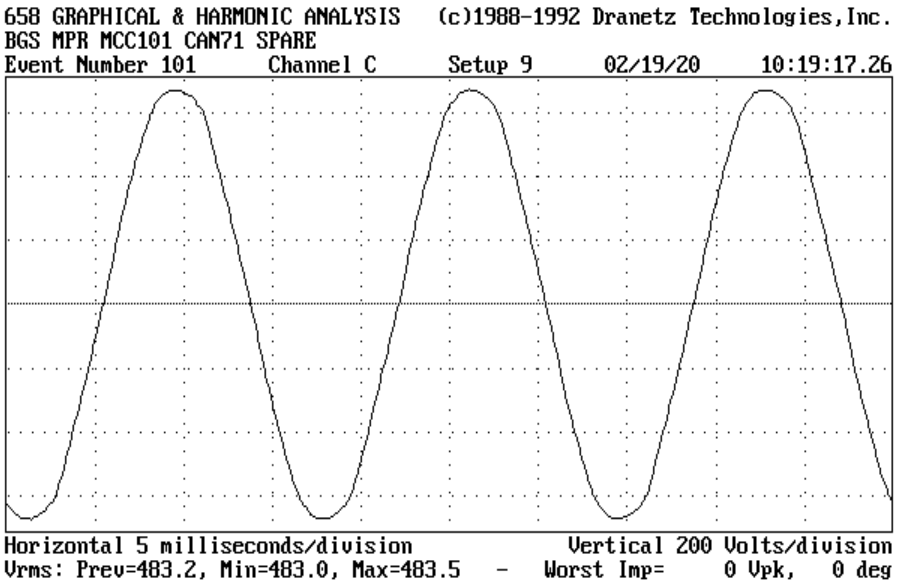


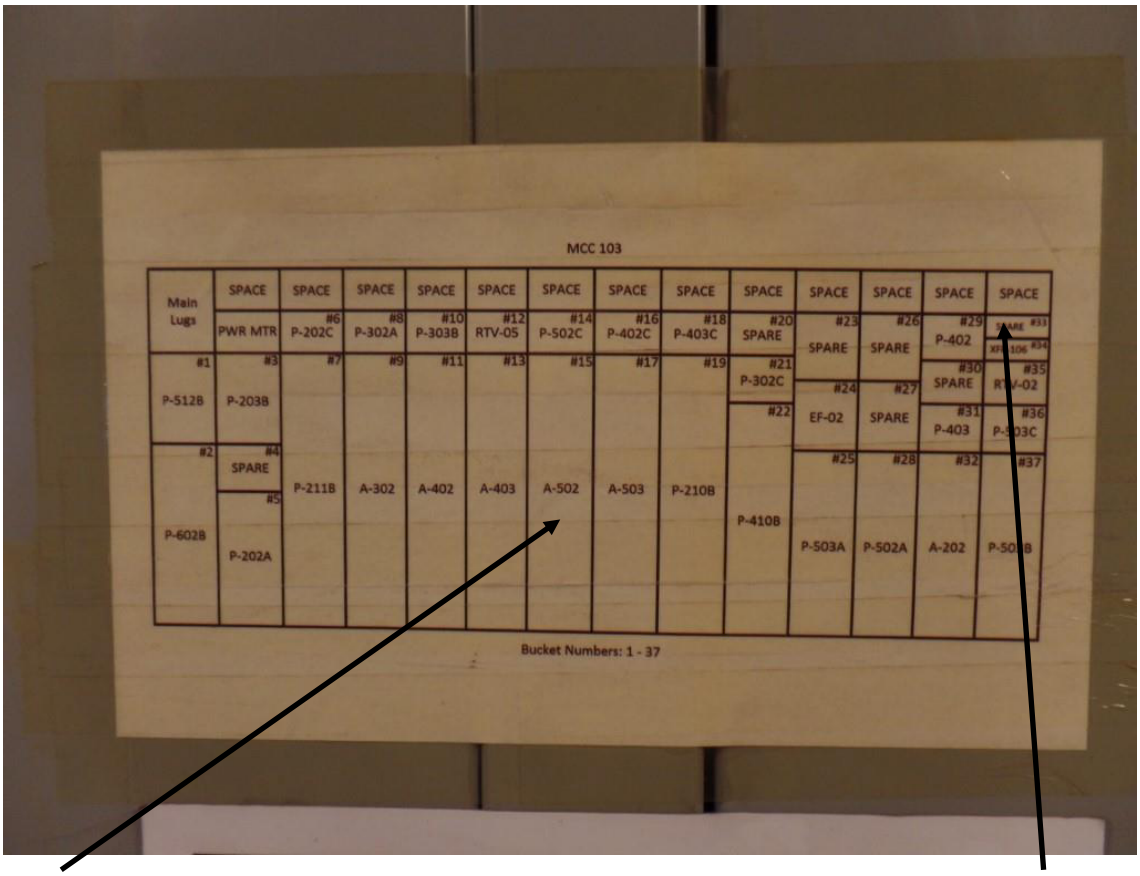
Chart 78

Chart 78for Event #101 has no surge events on the waveform. The voltage holds steady at 483.0 to 483.5 Vrms. Although there are no voltage surges on this phase of this event, as we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 118 Vpeak to a negative 106 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

The next test location was MCC 103.

MCC 103 Name Plates



VFD 5043 MCC 103 Panel Schedule Riser Diagram Spare Can 33

MCC 103 Full View from Left End

VFD 5043 Pump 502 Name Plates and Display Screen

VFD 5043 Pump 502 Voltage Probe and Current Clamp Connections

For the test on VFD 5043 Pump 502, the Dranetz was again set to monitor to voltage on Channel A from Phase A to Phase B, on Channel B from Phase B to Phase C, and on Channel C from Phase C to Phase A. For this test Channel D recorded the Phase A current. Chart 79 shows the Summary of the readings for Channel A during the monitoring period which lasted for 3 minutes and 10 seconds before the Dranetz internal memory was full. The time of the tests was from 11:17:56 to 11:21:06, Wednesday, February 19, 2020. There were 535 events captured during the monitoring.

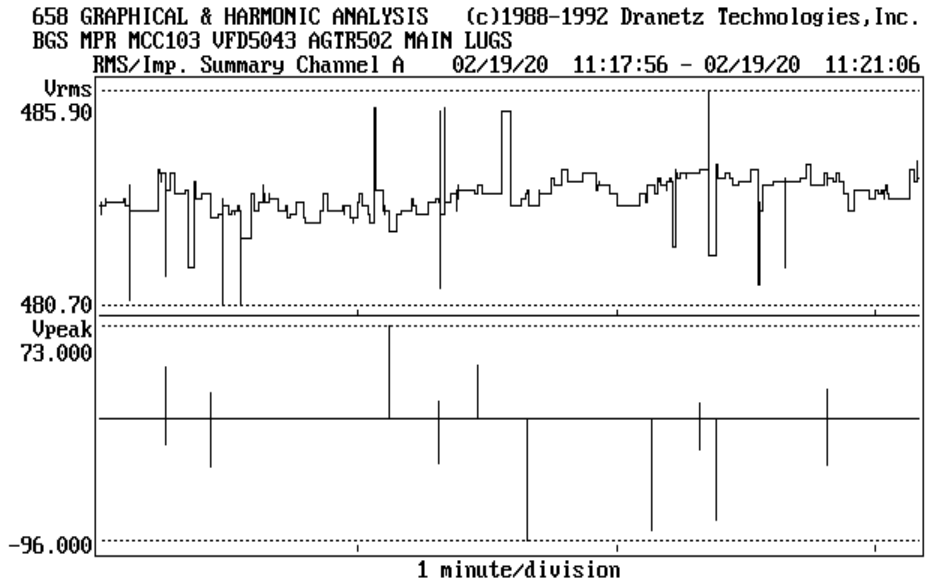


Chart 79

The chart shows the voltage fluctuating over a narrow range from 480.70 Vrms to 485.90 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 73.00 Vpeak Positive to 96.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 80 shows the Summary of the readings for Channel B.

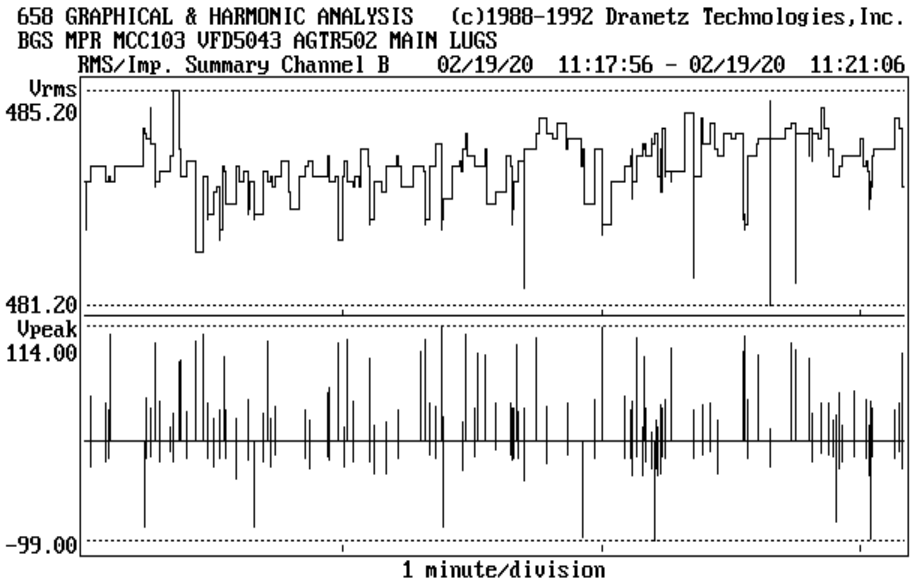


Chart 80

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 481.20 to 485.20 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 114.00 Vpeak to a negative 99.00 Vpeak. There is a very noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 81 shows the Summary of the readings from Channel C.

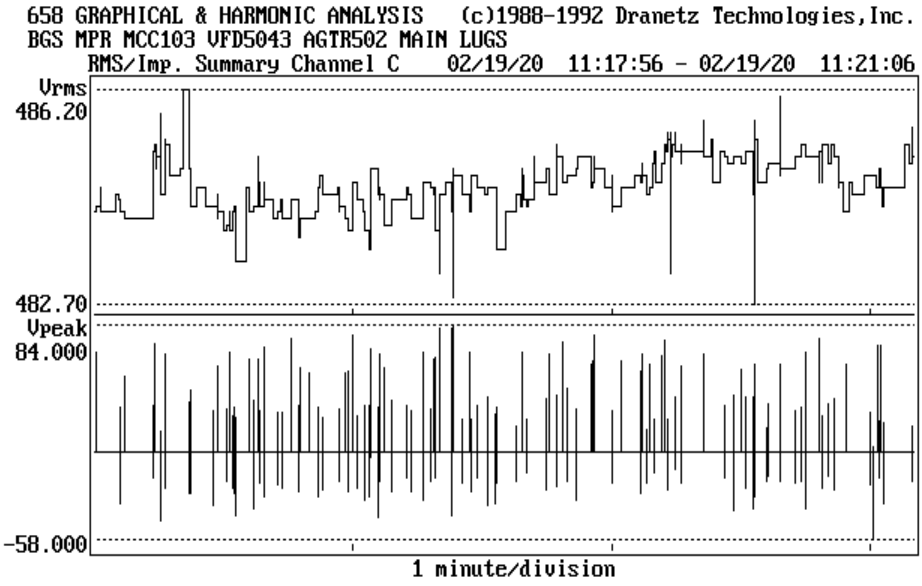


Chart 81

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 482.70 to 486.20 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 84.00 Vpeak to a negative 58.00 Vpeak. There is a further increase in the number of surge events.

Chart 82 shows the Summary of the current readings from Phase A.

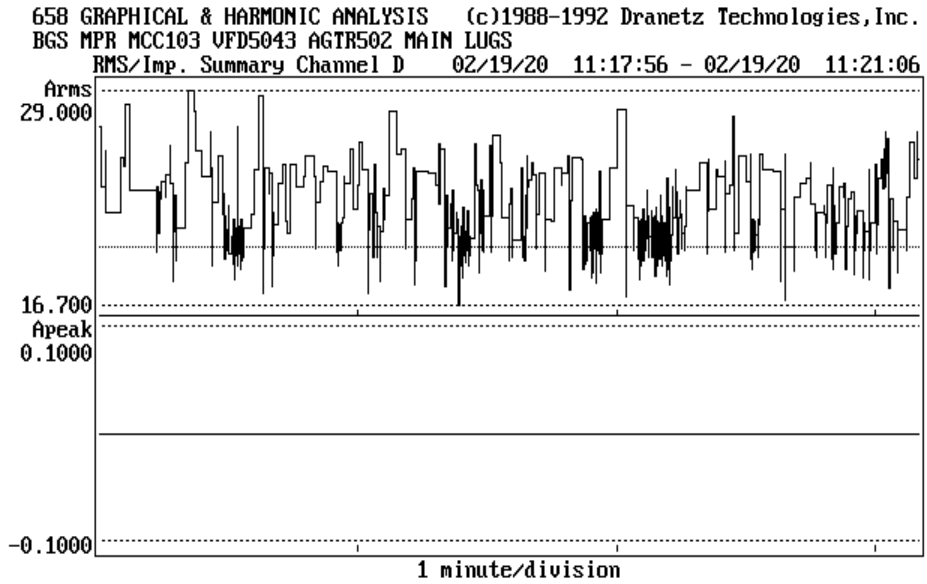


Chart 82

The current on Phase A fluctuates mildly from 16.700 Arms to 29.000 Arms and there were no recorded surge current events. This low but rapid current fluctuation is a result of the VFD drawing current in pulses several times per cycle to convert the AC voltage to DC voltage within the VFD. The VFD and motor were very lightly loaded at the time of the test.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 83, is from Event #170 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

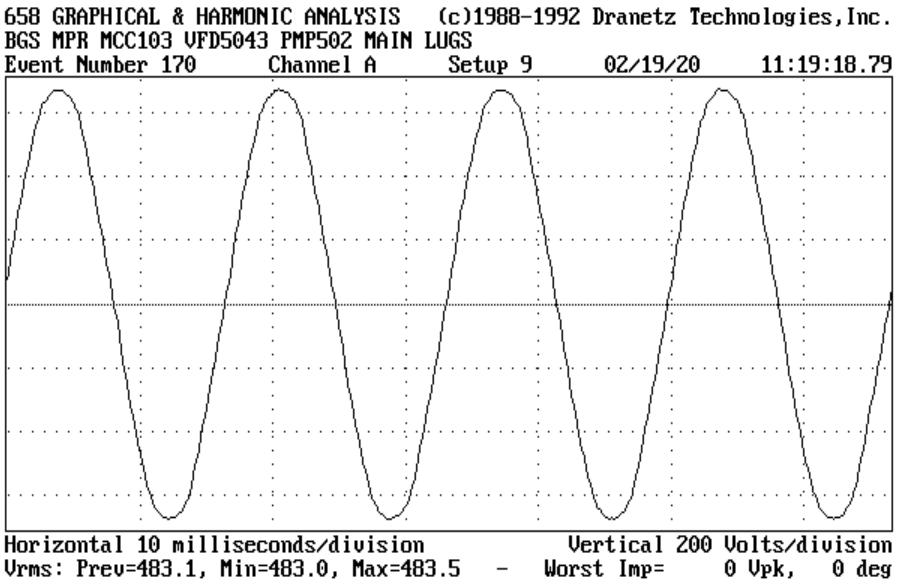


Chart 83

This chart shows the voltage waveform on Phase A to Phase B mode on Channel A. The voltage is stable at 483.0 to 483.5 Vrms. There is no surge activity during this event. Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 84 from Event #170 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

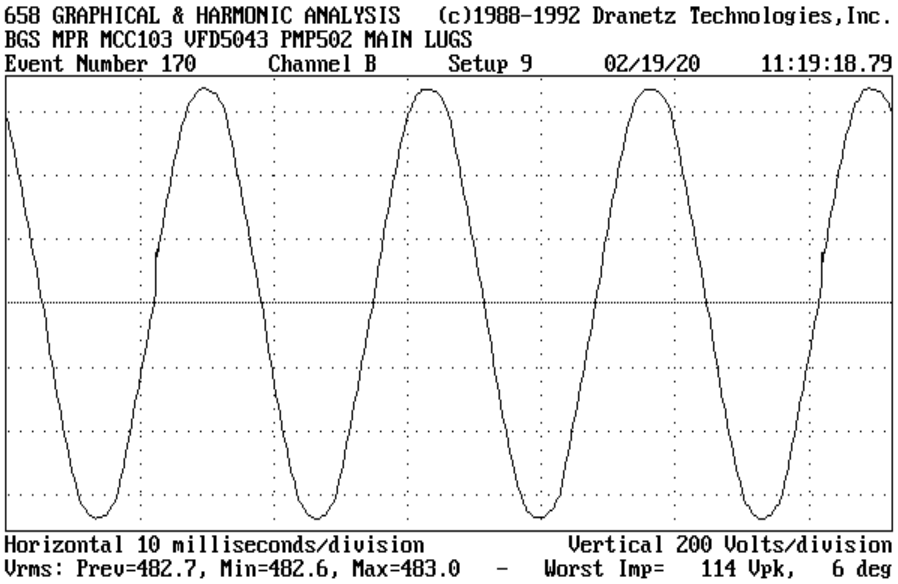


Chart 70

Chart 84 for event #170 shows a positive 114 Vpeak surge, at 6°. The voltage is stable at 482.60 to 483.0 Vrms. This surge event is occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 85 from Event #170 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

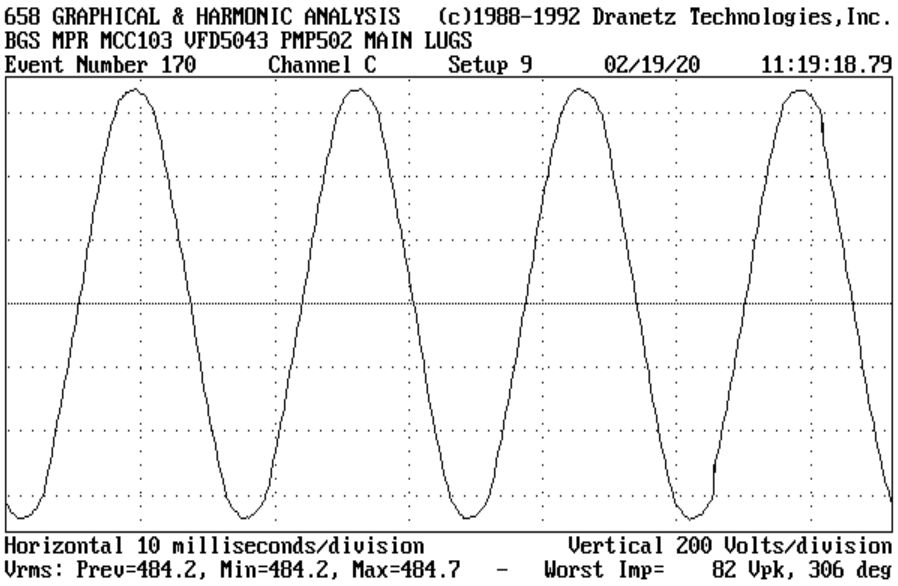


Chart 85

Chart 85 for Event #170 shows a positive 82 Vpeak surge at the 306° point on the wave form. The voltage holds steady at 484.2 to 484.7 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 114 Vpeak to a negative 99 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 86 is from Event #170 and shows the current on Phase A.

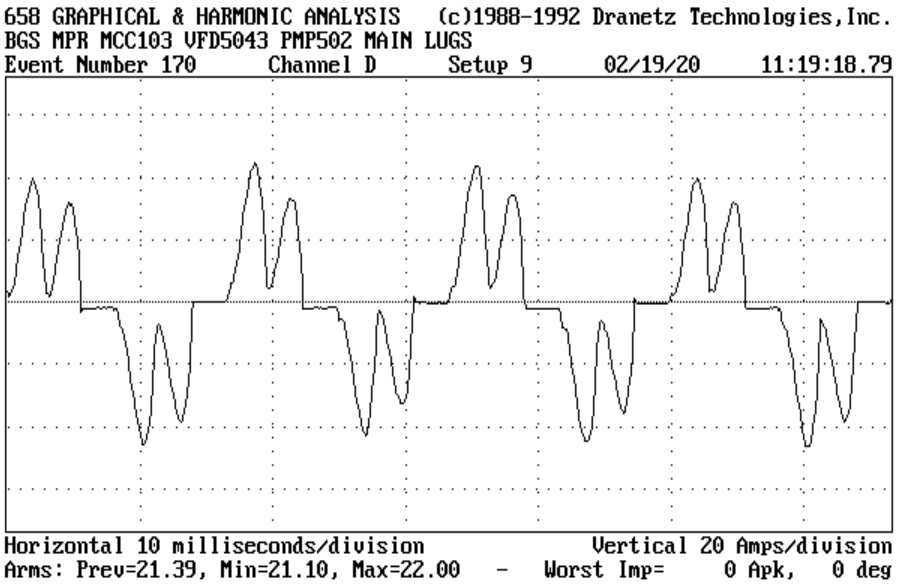


Chart 86

Chart 86 of Event #170 on Channel D shows the current on Phase A. The current is 21.10 to 22.00 Amps with no surge current reported. The distortion on the waveform is typical current harmonic distortion from the way the VFD is converting power from AC to DC by drawing current in pulses four times per cycle. That rate equals 864,000 times per hour. Notice the peaks of the current pulses are up to approximately 45 Apeak.

The next test was also on MCC 103, on the Spare Breaker in Can 33. The Dranetz was again set to monitor to voltage on Channel A from Phase A to Phase B, on Channel B from Phase B to Phase C, and on Channel C from Phase C to Phase A.

Spare Disconnect on MCC 103 in Can #33

Spare Disconnect on MCC 103 in Can #33 Voltage Probe Connections

Ground Connection on MCC 103 in Spare Disconnect Can #71

Chart 87 shows the Summary of the readings for Channel A during the monitoring period which lasted for 20 seconds before the Dranetz internal memory was full. The time of the tests was from 12:12:36 to 12:12:56 Wednesday, February 19, 2020. There were 66 events captured during the monitoring.

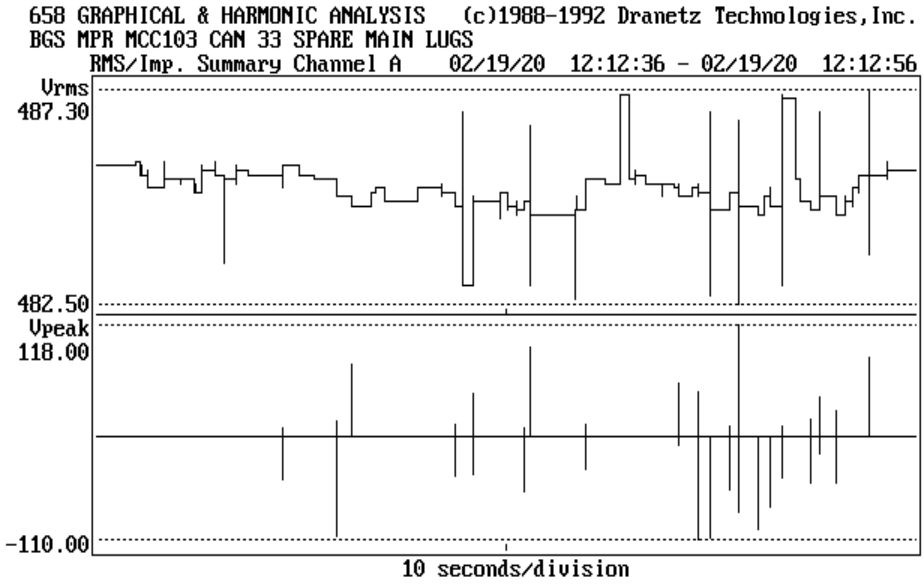


Chart 87

The chart shows the voltage fluctuating over a narrow range from 482.50 Vrms to 487.30 Vrms. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period ranging from 118.00 Vpeak Positive to 110.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 88 shows the Summary of the readings for Channel B.

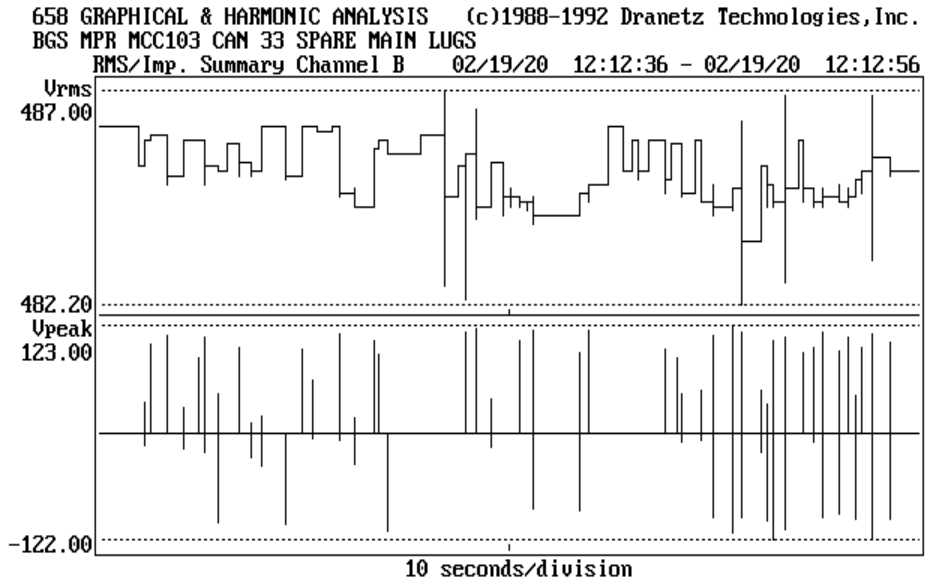


Chart 88

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 482.20 to 487.00 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 123.00 Vpeak to a negative 122.00 Vpeak. There is a very noticeable increase in the number of surge events recorded on Phase B to Phase C mode over those recorded on Phase A to Phase B mode.

Chart 89 shows the Summary of the readings from Channel C.

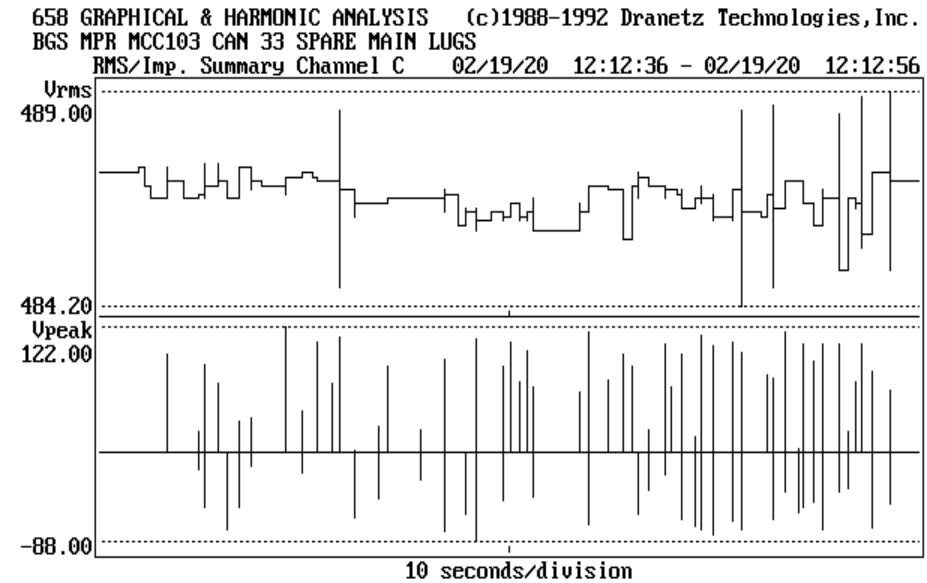


Chart 89

The nominal 480 Vrms on Phase B to Phase C mode has only minor fluctuations from 484.20 to 489.00 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 123.00 Vpeak to a negative 122.00 Vpeak. There is a further increase in the number of surge events.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 90, is from Event #20 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

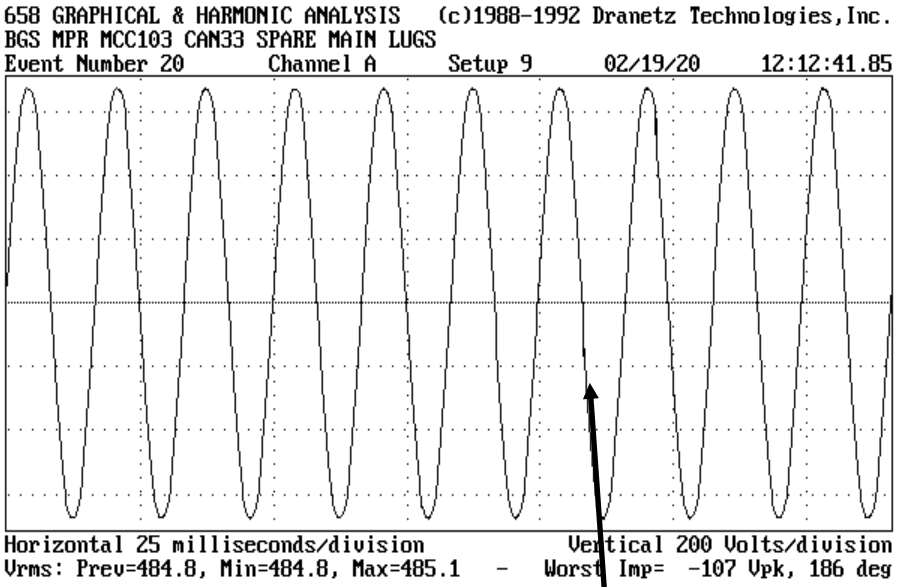


Chart 90

This chart shows the voltage waveform on Phase A to Phase B mode on Channel A. The voltage is stable at 484.8 to 485.1 Vrms. There is a negative 107 Vpeak surge event at 186°. Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 91 from Event #20 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

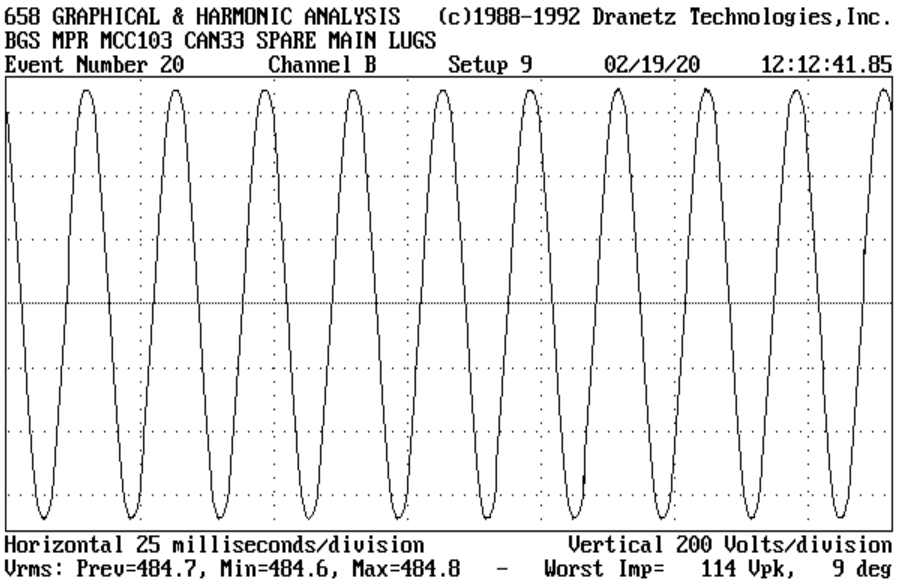


Chart 91

Chart 91 for event #20 shows a positive 114 Vpeak surge, at 9°. The voltage is stable at 484.6 to 484.8 Vrms. This surge event is occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 92 from Event #20 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

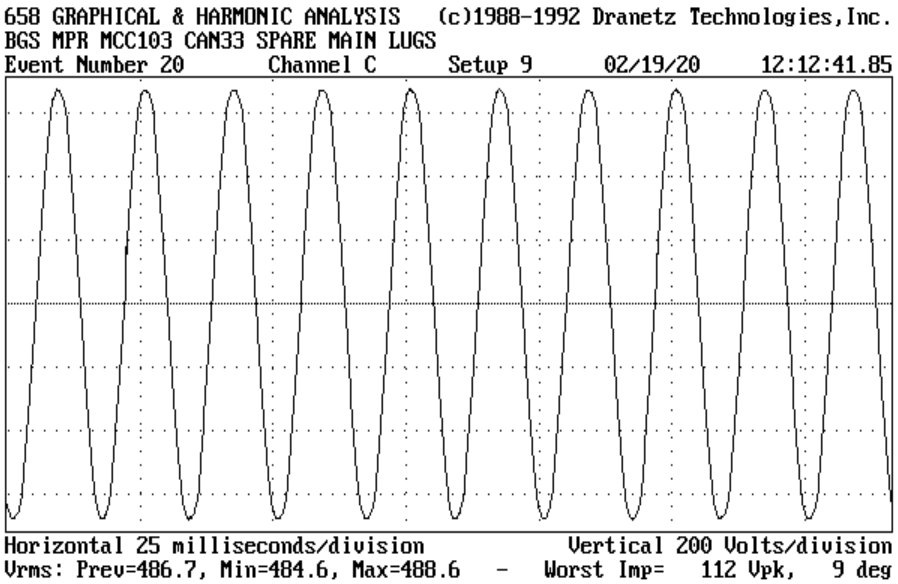


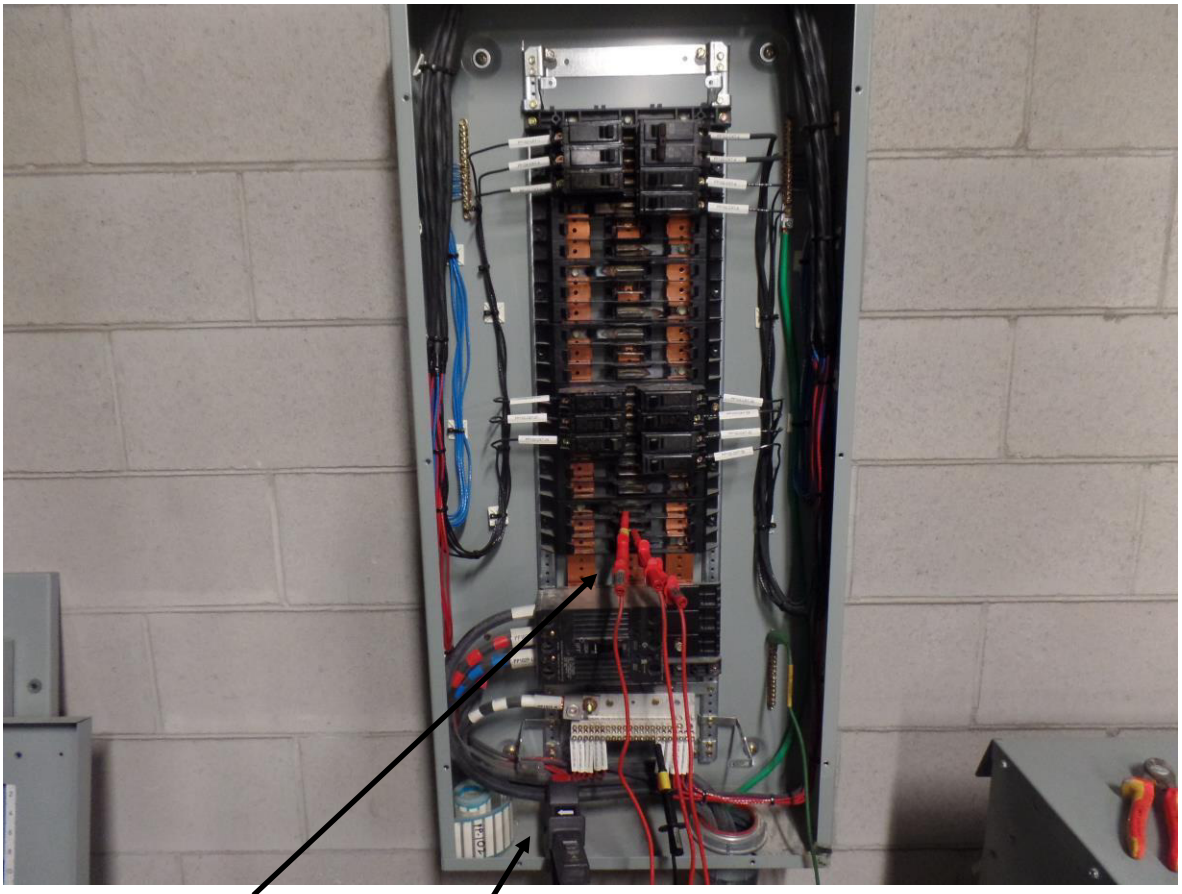
Chart 92

Chart 92 for Event #20 has a positive 112 Vpeak surge at 9°. The voltage holds steady at 484.6 to 488.6 Vrms. As we observed on the Summary for Channel C, there are even more surge events on the Phase C to Phase A mode.

The size of all of these surge events on each mode varies from a positive 123 Vpeak to a negative 122 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

We moved to Power Panel PP-102. This is a standard 120/208 V, 3Ø, 4-Wire, Wye system powering mainly the Heat Traces and other unknown electrical and possibly electronic loads. It was impossible at that time to determine exactly what was connected to this power panel because the labeling was inaccurate and all the breaker runs were distributed through cable trays and conduit leaving the Main Power Room. This is a problem with all four of the Power Panels in the Main Power Room, and is scheduled to be investigated and corrected by the Plant Electrician with assistance from , Lead Electrical Engineer from . The Dranetz was connected with Channel A monitoring the Phase A to Neutral voltage, Channel B monitoring the Phase B to Neutral voltage, Channel C monitoring the Phase C to Neutral voltage, and Channel D monitoring the current on Phase A. The monitoring period was from 13:54:30 on Wednesday, February 19, 2020 to 06:49:31 on Thursday, February 20, 2020 for a total of 16 hours, 55 minutes and 1 second, on Wednesday, February 19, 2020. This was to determine the impact of the Heat Traces on the other equipment in the panel. There were 18 events recorded during the monitoring period.

Names Plates for Power Panel PP-102



Voltage Probes and Current Probe connection for Power Panel PP-102

Test setup for Power Panel PP--102

Chart 93 displays the Summary of the voltage events on Channel A, Phase A to Phase B.

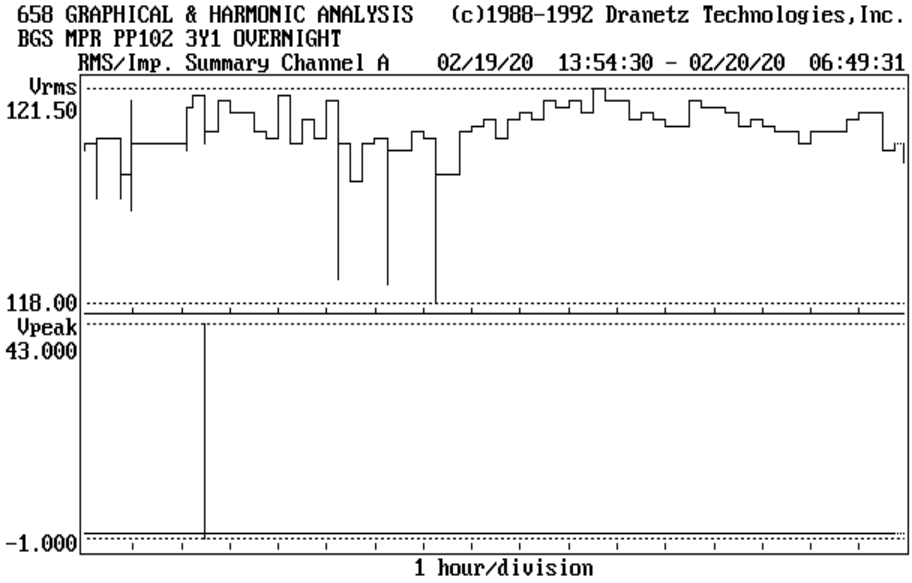


Chart 93

The chart shows the voltage fluctuating over a narrow range from 118.00 Vrms to 121.50 Vrms. This is stable voltage for an industrial plant. There was one surge event on Phase A to Neutral during the monitoring period, coinciding with the Heat Trace turning on. This is low-level switching surge activity that is not immediately catastrophic.

Chart 94 shows the Summary of the readings for Channel B.

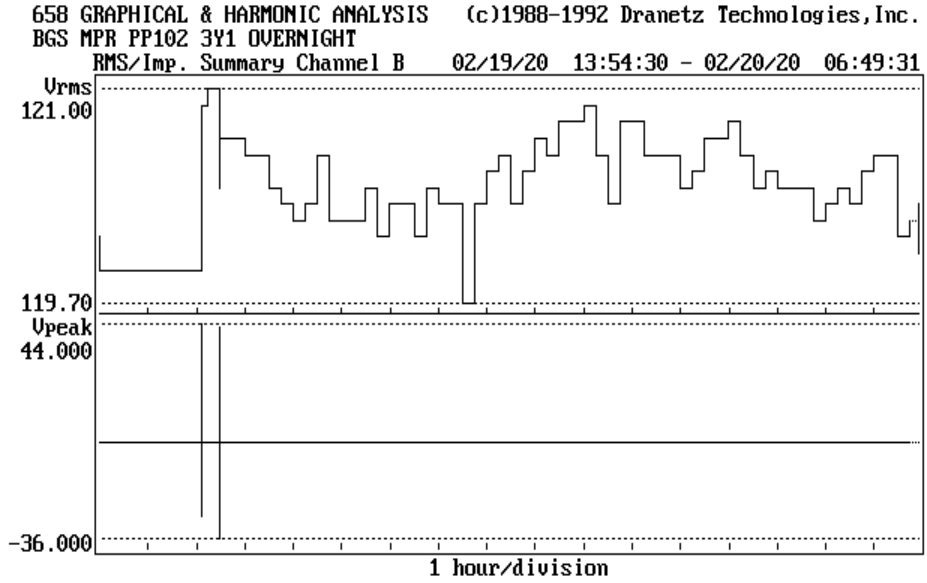


Chart 94

The nominal 120 Vrms on Phase B to Neutral mode has only minor fluctuations from 119.7 to 121.00 Vrms during the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 44.00 Vpeak to a negative 36.00 Vpeak. This also coincided with the Heat Trace turning on.

Chart 95 shows the Summary of the readings from Channel C.

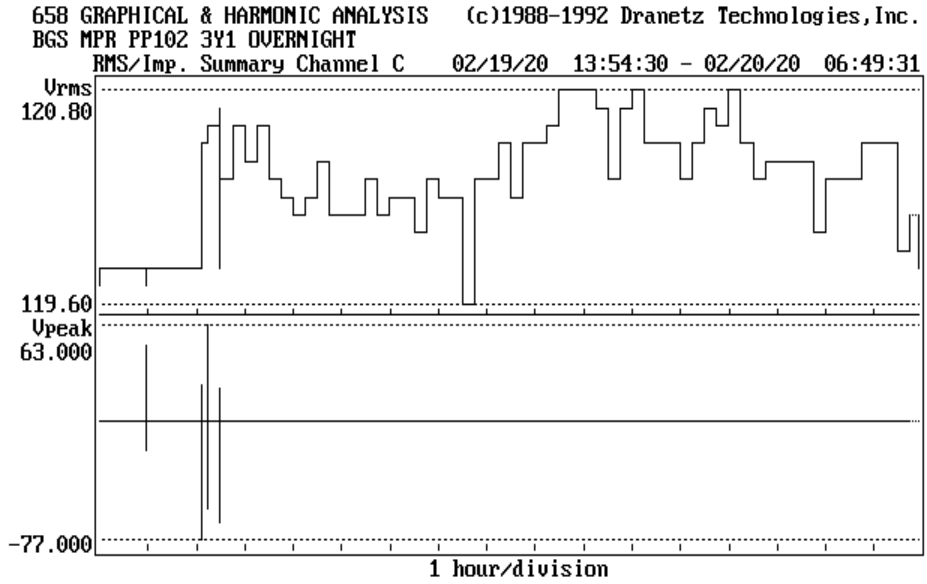


Chart 95

The nominal 120 Vrms on Phase C to Neutral mode has only minor fluctuations from 119.60 to 120.00 Vrms over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 63.00 Vpeak to a negative 77.00 Vpeak. In addition to the Heat Trace turning on, there were a few other surg events during the monitoring period.

Chart 96 shows the Summary of the current readings from Phase A.

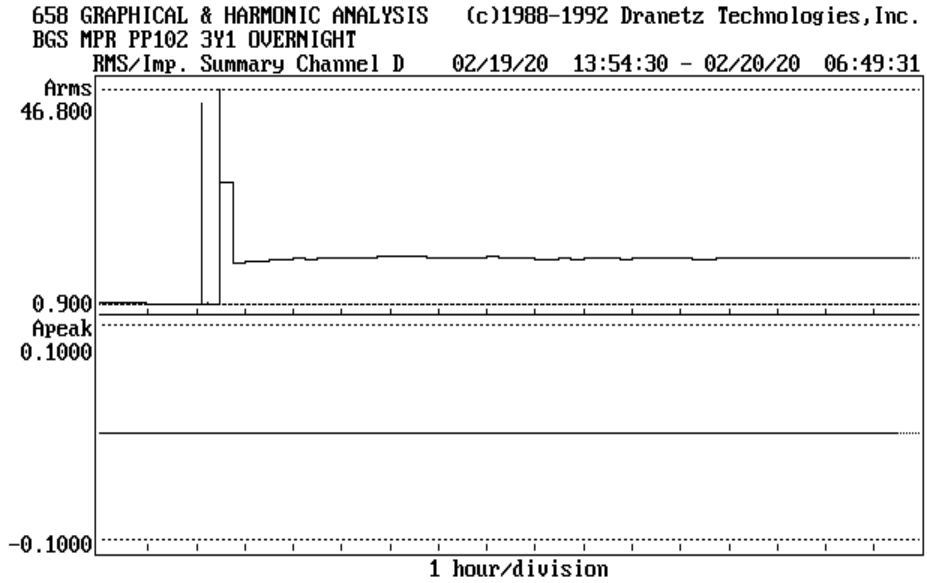


Chart 96

The current on Phase A showed a strong increase from 0.900 Arms to 46.8 Arms at the turn-on of the Heat Trace. Once the Heat Traces were turned on, they apparently remained on all night, with no other significant surge activity recorded during the monitoring period. This is an indication that the voltage surge events captured at this point are originating from the Heat Trace and other equipment powered from this panel.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 97, is from Event #12 and shows the readings from Channel A on the 120 Vrms Phase A to Neutral mode.

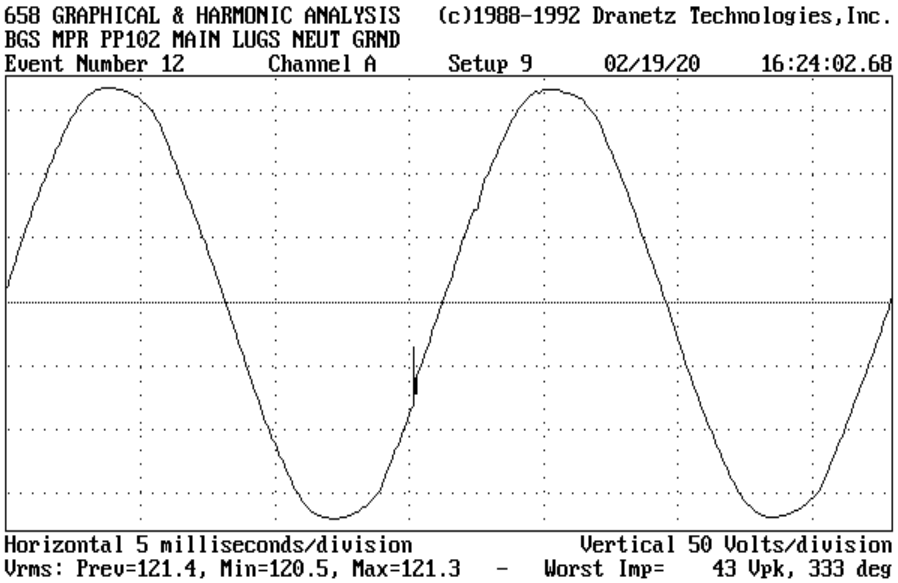


Chart 97

This chart displays the voltage surge events on Channel A for Phase A to Neutral. The voltage is stable at 120.5 to 121.3 Vrms. There is a positive 43 Vpeak surge event at 333°. Channel A does have surge events occurring at the start of the Heat Trace elements. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 98 from Event #12 and shows the readings from Channel B on the 120 Vrms Phase B to Neutral mode.

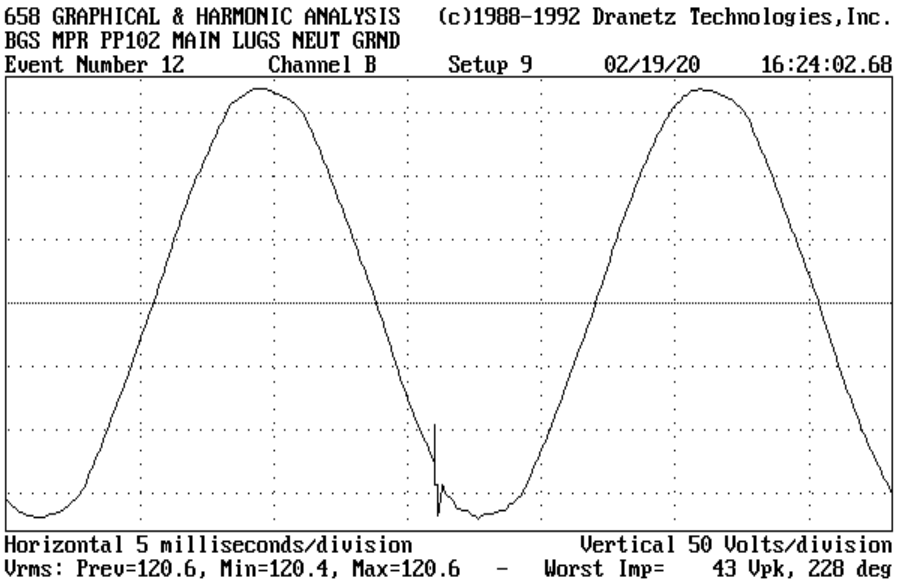


Chart 98

Chart 98 for event #69 shows a positive 43 Vpeak surge, at 228°. These surge events are occurring several times at the startup of the Heat Trace. The potential for cumulative damage, particularly in electronic equipment is even greater because of the increased number of surge events on Channel B over those on Channel A.

Chart 99 from Event #12 and shows the readings from Channel C on the 120 Vrms Phase C Neutral mode.

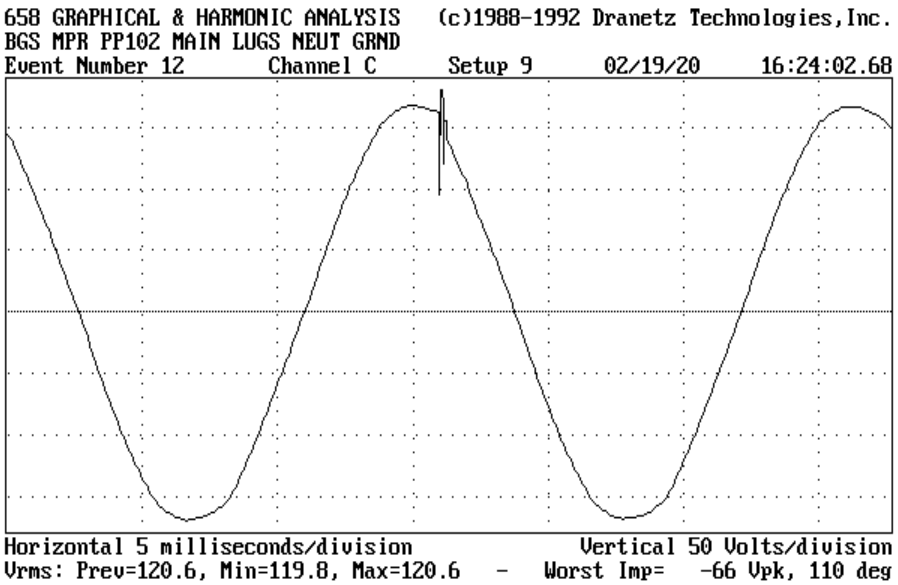


Chart 99

Chart 99 for Event #12 shows a negative 66 Vpeak surge at the 110° point on the wave form. The voltage holds steady at 119.8 to 120.6 Vrms. As we observed on the Summary for Channel C, there are more surge events on the Phase C to Neutral than on Phase A to Neutral mode.

The size of all of these surge events on each mode varies from a positive 63 Vpeak to a negative 77 Vpeak. At the rate of repetition observed, there is a probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 100 is from Event #12 and shows the current on Phase B.

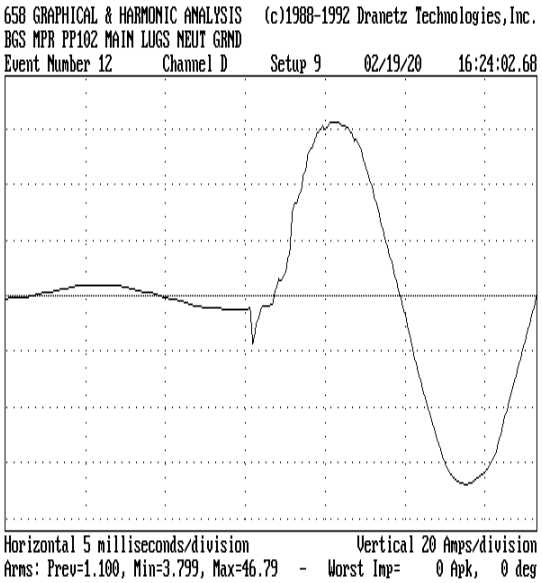
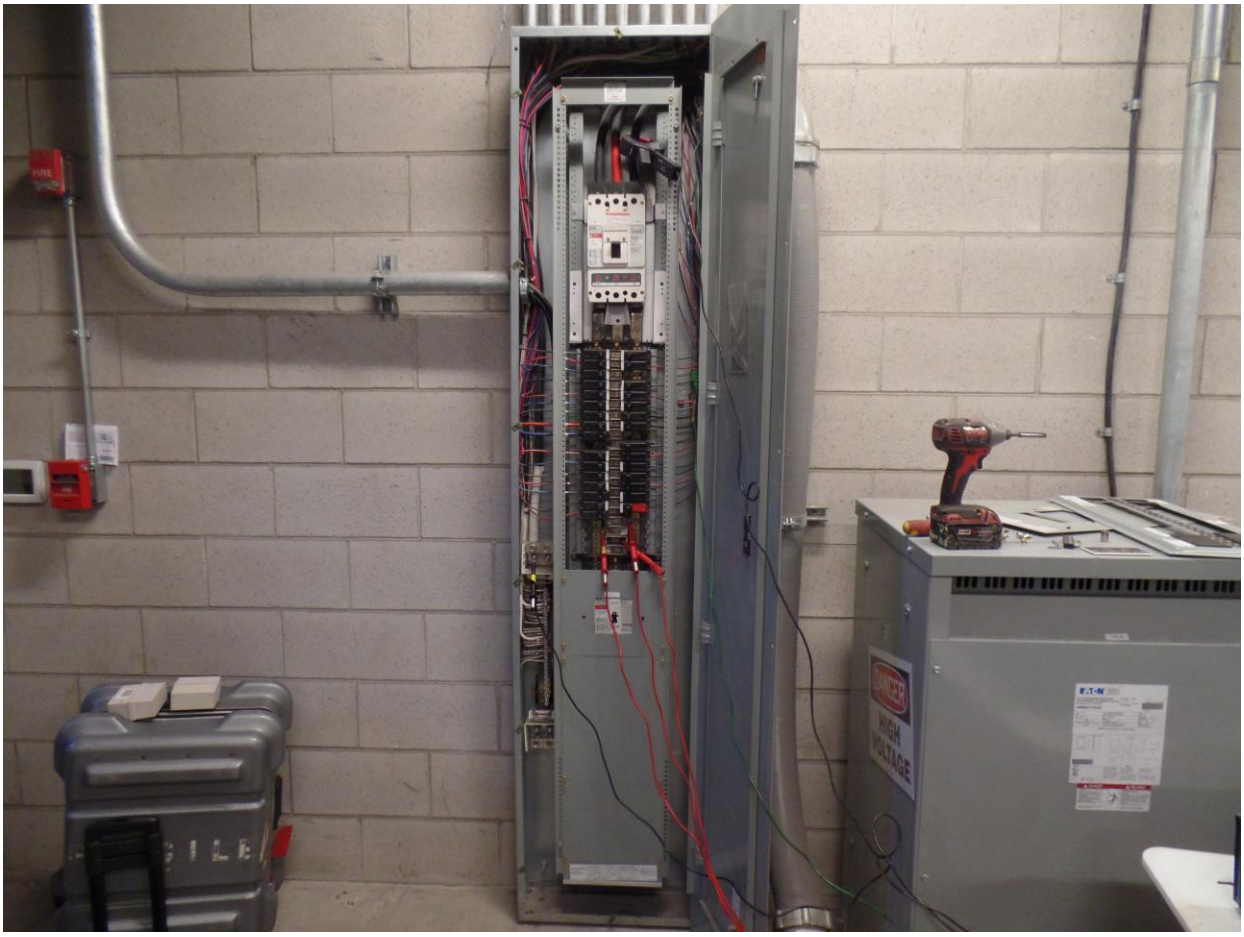


Chart 100

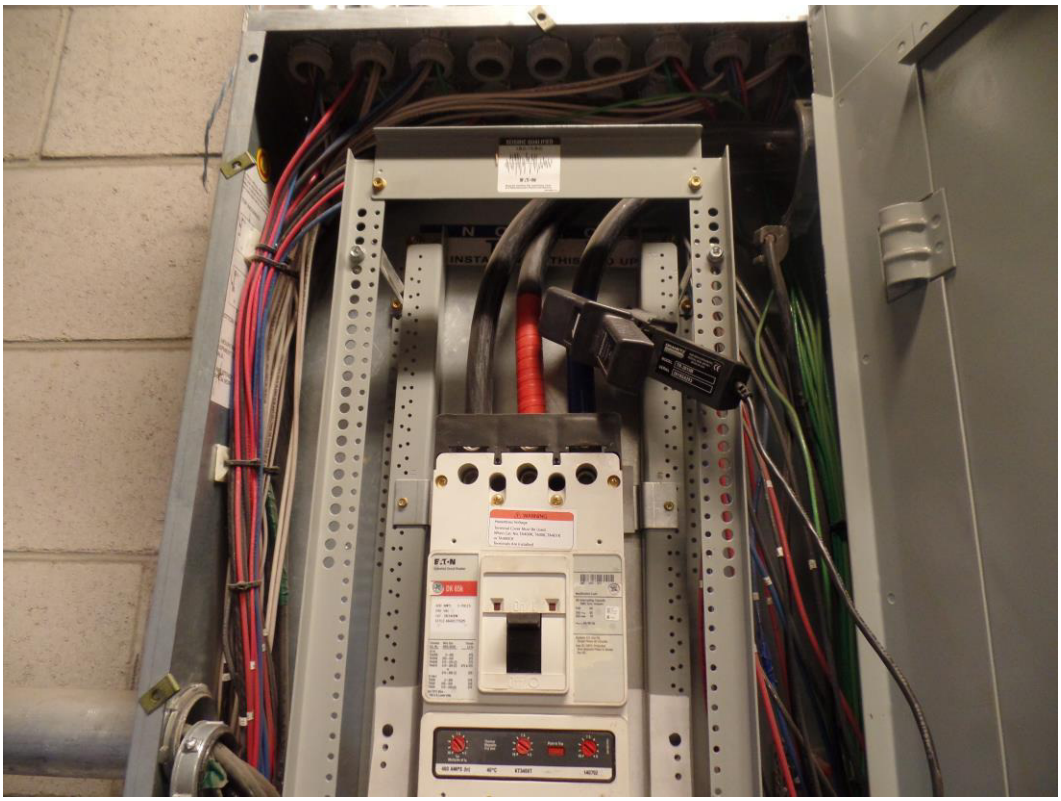
Chart 100 of Event #12 on Channel D shows the current on Phase A. The current is at 1.100 Arms at the start of the chart. It goes to 3.799 Arms and then, after an approximately 18 Amp negative spike, increases to a maximum of 46.79 Arms with a peak of around 65 Apeak. There were no surge current events reported. Once begun, the waveform appears clean and undistorted.

Until it can be determined what other equipment is powered from PP-102, it should be considered to contain electronic equipment and should be protected under those conditions.

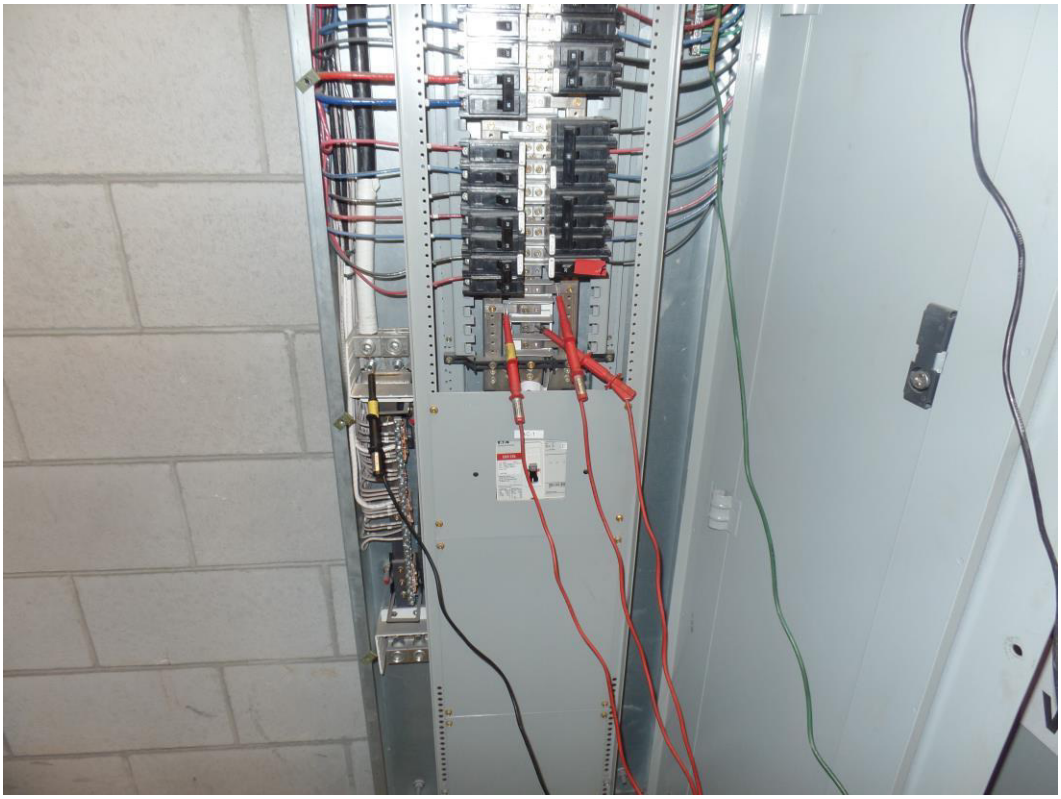
We moved to Power Panel PP-LB. This is a standard 120/208 V, 3Ø, 4-Wire, Wye system reportedly powering the two welders, exhaust fans, and the shop office computers in the shop and other unknown electrical and electronic loads. It was impossible at that time to determine exactly what was connected to this power panel because the labeling was inaccurate and all the breaker runs were distributed through cable trays and conduit leaving the Main Power Room. The Dranetz was connected with Channel A monitoring the Phase A to Neutral voltage, Channel B monitoring the Phase B to Neutral voltage, Channel C monitoring the Phase C to Neutral voltage, and Channel D monitoring the current on Phase C. The monitoring period was from 07:58:49 to 08:28:10 on Thursday, February 20, 2020 for a total of 29 minutes and 21 seconds. There were 35 events recorded during the monitoring period.



Power Panel PP-LB



Current Clamp on Phase C on Power Panel PP-LB



Voltage Probe connections for monitoring Power Panel PP-LB

Chart 101 displays the Summary of the voltage events on Channel A, Phase A to Neutral.

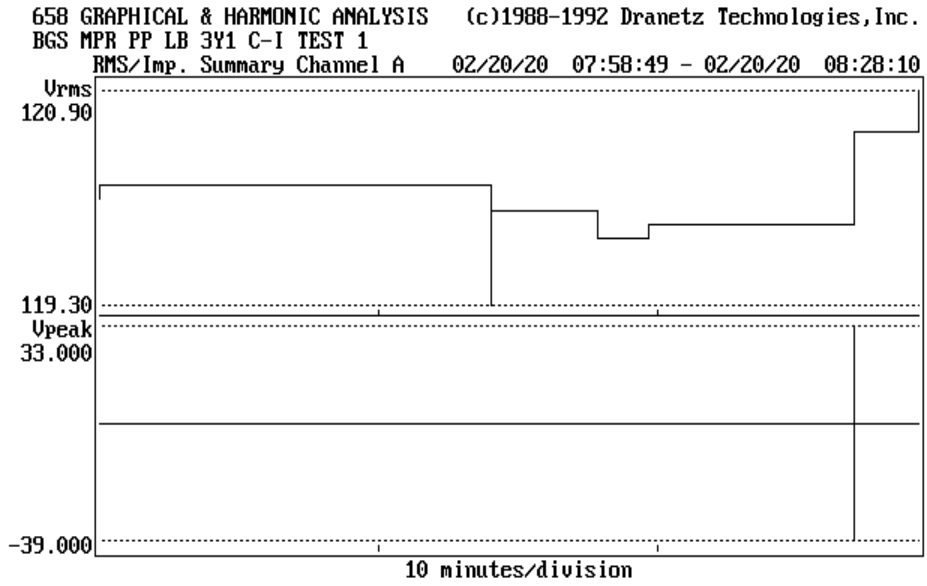


Chart 101

The chart shows the voltage fluctuating over a narrow range from 119.30 Vrms to 120.90 Vrms. This is stable voltage for an industrial plant. There were voltage surge events during the monitoring period ranging from 33.00 Vpeak Positive to 39.00 Vpeak Negative. This is low-level switching surge activity that is not immediately catastrophic.

Chart 102 shows the Summary of the readings for Channel B.

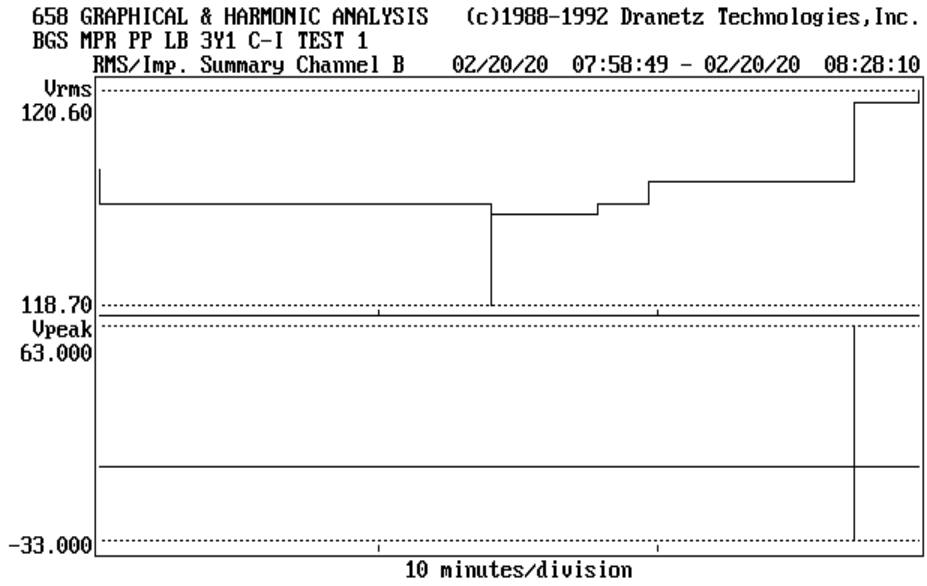


Chart 102

The nominal 120 Vrms on Phase B to Neutral mode has only minor fluctuations from 118.7 to 120.60 Vrms during the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 63.00 Vpeak to a negative 33.00 Vpeak.

Chart 103 shows the Summary of the readings from Channel C.

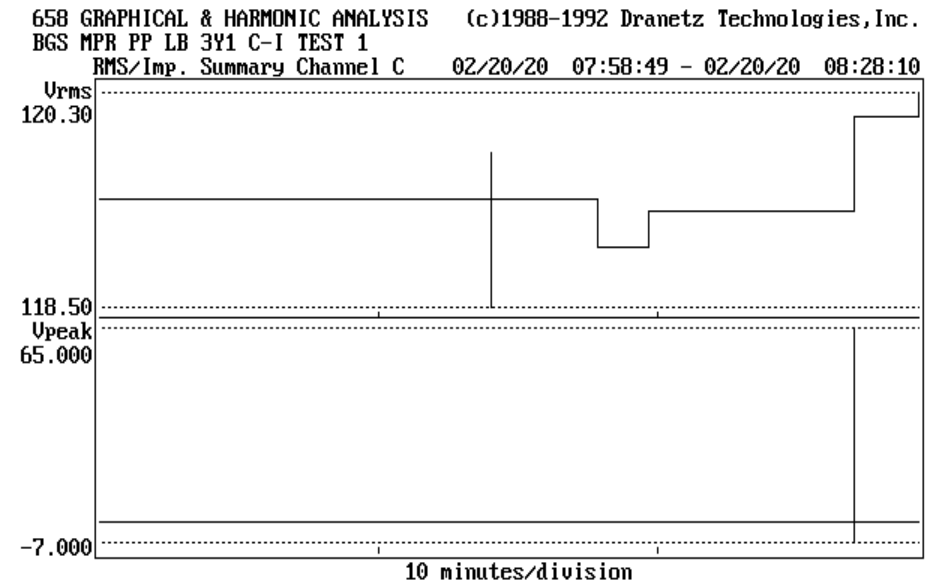


Chart 103

The nominal 120 Vrms on Phase C to Neutral mode has only minor fluctuations from 118.50 to 120.30 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. The surge events ranged from a positive 65.00 Vpeak to a negative 7.00 Vpeak.

Chart 104 shows the Summary of the current readings from Phase C.

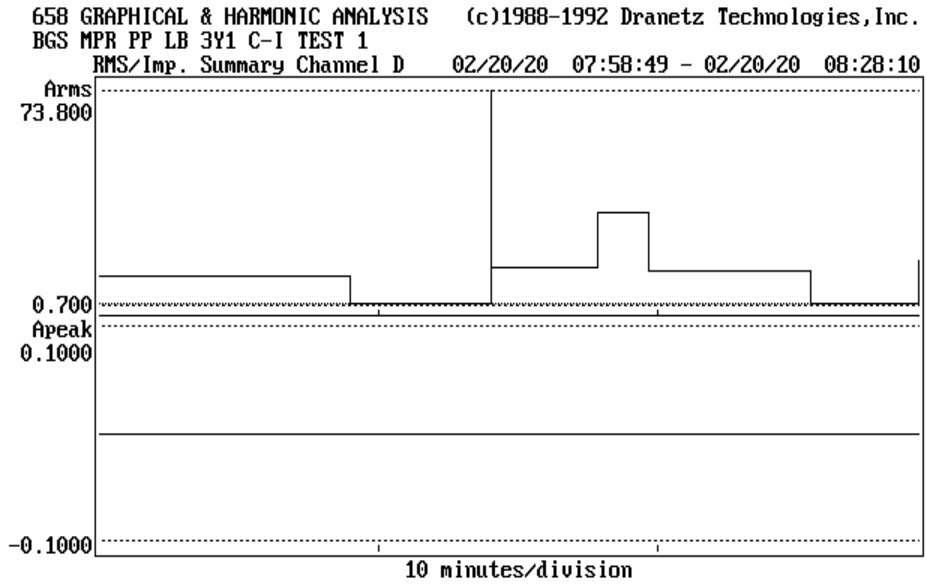


Chart 104

The current on Phase C fluctuates mildly from 10 Arms to 0.700 Arms, then sharply up to 73 Arms, then 12 Arms, then 36 Arms, then back to around 11 Arms, back down to 0.700 Arms and finally up to around 12 Arms. This is obviously due to switching on and off of equipment on powered from this Power Panel. There were no surge current events associated with these continuous current changes.

The welders and exhaust fans were turned on during this test. There is a large 73.8 Arms spike in voltage when the large load was activated, although it did not produce a voltage surge event. However, shortly after the large load was turned off, the voltage increased and there was a voltage surge event on all three phases. This was possibly due to the collapsing electrical field of the motors. The combination of welders and exhaust fans on the same panel with office computers and other electronics is placing the electronics at significant risk. There is an unused panel in the shop area. I would suggest moving the heavier electrical loads to this panel from Power Panel PP-LB. Surge protection on both panels will help to isolate them from each other, as well as provide a third level of lightning/catastrophic surge protection after the Main Distribution Panel and the MCCs.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 105, is from Event #31 and shows the readings from Channel A on the 120 Vrms Phase A to Neutral mode.

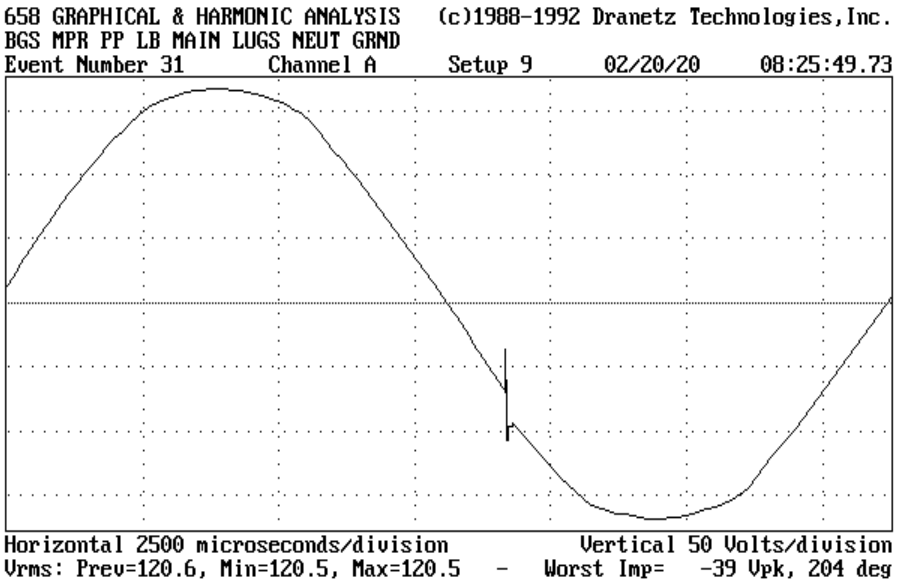


Chart 105

This chart displays the voltage surge events on Channel A for Phase A to Neutral. The voltage is stable at 120.5 Vrms. There is a negative 39 Vpeak surge event at 204°, with a second surge producing an approximately 60 Vpeak positive to negative swing. Channel A does have surge events occurring several times per minute during the short monitoring period. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 106 from Event #31 and shows the readings from Channel B on the 120 Vrms Phase B to Neutral mode.

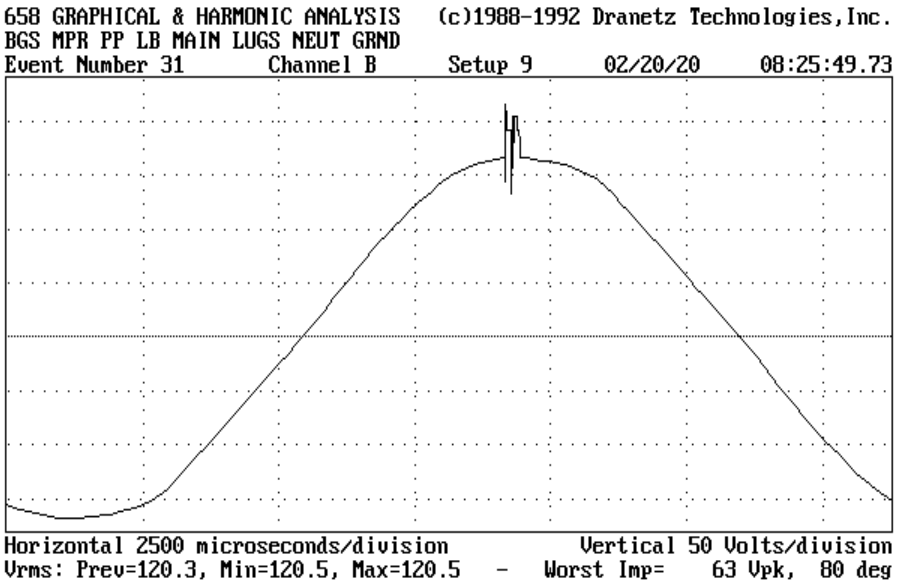


Chart 106

Chart 106 for event #69 shows a positive 63 Vpeak surge, at 80°. There are multiple secondary surges immediately following. The voltage is stable at 481.8 Vrms. These surge events are occurring repeatedly throughout the monitoring period on Channel B. The potential for cumulative damage, particularly in electronic equipment.

Chart 107 from Event #31 and shows the readings from Channel C on the 120 Vrms Phase C to Neutral mode.

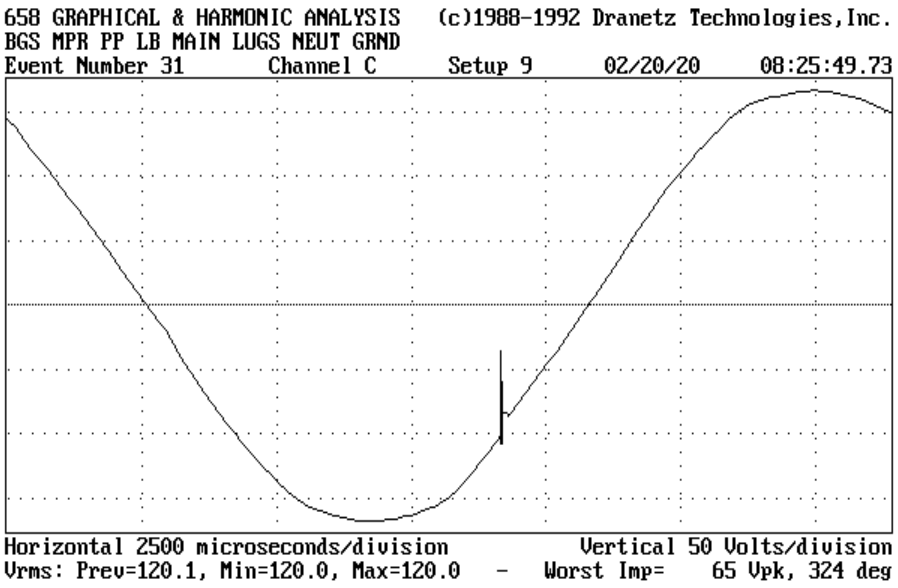


Chart 107

Chart 107 for Event #31 shows a 65 Vpeak surge at the 324° point on the wave form. The voltage holds steady at 120.0 Vrms.

The size of all of these surge events on each mode varies from a positive 65 Vpeak to a negative 39 Vpeak. At the rate of repetition observed, there is a probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 108 is from Event #31 and shows the current on Phase C.

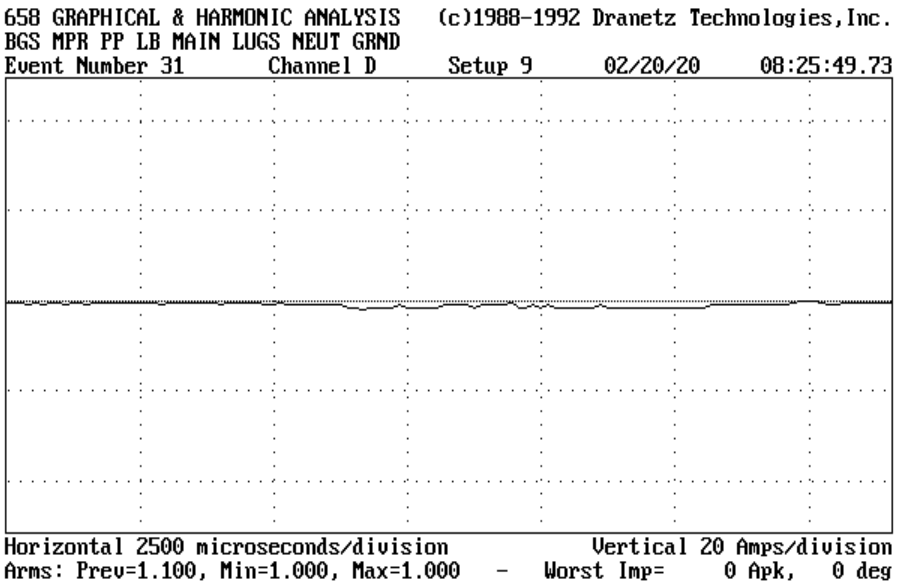


Chart 108

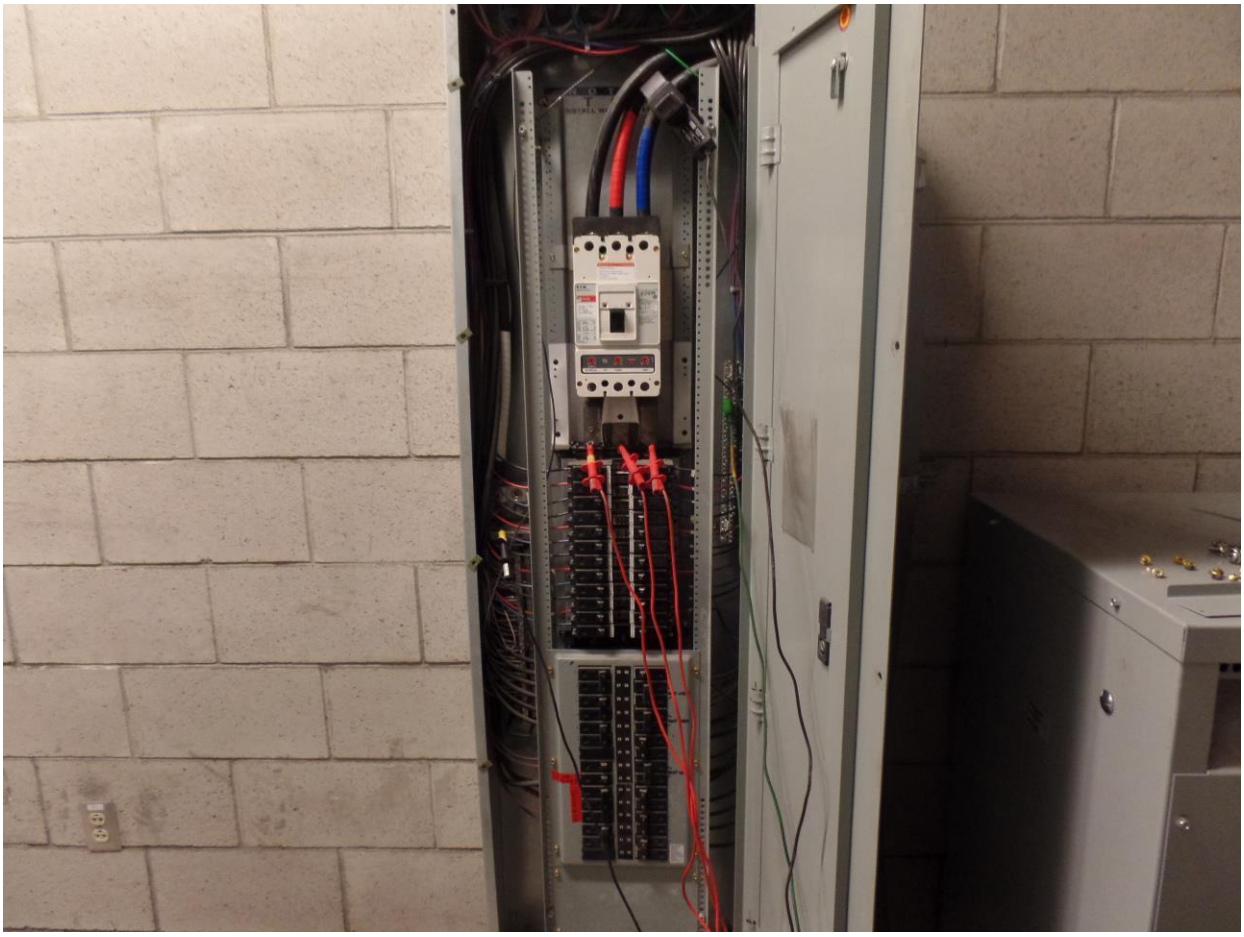
Chart 108 of Event #31 on Channel D shows the current on Phase C. The current is 1.000 Arms with no surge current reported There is no active load on Phase C at the time of this monitoring.

Power Panel PP-LB Name Plate

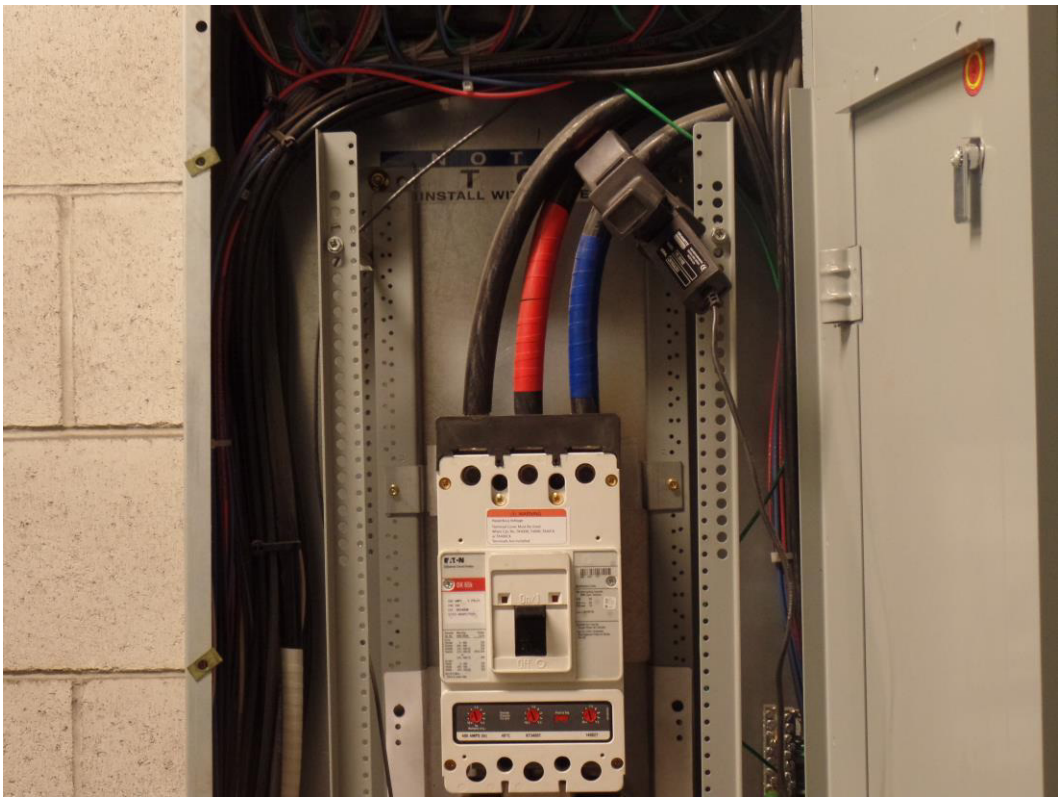
The voltage surge events observed on all three phases do not appear to be originating from the equipment powered from Power Panel PP-LB. The surge events appear to be coming from up line, from MCC 104 or from the main power source from the Mine Power.

We moved to Power Panel PP-LA. This is a standard 120/208 V, 3Ø, 4-Wire, Wye system reportedly powering office outlets and other electronic loads. It was impossible at that time to determine exactly what was connected to this power panel because the labeling was inaccurate and all the breaker runs were distributed through cable trays and conduit leaving the Main Power Room. The Dranetz was connected with Channel A monitoring the Phase A to Neutral voltage, Channel B monitoring the Phase B to Neutral voltage, Channel C monitoring the Phase C to Neutral voltage, and Channel D monitoring the current on Phase C. The monitoring period was from 09:17:07 to 10:23:56 on Thursday, February 20, 2020 for a total of 1 hour, 6 minutes and 49 seconds. There were 20 events recorded during the monitoring period.

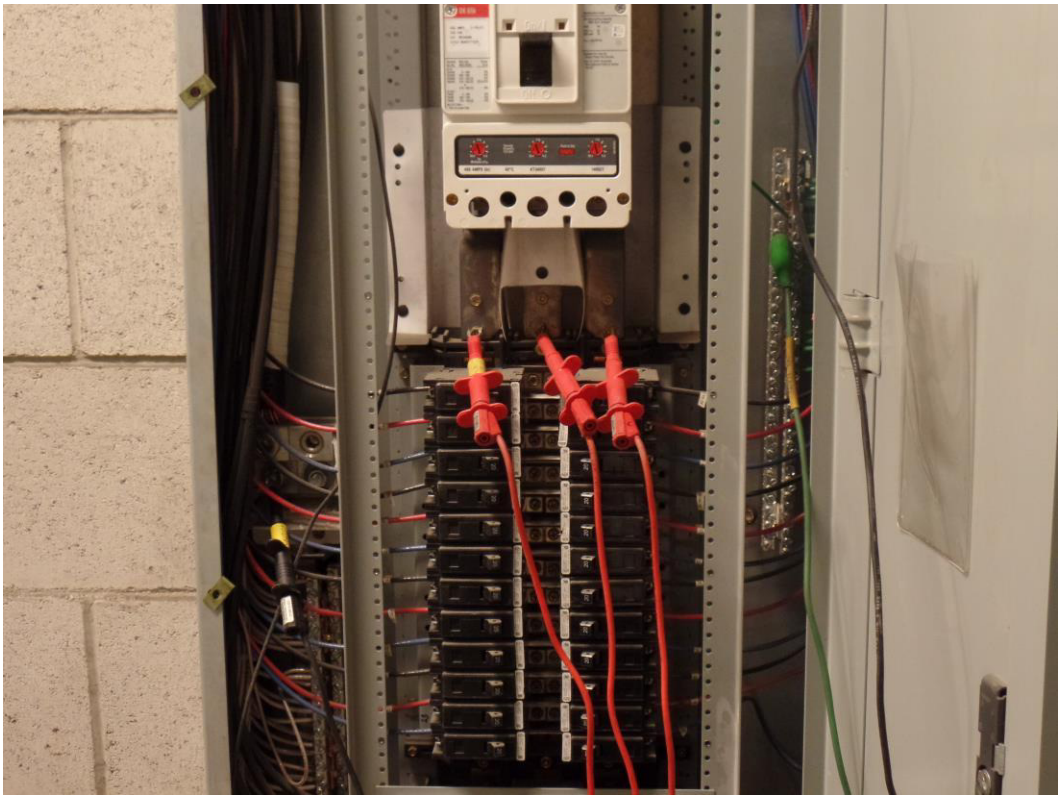
Power Panel PP-LA Name Plate



Power Panel PP-LA



Current Clamp on Phase C on Power Panel PP-LA



Voltage Probe connections for monitoring Power Panel PP-LA

Chart 109 displays the Summary of the voltage events on Channel A, Phase A to Neutral.

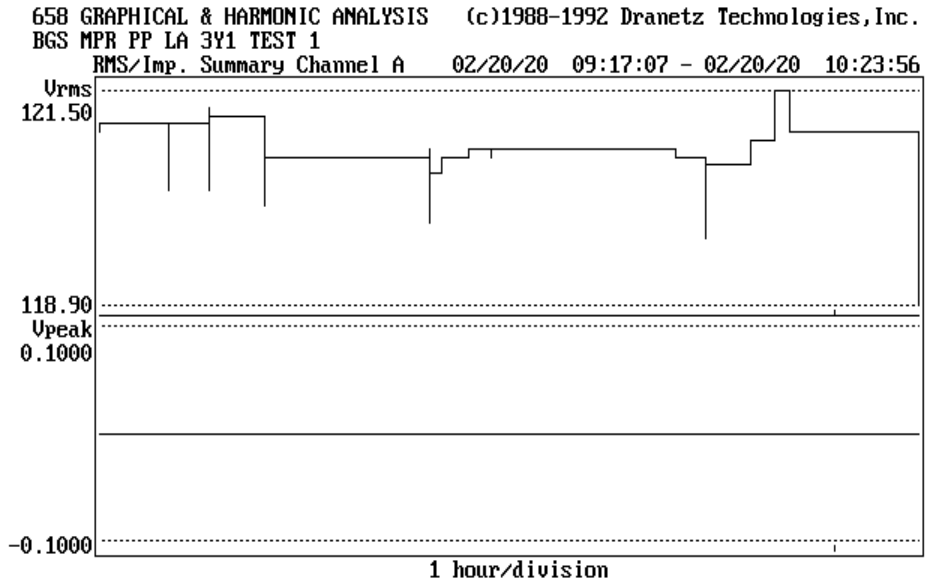


Chart 109

The chart shows the voltage fluctuating over a narrow range from 118.90 Vrms to 121.50 Vrms. This is stable voltage for an industrial plant. There were no voltage surge events during the monitoring period.

Chart 110 shows the Summary of the readings for Channel B.

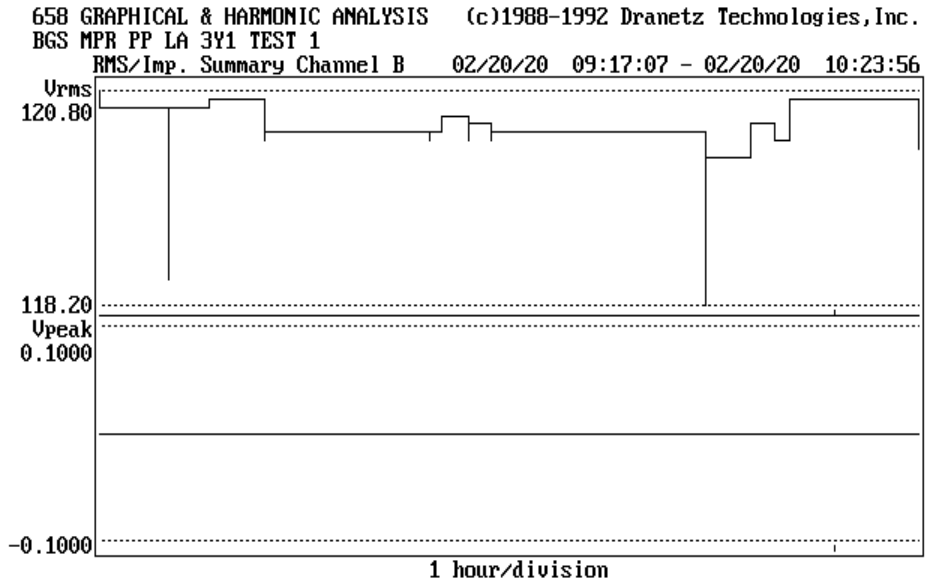


Chart 110

The nominal 120 Vrms on Phase B to Neutral mode has only minor fluctuations from 118.2 to 120.80 Vrms during the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. There were no surge events during the monitoring period.

Chart 111 shows the Summary of the readings from Channel C.

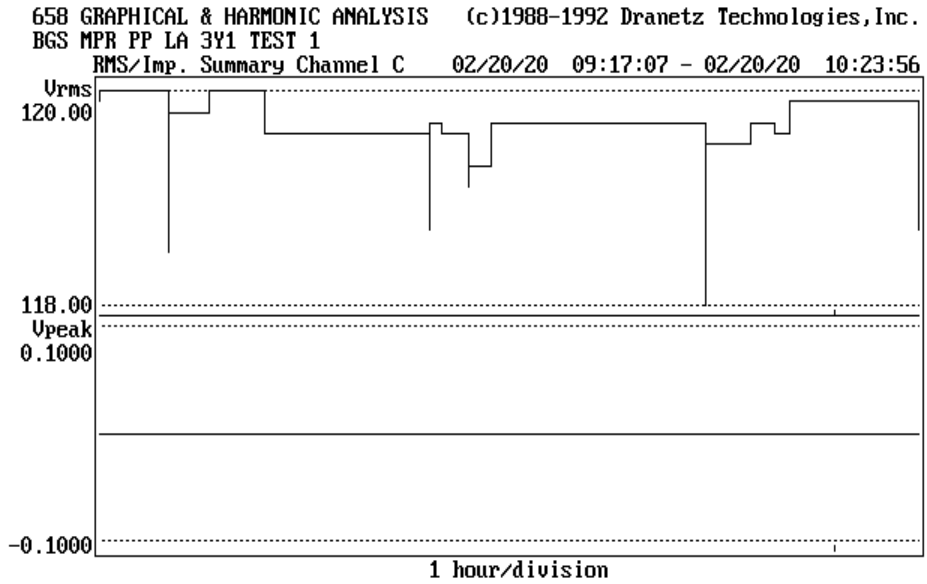


Chart 111

The nominal 120 Vrms on Phase C to Neutral mode has only minor fluctuations from 118.00 to 120.00 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. There were no surge events during the monitoring period.

Chart 112 shows the Summary of the current readings from Phase C.

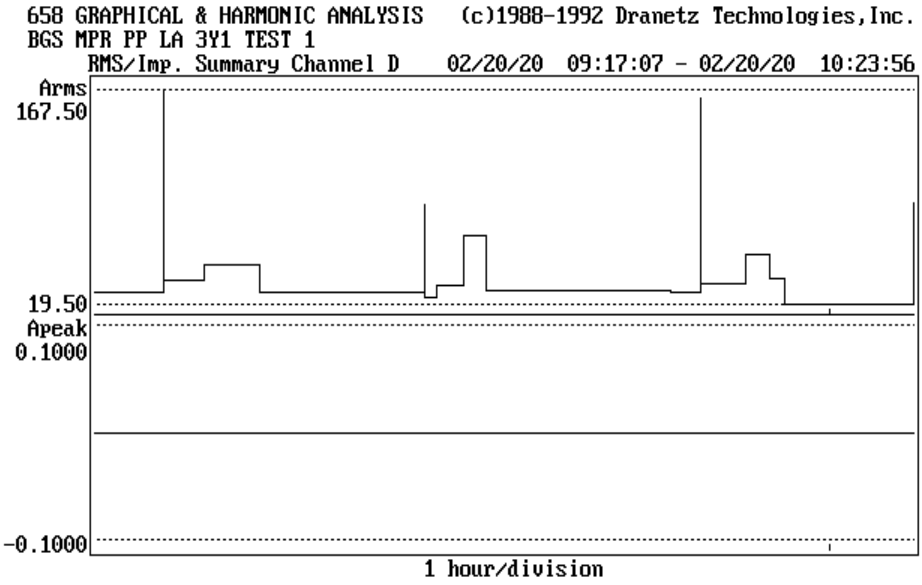


Chart 112

The current on Phase C starts out around 20 Arms, then rises sharply up to 167.5 Arms, then 25 to 30 Arms, then around 40 Arms, then back to around 20 Arms, back up to around 70 Arms, then down to 20 Arms, then a large spike to around 160 Arms and immediate return to around 30 Arms, another rise to 50 Arms, a short drop to around 35 Arms and then down to 19.5 Arms. All of these rises in current correspond to drops in voltage across all three phases. The larger current spikes (167 and 160 Arms) are more than would be seen from office type electronics. There are obviously some larger electrical or electronic items powered from this panel that are turning on sporadically and impacting the voltage and current. This is further justification for determining the actual loads on the panel and rebalancing the loads.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 113, is from Event #18 and shows the readings from Channel A on the 120 Vrms Phase A to Neutral mode.

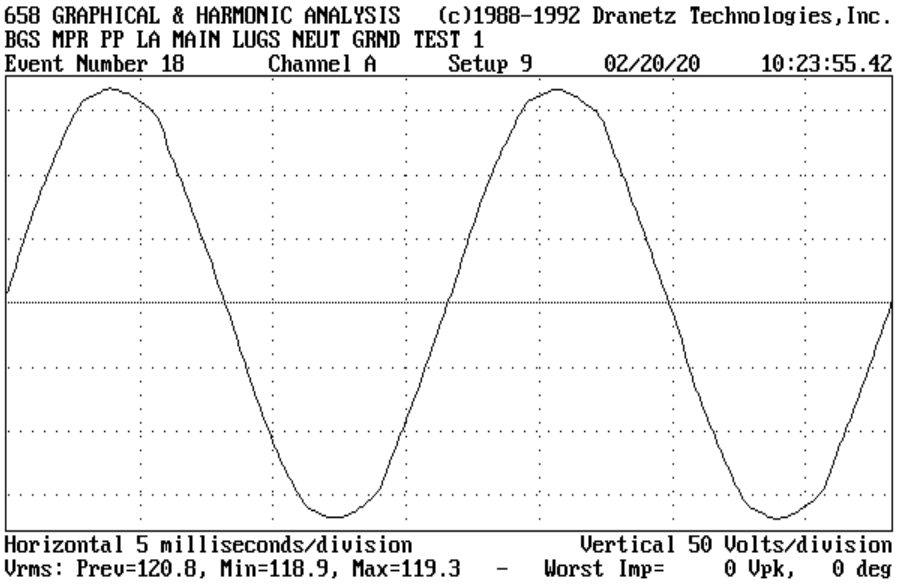


Chart 113

This chart displays the voltage surge events on Channel A for Phase A to Neutral. The voltage is stable at 118.9 to 119.3 Vrms. There is no surge activity during this event. We do know through testing that some of the offices are powered from Power Panel PP-LA, but we do not know what other offices or equipment are also powered. Most of the offices are at the other end of the building from the Main Power Room where Power Panel PP-LA is located. The surges being generated by the switch-mode power supplies and other electronic controls in the offices may be remaining local to the office area and circulating among the equipment on the outlets within that circuit, and not traveling all the way back to the power panel. If a surge protective device (SPD) at Power Panel PP-LA does not significantly reduce the amount of computer damage, it may be necessary to place Type 3, plug-on type SPDs in the offices that are still experiencing problems.

Chart 114 from Event #18 and shows the readings from Channel B on the 120 Vrms Phase B to Neutral mode.

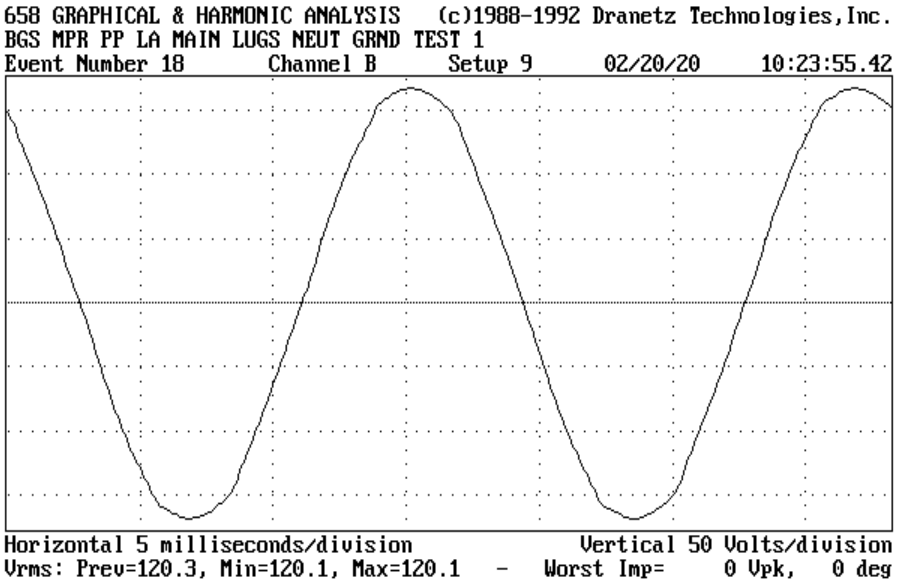


Chart 114

Chart 114 for event #18 shows a stable voltage at 120.1 Vrms and no surge events.

Chart 115 from Event #31 and shows the readings from Channel C on the 120 Vrms Phase C to Neutral mode.

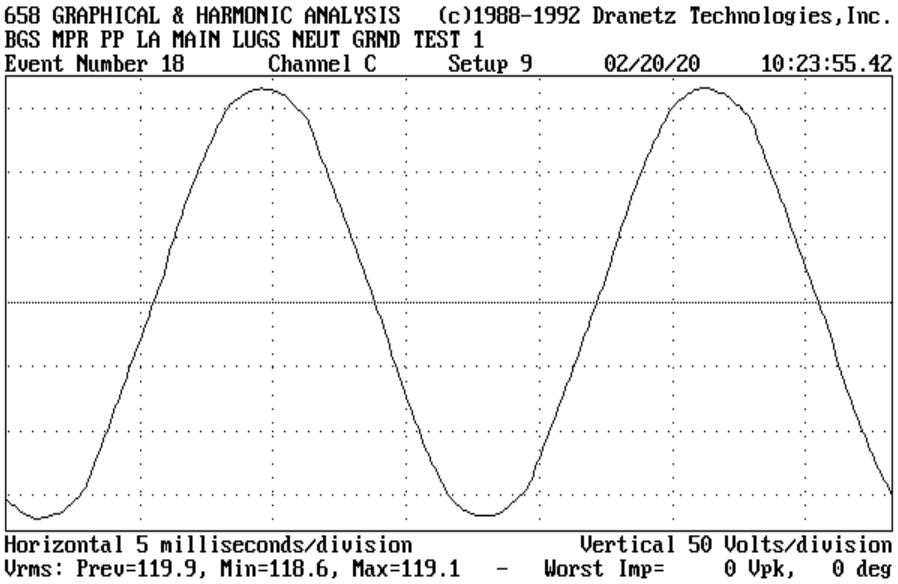


Chart 115

Chart 115 for Event #18 shows a stable voltage from 118.6 to 119.1 Vrms and no surge events.

The absence of surge activity at these panels does not remove the need for surge protection. The equipment in the offices includes computers, system monitoring stations, test equipment and others specific to the operation. Most of these are linked to the control room monitoring and control panels through data lines. Any surge activity that can cause cumulative or catastrophic damage to the office equipment can potentially travel on the data lines back to the master controls and impact the operational capability of the facility. The proper application of staged surge protection at the Main Distribution Panel, MCCs, Power (Branch) Panels, and if necessary, selected local circuits can reduce and, in most cases, prevent the surge events from reaching levels sufficient to damage the electrical and electronic equipment within the facility.

Chart 116 is from Event #18 and shows the current on Phase C.

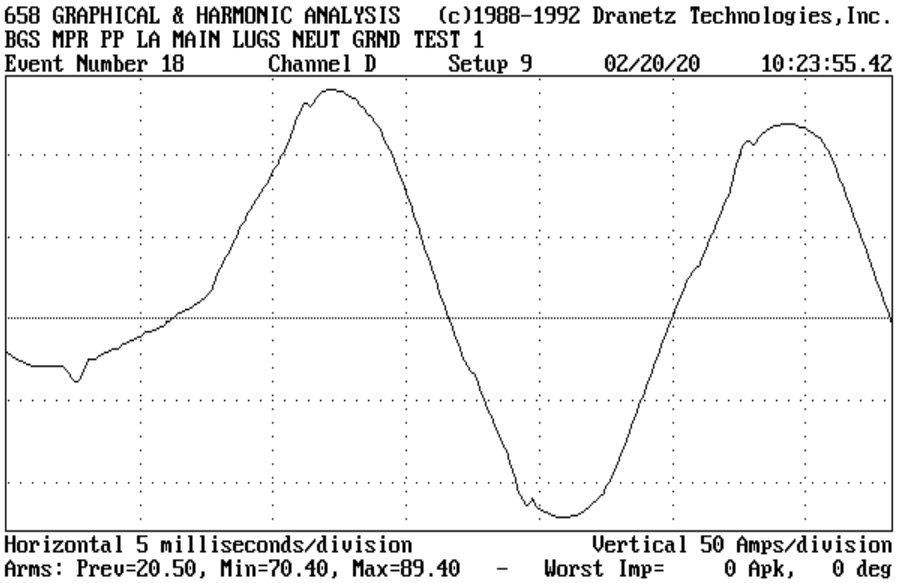
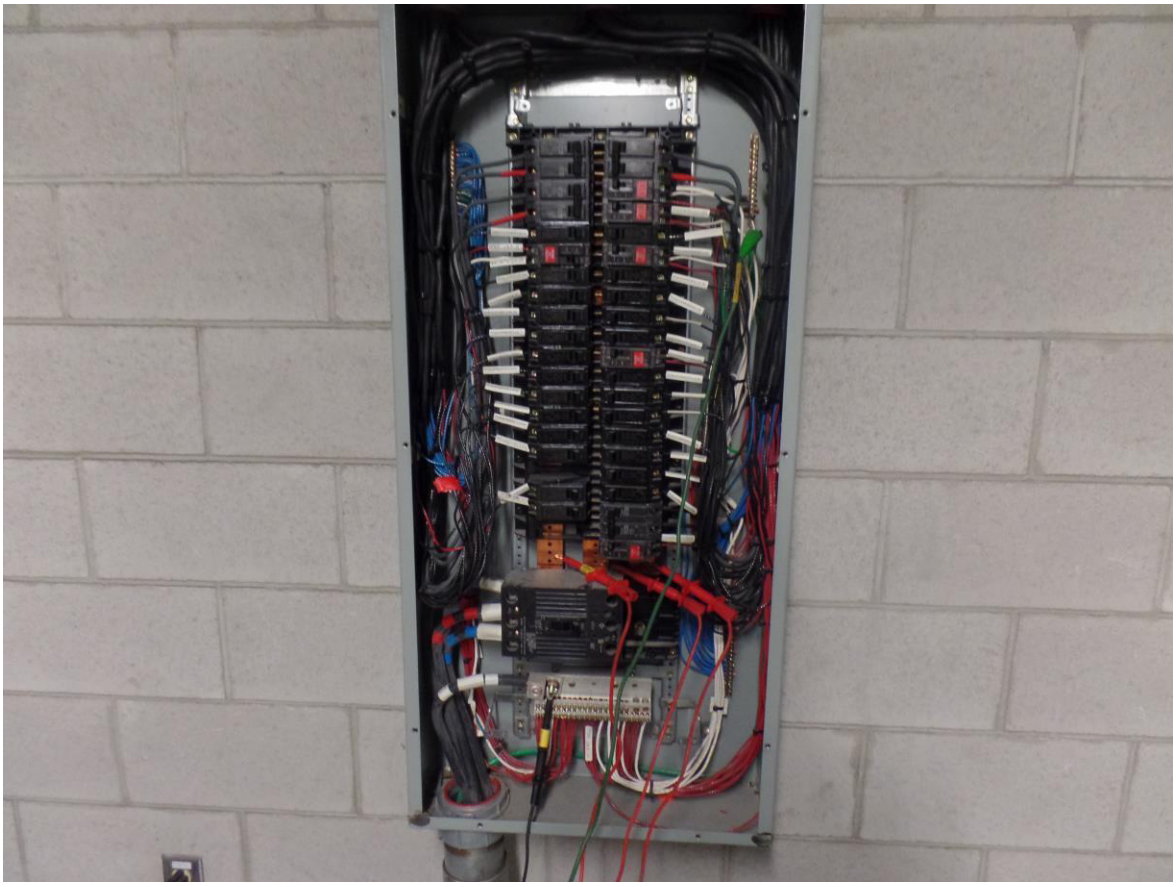


Chart 116

Chart 116 of Event #18 on Channel D shows the current on Phase C. The current starts at 20.50 Arms, rises to 70.40 Arms and then to 89.40 Arms, with no surge current reported This is not from turning on some office equipment. Other, large current items are also powered from this Power Panel. It is never a good idea to consolidate mixed equipment on the same Power Panel. Heavy, large current item should be on their own Power Panel, and electronic and lighting controls should be on a separate Power Panel. Separating the two types of equipment reduces the likelihood of impulses from the damaging the electronics, and the cumulative ring wave surge activity from the electronics deteriorating the motor insulation and controls for the heavy equipment. The application of properly sized and installed SPDs on these panels will further reduce the risk as well as provide the third level of protection from external catastrophic surge events such as lightning or blown transformers.

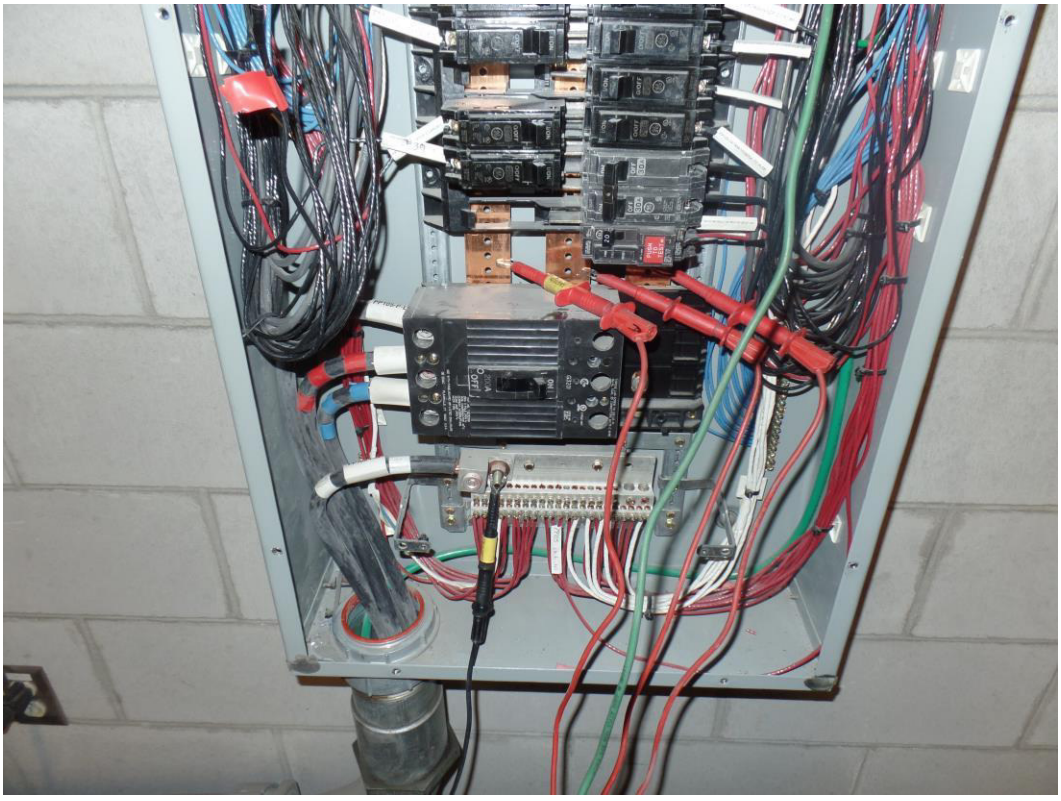
We next moved to Power Panel PP-105. This is a standard 120/208 V, 3Ø, 4-Wire, Wye system reportedly powering office outlets and other electronic loads. It was impossible at that time to determine exactly what was connected to this power panel because the labeling was inaccurate and all the breaker runs were distributed through cable trays and conduit leaving the Main Power Room. The Dranetz was connected with Channel A monitoring the Phase A to Neutral voltage, Channel B monitoring the Phase B to Neutral voltage, Channel C monitoring the Phase C to Neutral voltage, and Channel D monitoring the current on Phase B. The monitoring period was from 11:09:54 to 12:10:31 on Thursday, February 20, 2020 for a total of 1 hour and 37 seconds. There were 3 events recorded during the monitoring period.

Power Panel PP-LA Name Plate

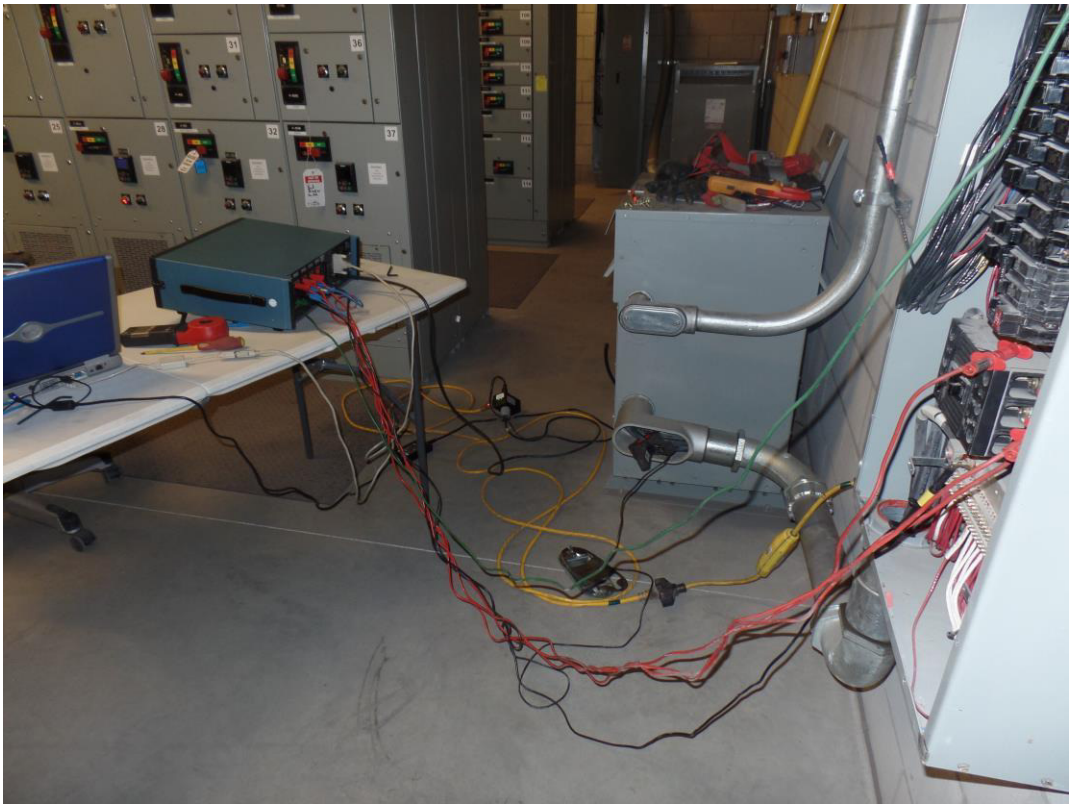


Power Panel PP-105

Current Clamp on Phase C on Power Panel PP-105



Voltage Probe connections for monitoring Power Panel PP-105



Test Setup for Power Panel PP-105

Chart 117 displays the Summary of the voltage events on Channel A, Phase A to Neutral.

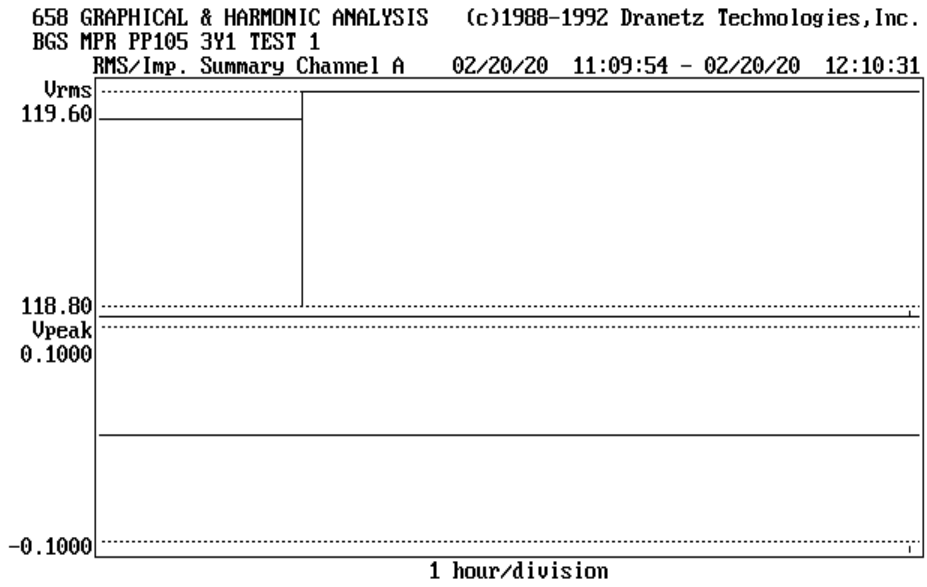


Chart 117

The chart shows the voltage fluctuating over a narrow range from 118.80 Vrms to 119.60 Vrms. This is stable voltage for an industrial plant. There were no voltage surge events during the monitoring period.

Chart 118 shows the Summary of the readings for Channel B.

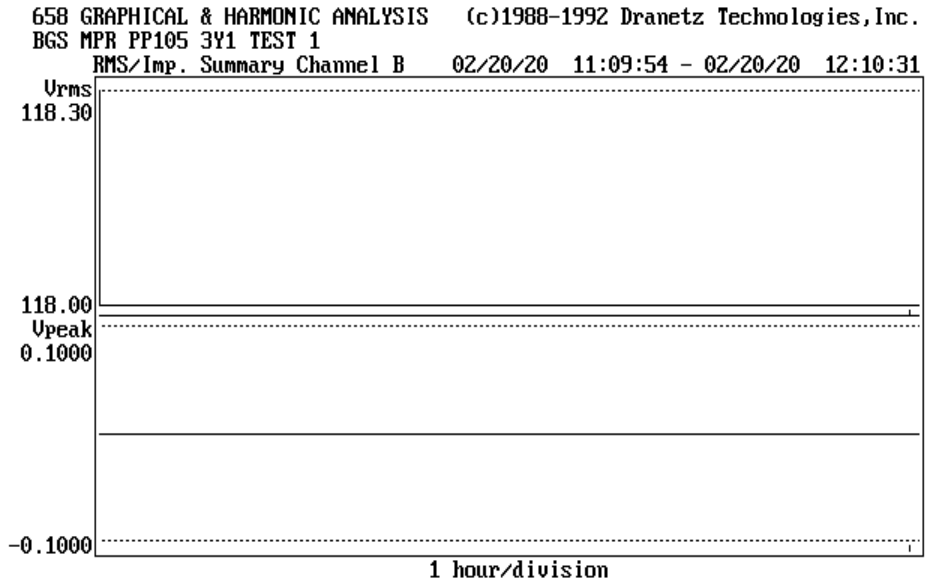


Chart 118

The nominal 120 Vrms on Phase B to Neutral mode has only minor fluctuations from 118.00 to 118.30 Vrms during the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. There were no surge events during the monitoring period.

Chart 119 shows the Summary of the readings from Channel B.

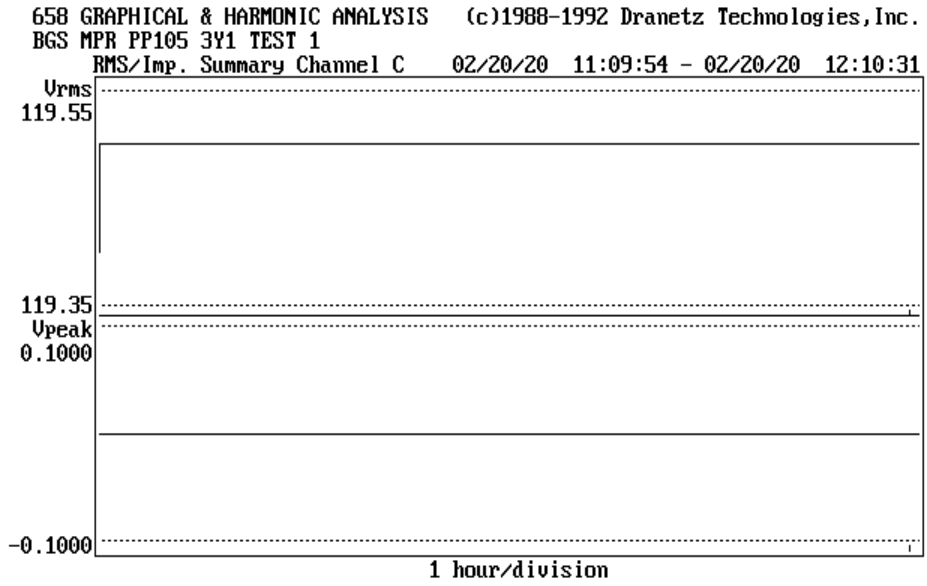


Chart 119

The nominal 120 Vrms on Phase C to Neutral mode has only minor fluctuations from 119.35 to 119.55 over the course of the monitoring period. This level of fluctuation is normal, particularly in relation to the voltage surge events recorded during the same period. There were no surge events during the monitoring period.

Chart 120 shows the Summary of the current readings from Phase B.

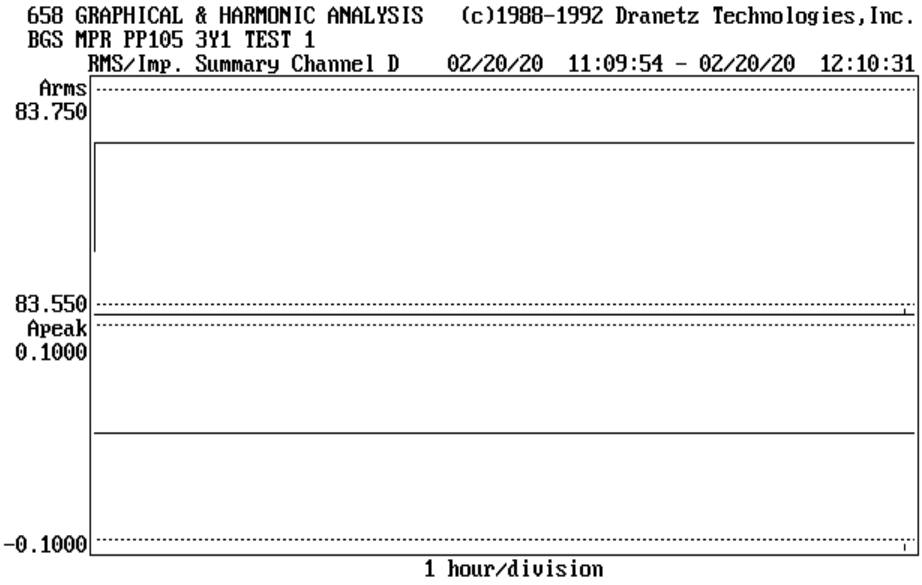


Chart 120

The current on Phase B starts with a rise to 83.750 Arms and remains constant at that level throughout the testing. The loads on this Power Panel are a mix of 1 Ø, 2 Ø, and 3 Ø breakers. Once again, the labeling for the loads on this panel are inconsistent and we were unable to determine how many of the loads are incorrectly labeled. There are obviously some larger electrical or electronic items powered from this panel although they appear to be running with no changes in load or speed. This is further justification for determining the actual loads on the panel and rebalancing the loads.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 121, is from Event #18 and shows the readings from Channel A on the 120 Vrms Phase A to Neutral mode.

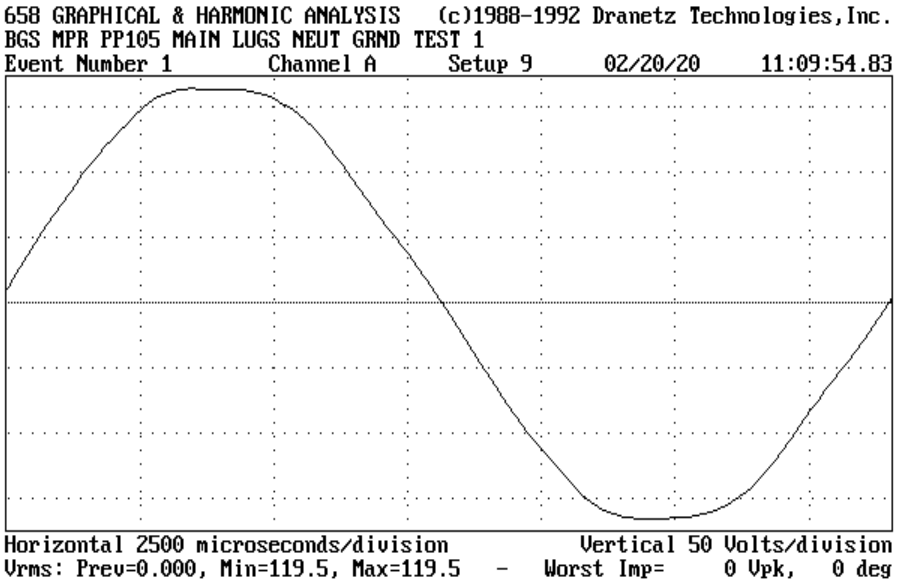


Chart 121

This chart displays the voltage surge events on Channel A for Phase A to Neutral. The voltage is stable at 119.5 Vrms. There is no surge activity during this event. The surges being generated by the switch-mode power supplies and other electronic controls in the offices or other areas may be remaining local to the office area and circulating among the equipment on the outlets within that circuit, and not traveling all the way back to the power panel. If a surge protective device (SPD) at Power Panel PP-105 does not significantly reduce the amount of equipment damage, it may be necessary to place Type 3, plug-on type SPDs in the areas that are still experiencing problems.

Chart 122 from Event #18 and shows the readings from Channel B on the 120 Vrms Phase B to Neutral mode.

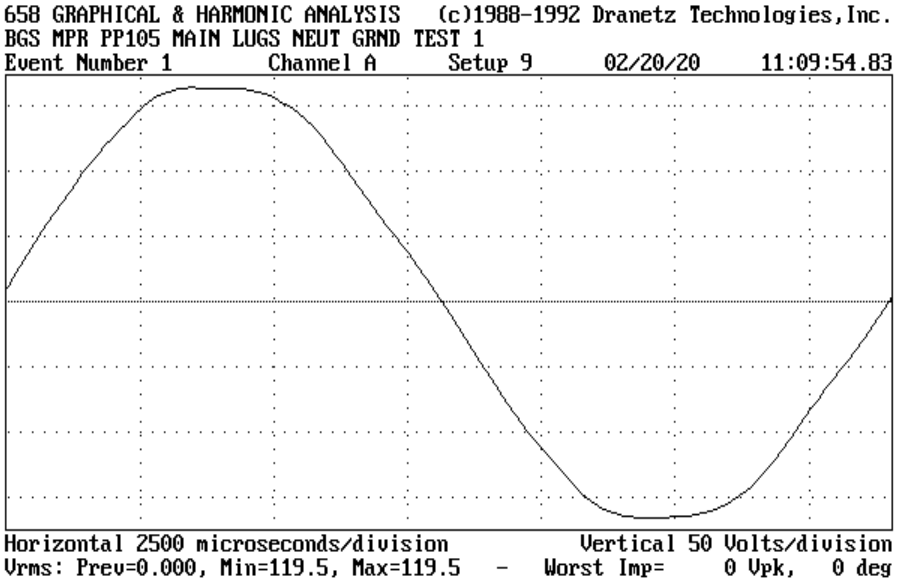


Chart 122

Chart 122 for event #1 shows a stable voltage at 119.5 Vrms and no surge events.

Chart 123 from Event #1 and shows the readings from Channel C on the 120 Vrms Phase C to Neutral mode.

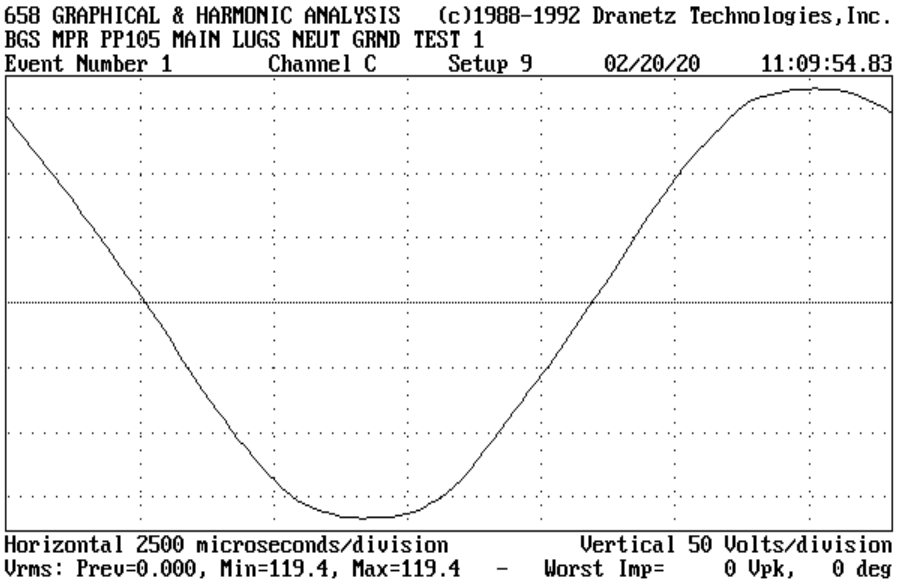


Chart 123

Chart 123 for Event #1 shows a stable voltage from 119.4 Vrms and no surge events.

The absence of surge activity at these panels does not remove the need for surge protection. The equipment in the offices includes computers, system monitoring stations, test equipment and others specific to the operation. Most of these are linked to the control room monitoring and control panels through data lines. Any surge activity that can cause cumulative or catastrophic damage to the office equipment can potentially travel on the data lines back to the master controls and impact the operational capability of the facility. The proper application of staged surge protection at the Main Distribution Panel, MCCs, Power (Branch) Panels, and if necessary, selected local circuits can reduce and, in most cases, prevent the surge events from reaching levels sufficient to damage the electrical and electronic equipment within the facility.

Chart 124 is from Event #1 and shows the current on Phase B.

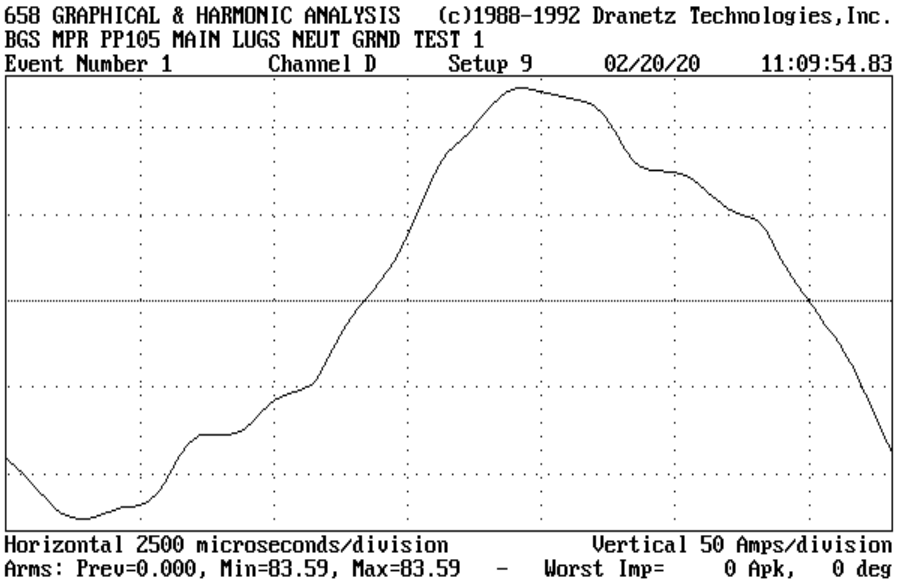


Chart 124

Chart 124 of Event #1 on Channel D shows the current on Phase B. The current remains stable at 83.59 Arms. This current level on the Power Panel indicates the presence of some larger power equipment. The harmonic distortion on the current waveform indicates the presence of non-linear loads.

Chart 125 shows the harmonic content of the current waveform from Chart 124.

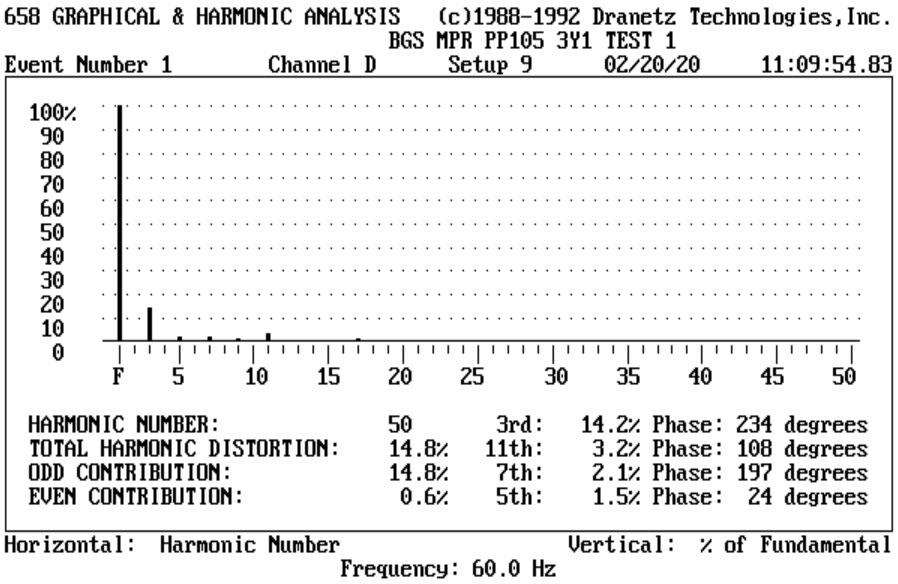


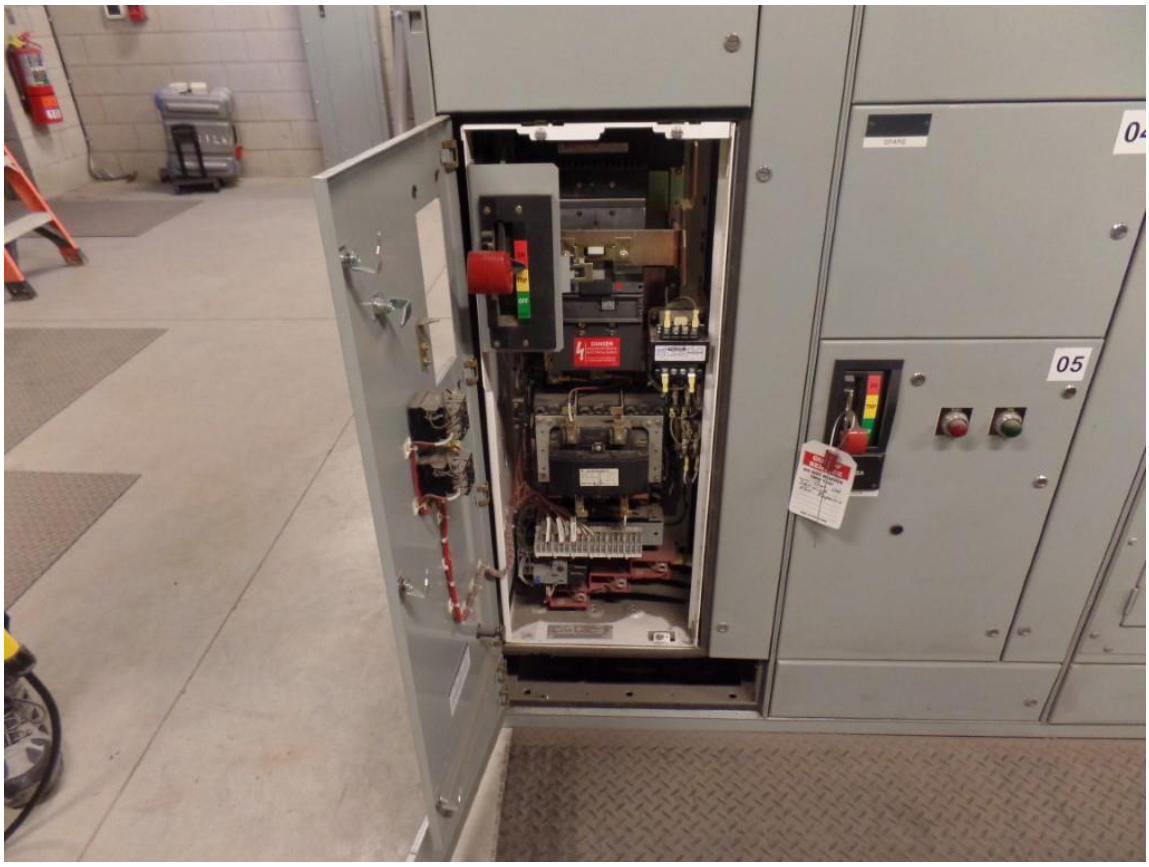
Chart 125

Chart 125 shows the Total Harmonic Distortion level of 14.8% and Highest Individual Harmonic Distortion level of 14.2%, which are above the IEEE 519.1992 standard levels of 5% THD and 3% IHD for voltage. Since this is current, and the voltage waveforms show little or no Harmonic Distortion, the current Harmonic Distortion is not relevant. Until the current Harmonic Distortion levels reaches a point that it forces the voltage Harmonic Distortion levels above the IEEE 591-1992 allowable levels, the Harmonic Distortion of the current is not considered significant.

The application of properly sized and installed SPDs on these panels will further reduce the risk as well as provide the third level of protection from external catastrophic surge events such as lightning or blown transformers.

We next moved to Pump 602B on MCC 103. We were told that starting this 225 HP pump would sometimes dim the lights in the entire facility. We connected to the pump incoming lines with the pump turned off. We then had the control room start the pump while we were monitoring the voltage and current.

Pump 602B Name Plate



Pump 602B

Pump 602B Voltage Probe Connections

For the test on Pump 602B, the Dranetz was again set to monitor to voltage on Channel A from Phase A to Phase B, on Channel B from Phase B to Phase C, and on Channel C from Phase C to Phase A. For this test Channel D recorded the Phase A current. Chart 126 shows the Summary of the readings for Channel A during the monitoring period which lasted for 1 minute and 34 seconds before the Dranetz internal memory was full. The time of the tests was from 12:42:15 to 12:43:39, Thursday, February 20, 2020. There were 56 events captured during the monitoring.

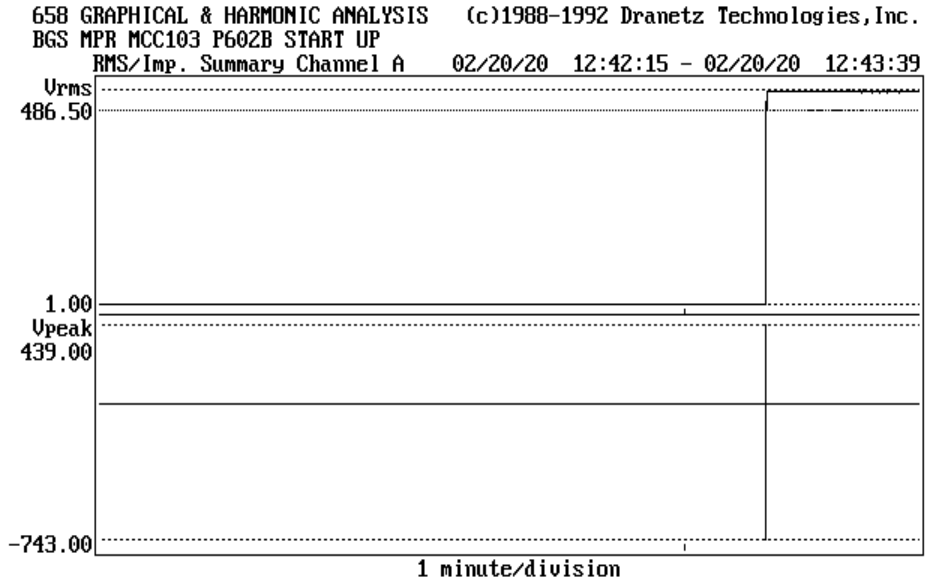


Chart 126

The chart shows the voltage at 1.00 Vrms until Pump 602B is turned on at the Control Room. The voltage then immediately goes to 486.50 Vrms. This is accompanied by a set of surge events ranging from 439.00 Vpeak positive to 743.00 Vpeak negative. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period. This is switching surge activity that is not immediately catastrophic.

Chart 127 shows the Summary of the readings for Channel B.

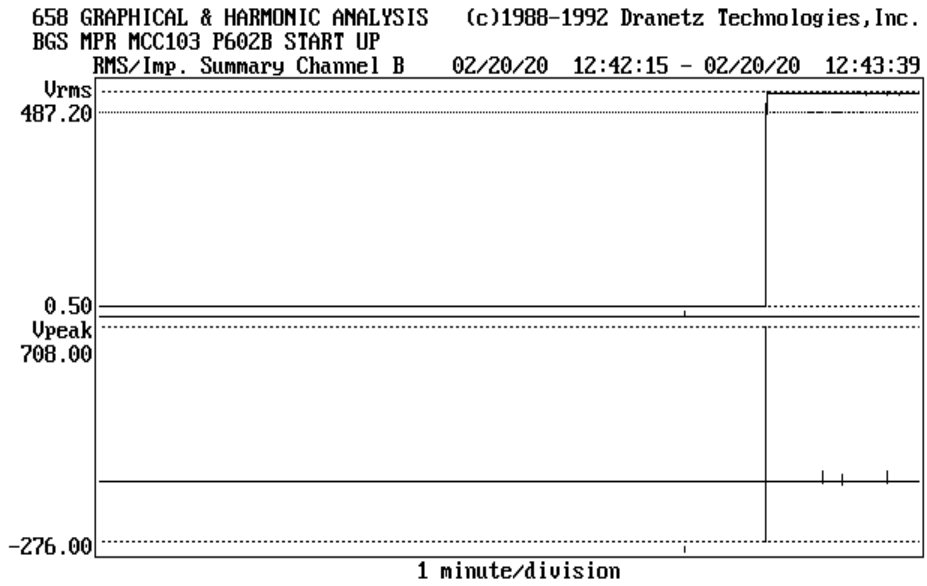


Chart 127

The chart shows the voltage at 0.50 Vrms until Pump 602B is turned on at the Control Room. The voltage then immediately goes to 487.20 Vrms. This is accompanied by a set of surge events ranging from 708.00 Vpeak positive to 276.00 Vpeak negative. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period. This is switching surge activity that is not immediately catastrophic.

Chart 128 shows the Summary of the readings from Channel C.

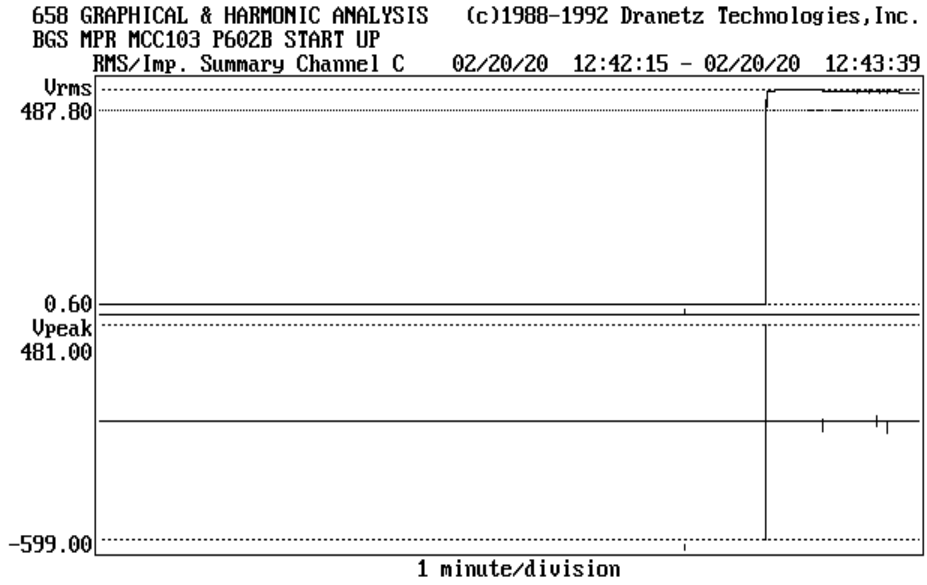


Chart 128

The chart shows the voltage at 0.60 Vrms until Pump 602B is turned on at the Control Room. The voltage then immediately goes to 487.80 Vrms. This is accompanied by a set of surge events ranging from 481.00 Vpeak positive to 599.00 Vpeak negative. This is stable voltage for an industrial plant. There were several voltage surge events during the monitoring period. This is switching surge activity that is not immediately catastrophic.

Chart 129 shows the Summary of the current readings from Phase A.

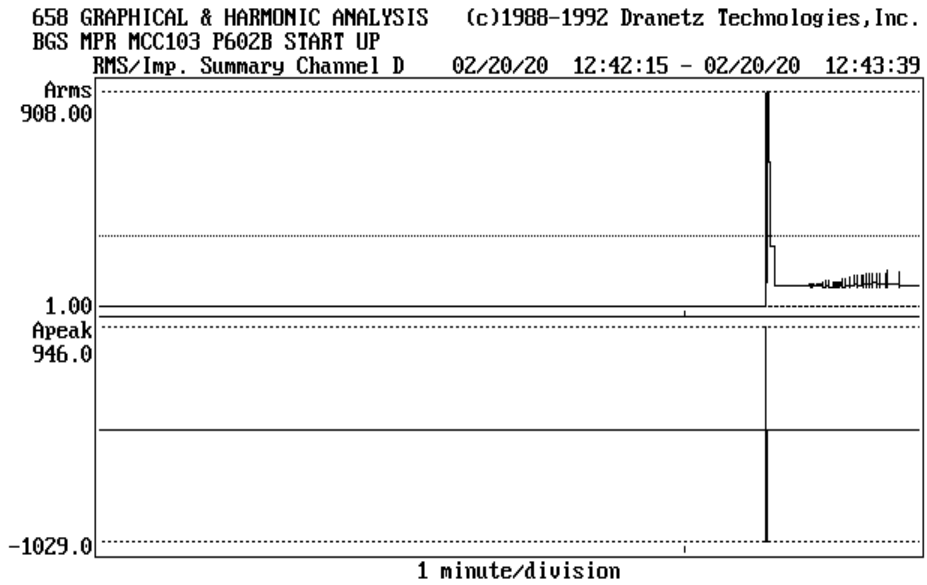


Chart 129

The chart shows the current at 1.00 Arms until Pump 602B is turned on at the Control Room. The voltage then immediately goes to 908.00 Arms. This is accompanied by a set of surge current events ranging from 946.00 Vpeak positive to 1029.00 Vpeak negative. There were several minor current fluctuations during the monitoring period. This is switching surge activity that is not immediately catastrophic.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 130, is from Event #4 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

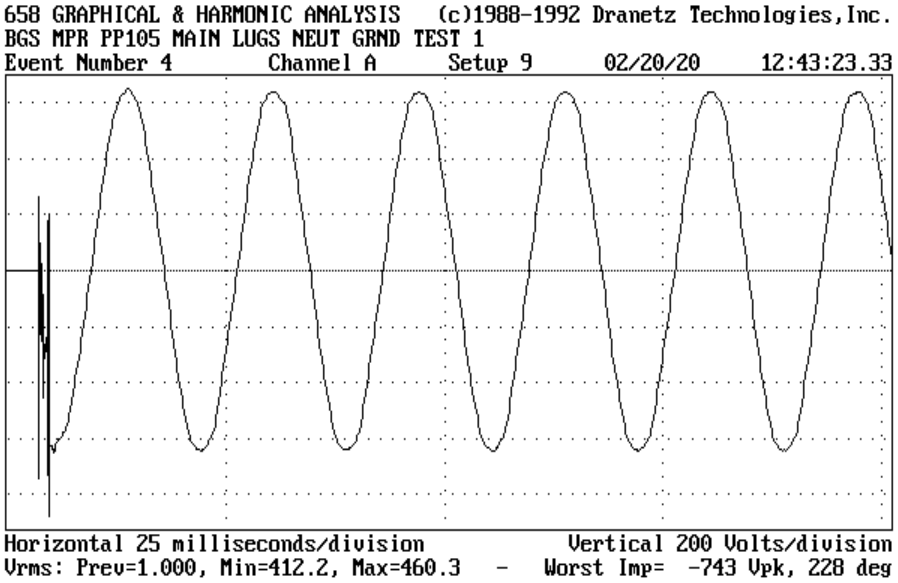


Chart 130

This chart shows the voltage waveform on Phase A to Phase B mode on Channel A. The voltage is at 1.000 Vrms before the power to Pump 602B is turned on. At startup, there is a negative voltage surge of 743 Vpeak, followed immediately by several oscillating ring wave surges of lesser magnitude. Over time, they will have a cumulative damaging effect on the electronic and even the electrical equipment.

Chart 131 from Event #4 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

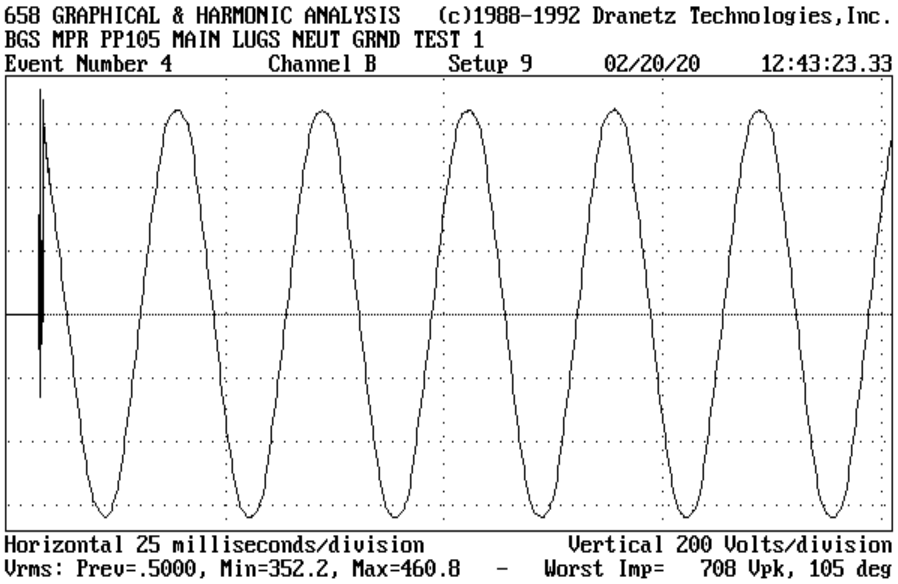


Chart 131

This chart shows the voltage waveform on Phase B to Phase C mode on Channel B. The voltage is at 0.5000 Vrms before the power to Pump 602B is turned on. At startup, there is a positive voltage surge of 708 Vpeak, followed immediately by several oscillating ring wave surges of lesser magnitude.

Chart 132 from Event #4 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

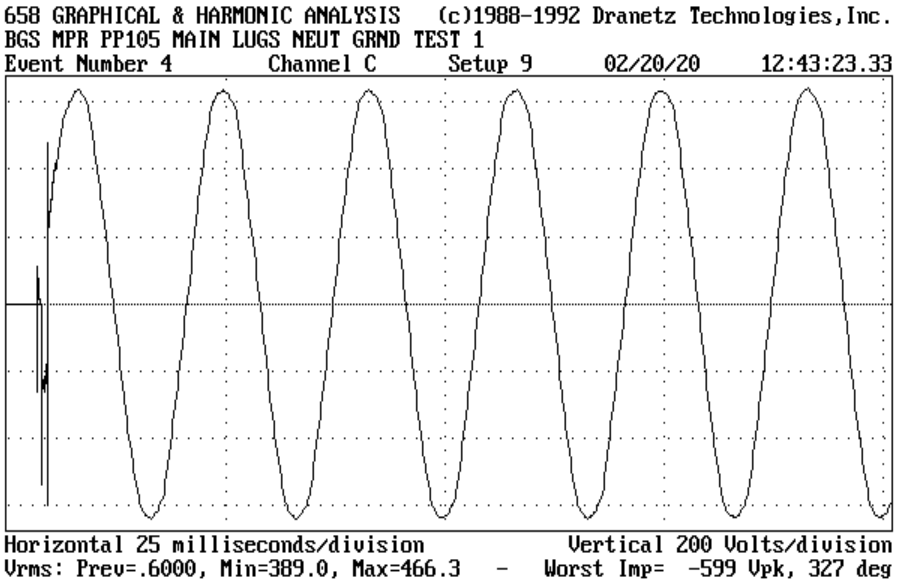


Chart 132

This chart shows the voltage waveform on Phase C to Phase A mode on Channel C. The voltage is at 0.6000 Vrms before the power to Pump 602B is turned on. At startup, there is a negative voltage surge of 599 Vpeak, followed immediately by several oscillating ring wave surges of lesser magnitude.

The size of all of these surge events on each mode varies from a positive 114 Vpeak to a negative 99 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 133 is from Event #4 and shows the current on Phase A.

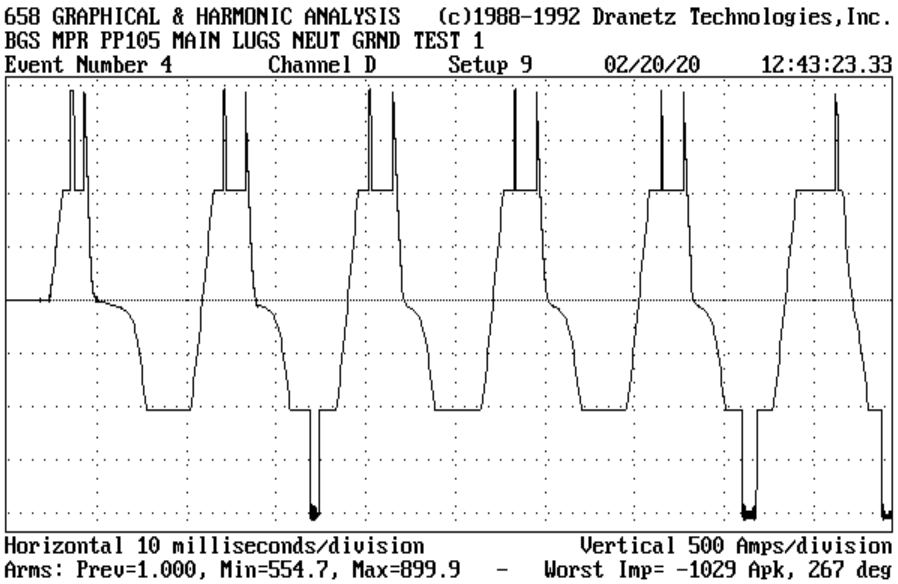


Chart 133

Chart 133 of Event #4 on Channel D shows the current on Phase A. The current starts at 1.000 Arms. At turn on, the current rises to 554.7 Arms and then to a maximum of 899.9 Arms. The distortion on the waveform is typical current harmonic distortion from the way the motor is drawing power during the startup phase of operation. Notice the peaks of all the current pulses are up to approximately 1000 Apeak. The recorded worst surge current is a negative 1029 Apeak.

The following charts are of a second individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 134, is from Event #7 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

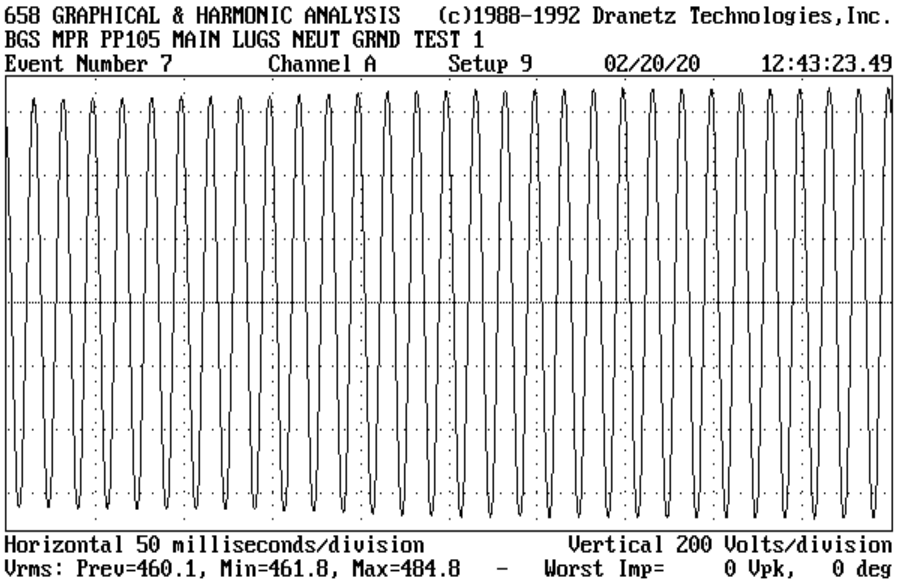


Chart 1340

This chart shows the voltage waveform on Phase A to Phase B mode on Channel A. The voltage is rising from 460.1 Vrms to 484.8 Vrms and there are no additional surges at this point.

Chart 135 from Event #74 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

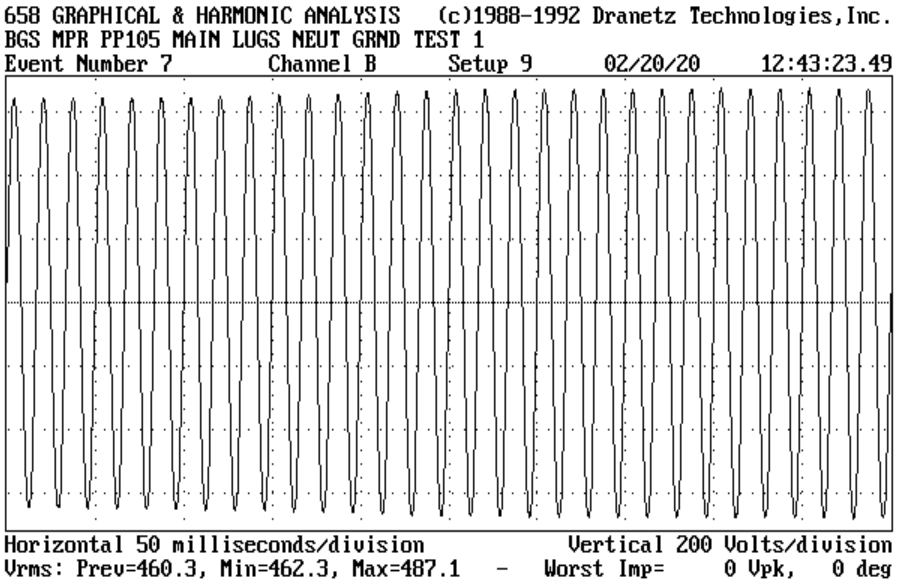


Chart 135

This chart shows the voltage waveform on Phase B to Phase C mode on Channel B. The voltage is rising from 460.3 Vrms to 487.1 Vrms and there are no additional surges at this point.

Chart 136 from Event #7 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

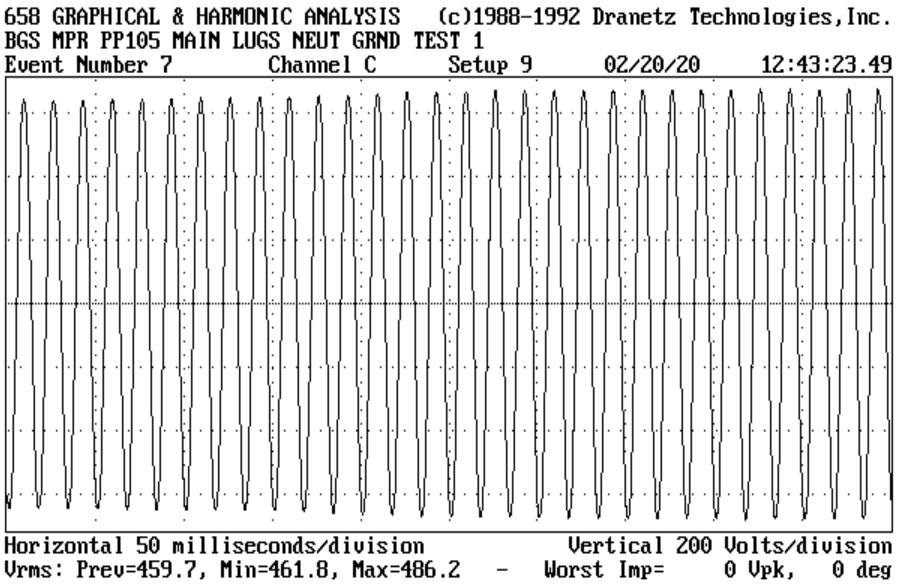


Chart 136

This chart shows the voltage waveform on Phase C to Phase A mode on Channel C. The voltage is rising from 459.7 Vrms to 486.2 Vrms and there are no additional surges at this point.

Chart 137 is from Event #7 and shows the current on Phase A.

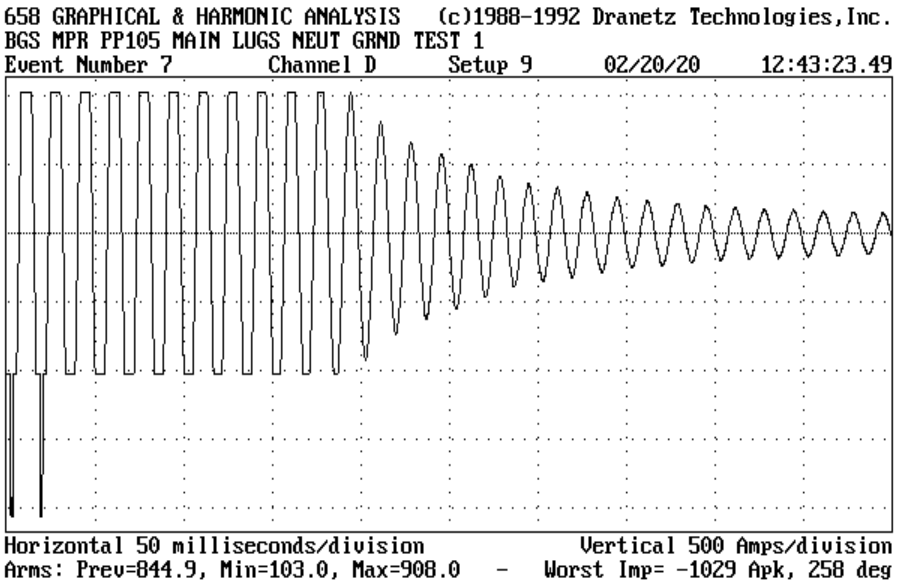


Chart 137

Chart 137 of Event #4 on Channel D shows the current on Phase A. The current starts at the maximum of 908.0 Arms and as the motor comes to full speed the current drops to normal levels of 103.0 Arms and the waveform returns to normal sinusoidal shape. There is still a negative 1029 Apeak surge current on the first two current pulses.

The following charts are of a third individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 138, is from Event #54 and shows the readings from Channel A on the 480 Vrms Phase A to Phase B mode.

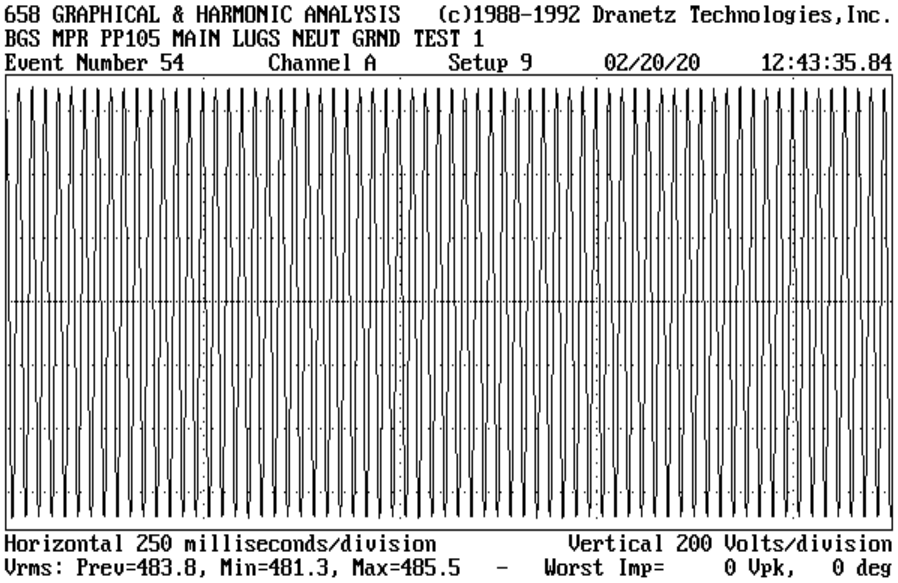


Chart 138

This chart shows the voltage waveform on Phase A to Phase B mode on Channel A. The voltage is stable at 481.3 to 485.5 Vrms. There are no surge events. The motor is running at constant speed.

Chart 139 from Event #54 and shows the readings from Channel B on the 480 Vrms Phase B to Phase C mode.

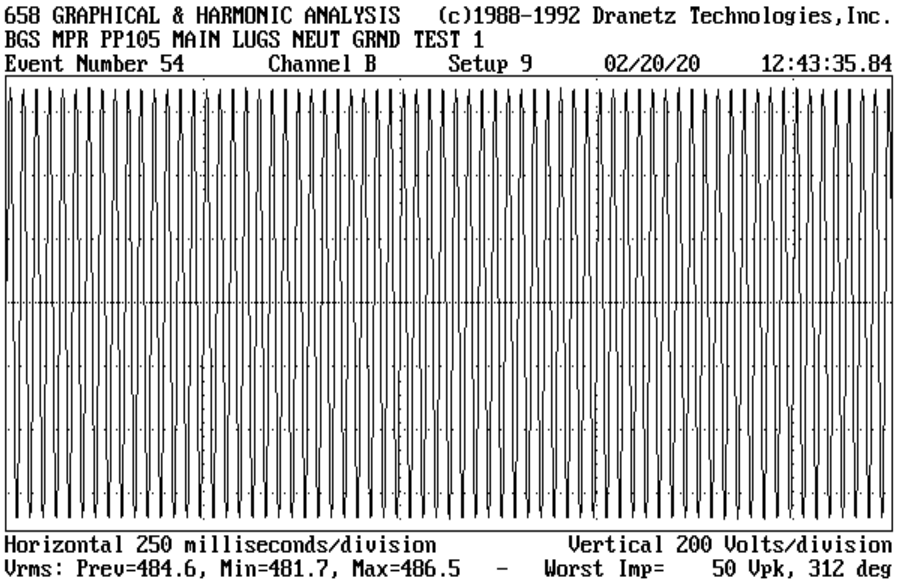


Chart 139

This chart shows the voltage waveform on Phase B to Phase C mode on Channel B. The voltage is stable at 481.7 to 486.5 Vrms and there is a 50 Vpeak surge at 312°.

Chart 140 from Event #54 and shows the readings from Channel C on the 480 Vrms Phase B to Phase C mode.

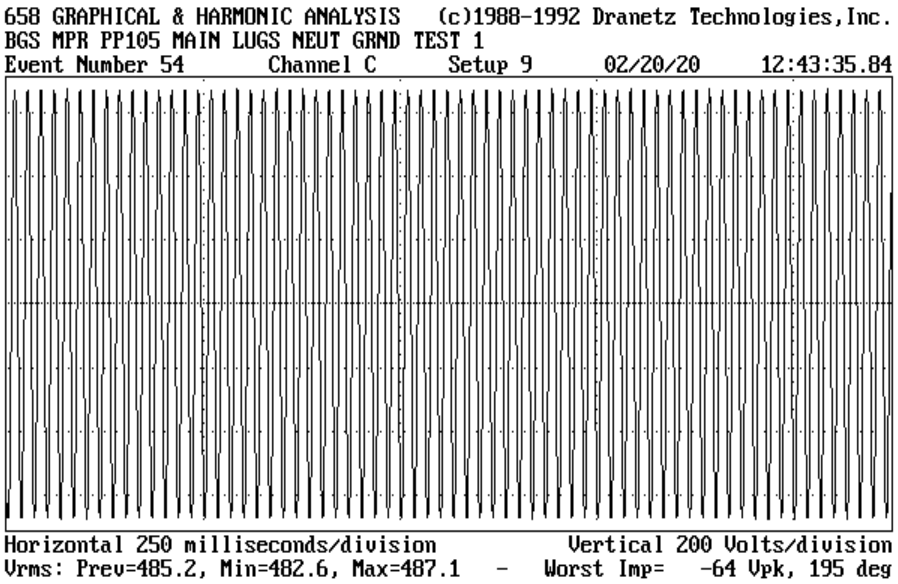


Chart 140

This chart shows the voltage waveform on Phase B to Phase C mode on Channel B. The voltage is stable at 482.6 to 487.1 Vrms and there is a negative 64 Vpeak surge at 195°.

The size of all of these surge events on each mode varies from a positive 50 Vpeak to a negative 64 Vpeak. At the rate of repetition observed, there is a strong probability that this low-level, repetitive surge activity will produce cumulative damage in the more sensitive equipment within the plant electrical distribution system.

Chart 141 is from Event #54 and shows the current on Phase A.

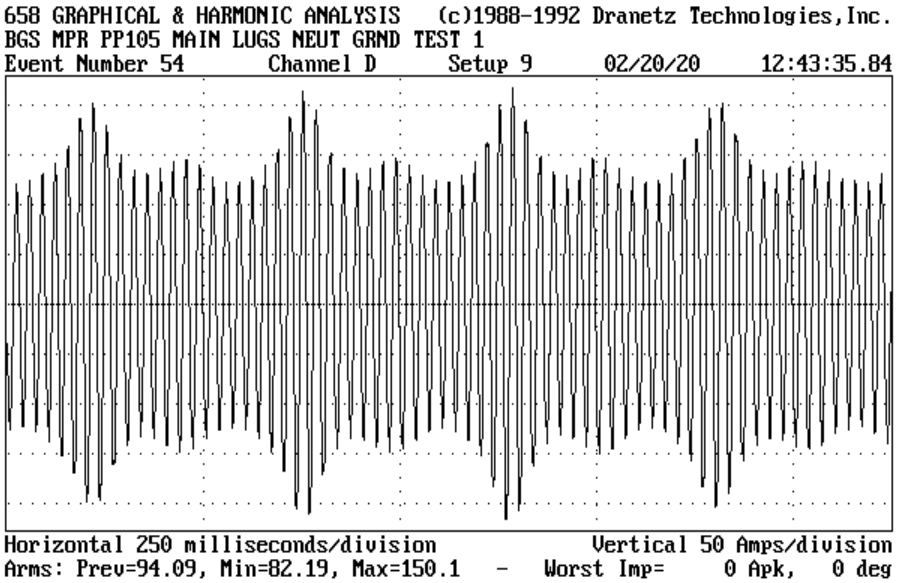
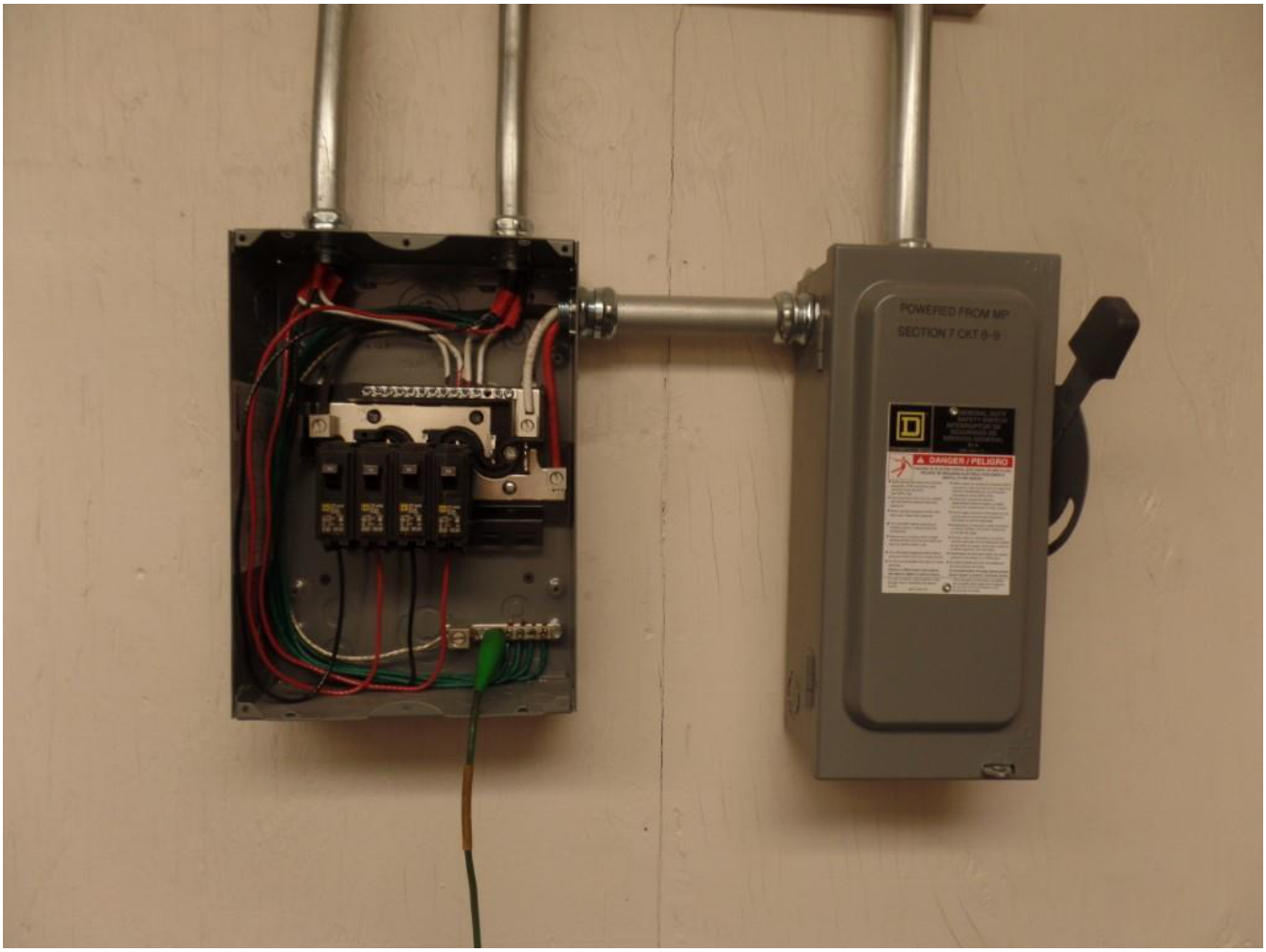


Chart 141

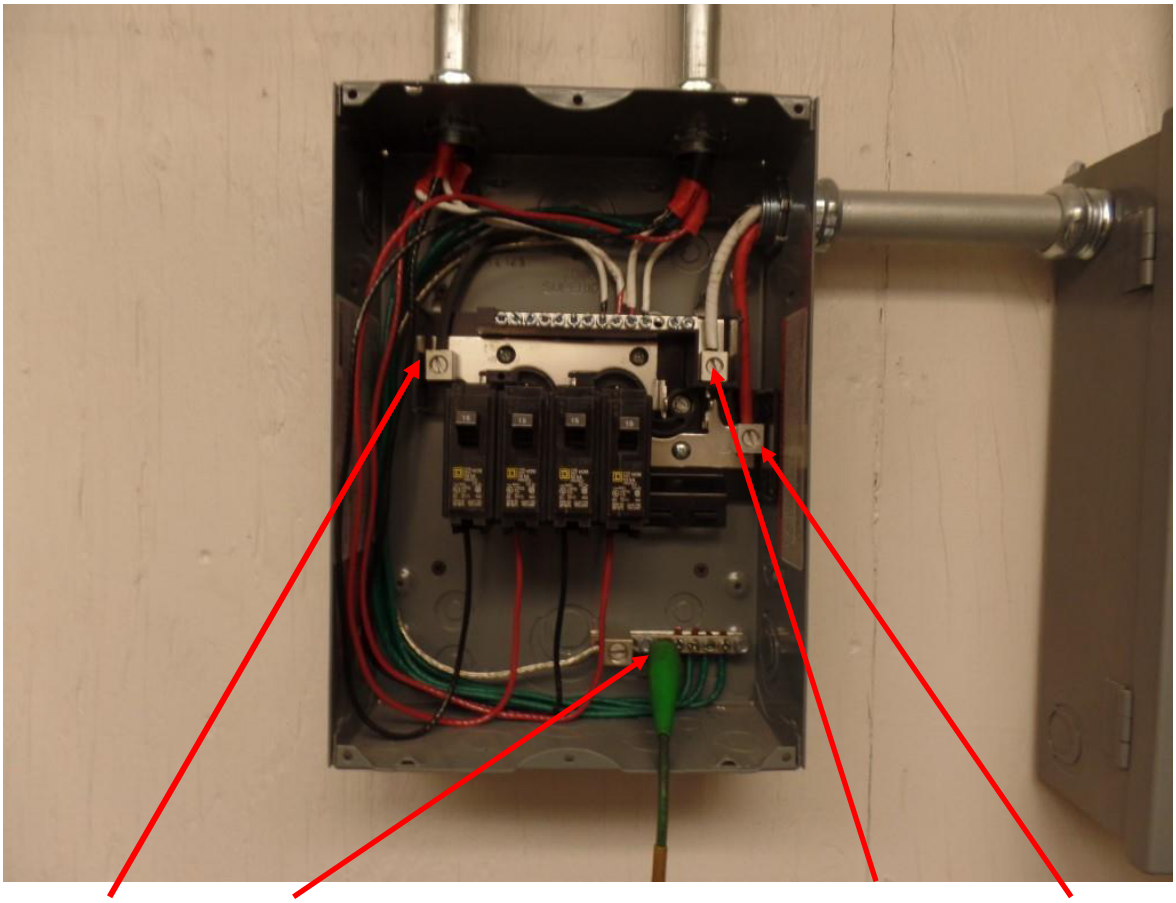
Chart 141 of Event #54 on Channel D shows the current on Phase A. The current ranges from 82.19 Arms to 150.1 Arms on a regular cycle of peaks and valleys. Notice the peaks of the highest current pulses are up to approximately 900 Apeak.

The voltage level and frequency of occurrence of surge activity generated back onto the MCC buss system by the start and stop of these large 200 to 225 HP motors creates a major concern for the stability and long-term survivability of the drives, controls and other equipment on the MCCs. Along with the surge events continuously traveling downline from the Main Distribution Panel and the Mine Power, the established history of lightning damage further supports the need for staged SPDs on the MCCs and the Main Distribution Panel.

The next area of testing was the IT/Telecom Power Panel off the Conference Room. This is a standard 120/240 V, 1Ø, 3-Wire, Split-Phase system supplying the IT and Telecom equipment in the rack and control cabinet in the closet off the Conference Room. The Dranetz was connected with Channel A monitoring the Phase A to Neutral voltage, Channel B monitoring the Phase B to Neutral voltage, Channel C monitoring the Neutral to Ground voltage. It was not possible to get the current clamp from Channel D onto either of the two-phase leads. The monitoring period was from 13:27:24 to 13:42:25 on Thursday, February 20, 2020 for a total of 15 minutes and 1 seconds. There were 3 events recorded during the monitoring period.



IT/Telecom Power Panel with Upline Disconnect



IT/Telecom Power Panel Test Setup

Chart 142 displays the Summary of the voltage events on Channel A, Phase A to Neutral.

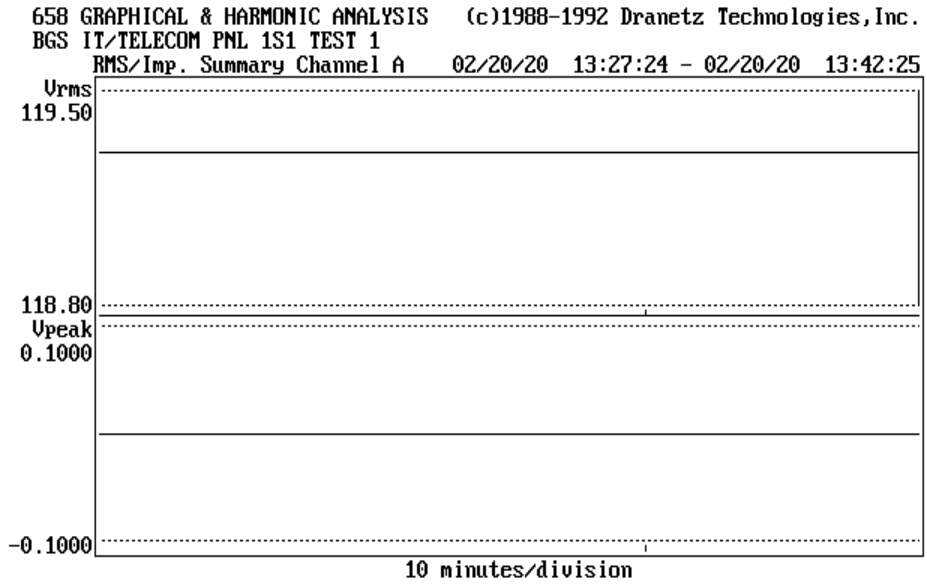


Chart 142

The chart shows the voltage fluctuating over a narrow range from 118.80 Vrms to 119.50 Vrms. This is stable voltage for an industrial plant. There were no voltage surge events during the monitoring period.

Chart 143 displays the Summary of the voltage events on Channel B, Phase B to Neutral.

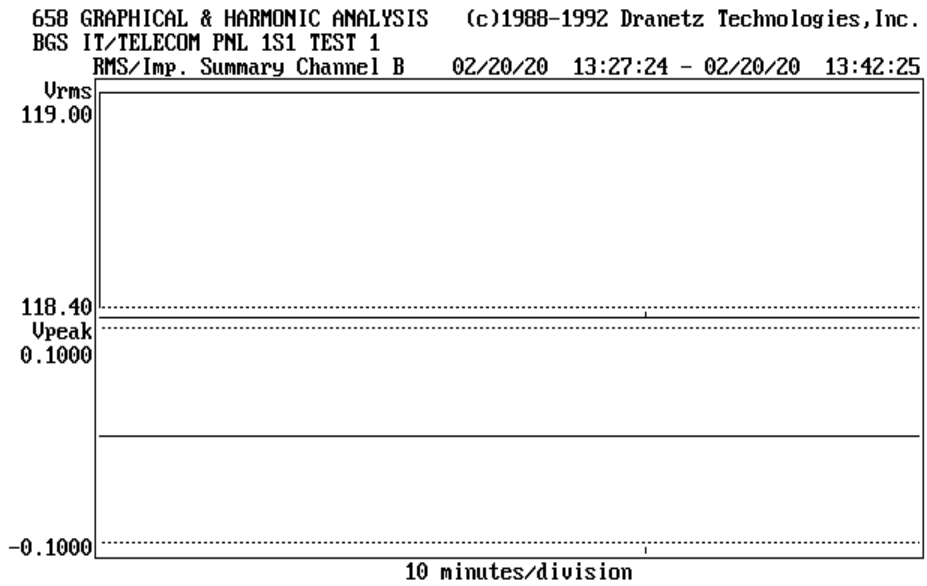


Chart 143

The chart shows the voltage fluctuating over a narrow range from 118.40 Vrms to 119.00 Vrms. This is stable voltage for an industrial plant. There were no voltage surge events during the monitoring period.

Chart 144 displays the Summary of the voltage events on Channel C, Neutral to Ground voltage.

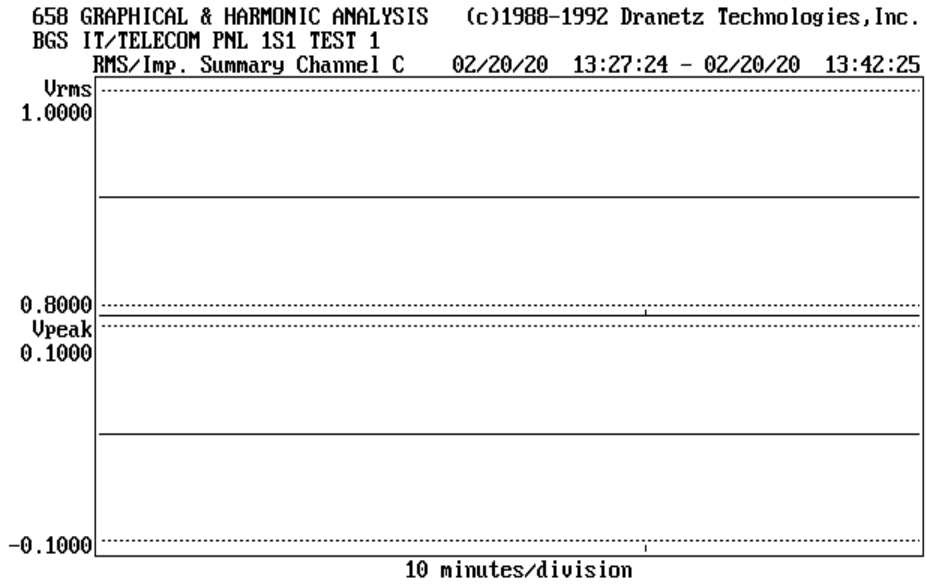


Chart 144

The chart shows the voltage fluctuating over a narrow range from 0.8000 Vrms to 1.0000 Vrms. This is stable voltage for an industrial plant. There were no voltage surge events during the monitoring period.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 145, is from Event #1 and shows the readings from Channel A on the 120 Vrms Phase A to Neutral mode.

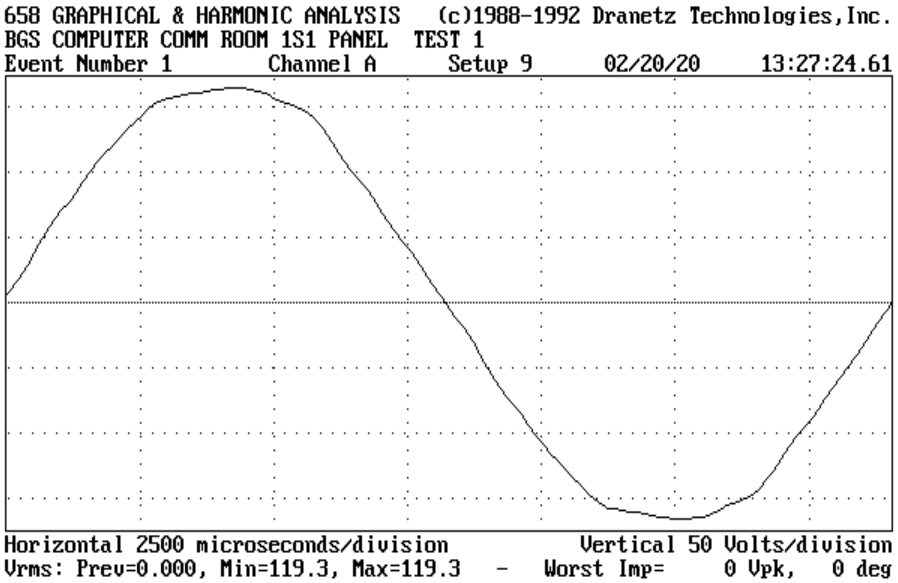


Chart 145

This chart displays the voltage surge events on Channel A for Phase A to Neutral. The voltage is stable at 119.3 Vrms. There is no surge activity during this event. The surges being generated by the switch-mode power supplies and other electronic controls in the rack may be remaining local to the rack and circulating among the equipment on the outlets within that rack, and not traveling all the way back to the power panel. If a surge protective device (SPD) at IT/Telecom Power Panel does not significantly reduce the amount of equipment damage, it may be necessary to place Type 3, plug-on type SPDs on the plug-in strip within the rack. An SPD at the IT/Telecom Power Panel will also provide the third level of defense against lightning and other catastrophic surge events coming down line from the Main Distribution Panel and the Mine Power.

Chart 146 from Event #1 and shows the readings from Channel B on the 120 Vrms Phase B to Neutral mode.

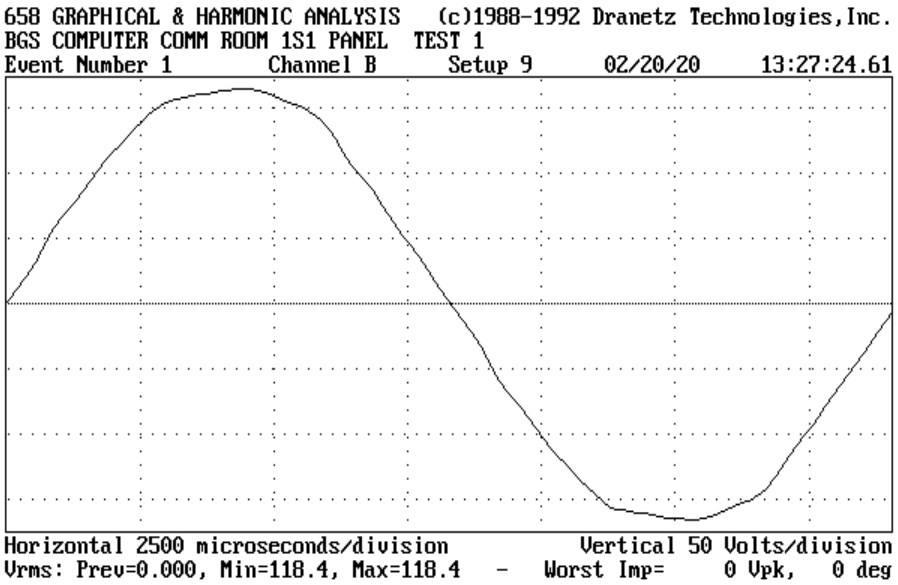


Chart 146

Chart 146 for event #1 shows a stable voltage at 119.5 Vrms and no surge events.

Chart 147 from Event #1 and shows the readings from Channel C on the 120 Vrms Neutral to Ground mode.

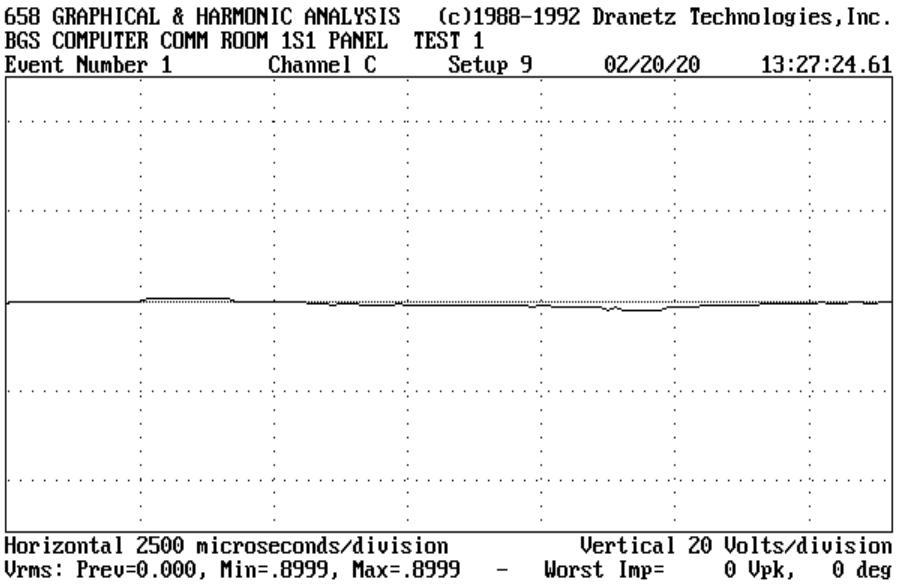


Chart 147

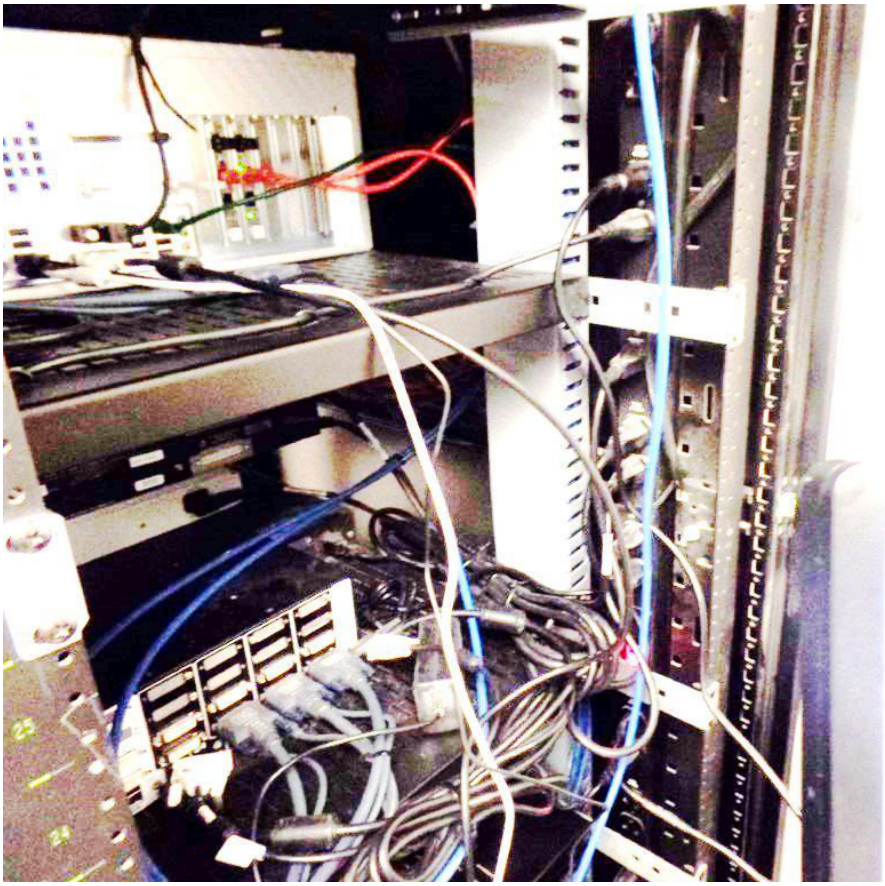
Chart 147 for Event #1 shows a stable voltage of .8999 Vrms and no surge events on the Neutral to Ground mode.

The absence of surge activity at these panels does not remove the need for surge protection. The equipment in the rack includes computers and network servers and other equipment specific to the operation. Most of these are linked to the control room monitoring and control panels through data lines. Any surge activity that can cause cumulative or catastrophic damage to the rack equipment can potentially travel on the data lines back to the master controls and impact the operational capability of the facility. The proper application of staged surge protection at the Main Distribution Panel, MCCs, Power (Branch) Panels, and if necessary, selected local circuits can reduce and, in most cases, prevent the surge events from reaching levels sufficient to damage the electrical and electronic equipment within the facility.

The application of properly sized and installed SPDs on these panels will further reduce the risk as well as provide the third level of protection from external catastrophic surge events such as lightning or blown transformers.

The last test was on the Plug-in Strip on the Rack in the IT/Telecom Room off the Conference Room. This is a standard 120 V, 1Ø, 2-Wire, system powering the rack equipment from the outlets on the Plug-in Strip. The Dranetz was connected with Channel A monitoring the Phase A to Neutral voltage, Channel B monitoring the Neutral to Ground voltage. The monitoring period was from 14:07:45 to 14:15:54 on Thursday, February 20, 2020 for a total of 8 minutes and 9 seconds. There were 10 events recorded during the monitoring period.

IT/Telecom Rack Equipment



IT/Telecom Rack Plug-in Strip on right side of Rack

Chart 148 displays the Summary of the voltage events on Channel A, Phase A to Neutral.

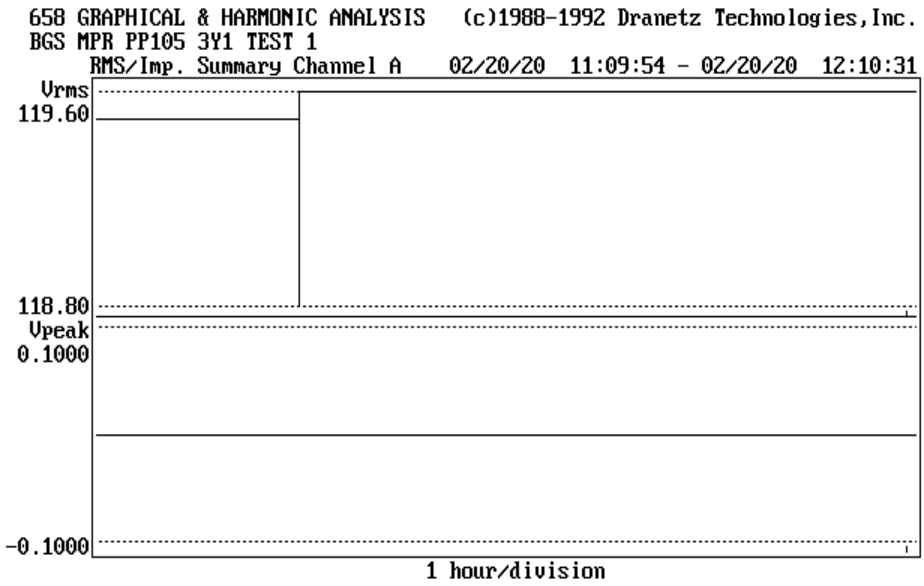


Chart 148

The chart shows the voltage is stable at 118.80 to 119.60 Vrms. There were no voltage surge events during the monitoring period.

Chart 149 shows the Summary of the readings for Channel B, Neutral to Ground voltage.

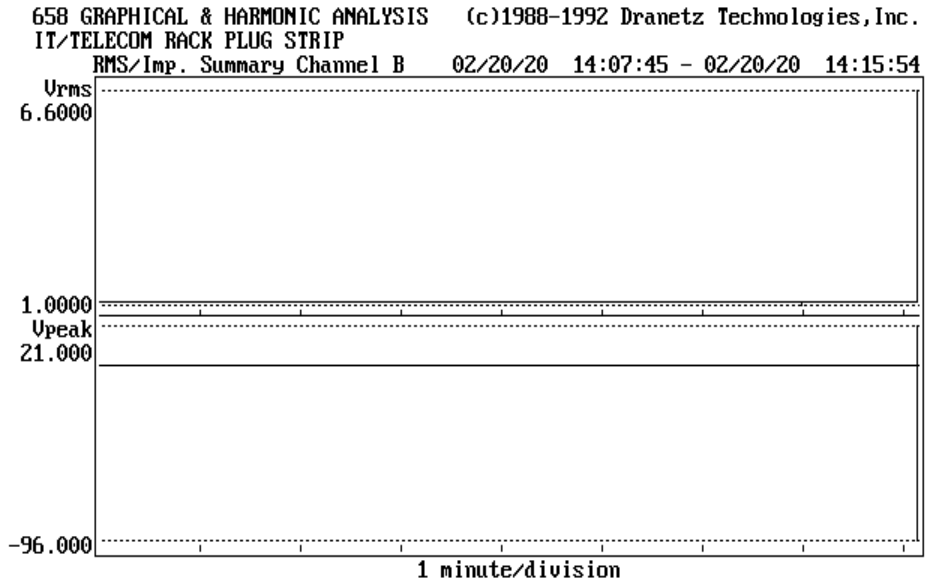


Chart 149

The Neutral to Ground voltage was stable at 1.000 Vrms throughout the monitoring period, rising to 6.6000 Vrms as power was turned off at the end of the monitoring period. This is normal.

The following charts are of an individual event captured during the monitoring period that represents the activity observed throughout the monitoring period. The first chart, number 150, is from Event #1 and shows the readings from Channel A on the 120 Vrms Phase A to Neutral mode.

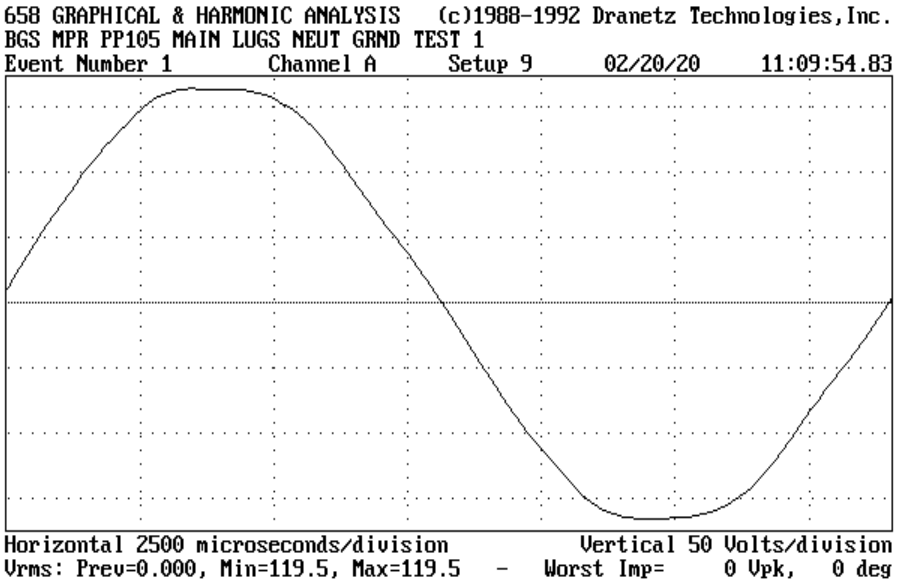


Chart 150

This chart displays the voltage surge events on Channel A for Phase A to Neutral. The voltage is stable at 119.5 Vrms. There is no surge activity during this event. If a surge protective device (SPD) at the IT/Telecom Power Panel does not significantly reduce the amount of equipment damage, it may be necessary to place Type 3, plug-on type SPDs on the Plug-in Strip itself to provide a central point for any external or internal surge activity to take the path of least resistance off the electrical system rather than going down a power cord to other equipment on the rack.

Chart 151 from Event #1 and shows the readings from Channel B on the 120 Vrms Neutral to Ground mode.

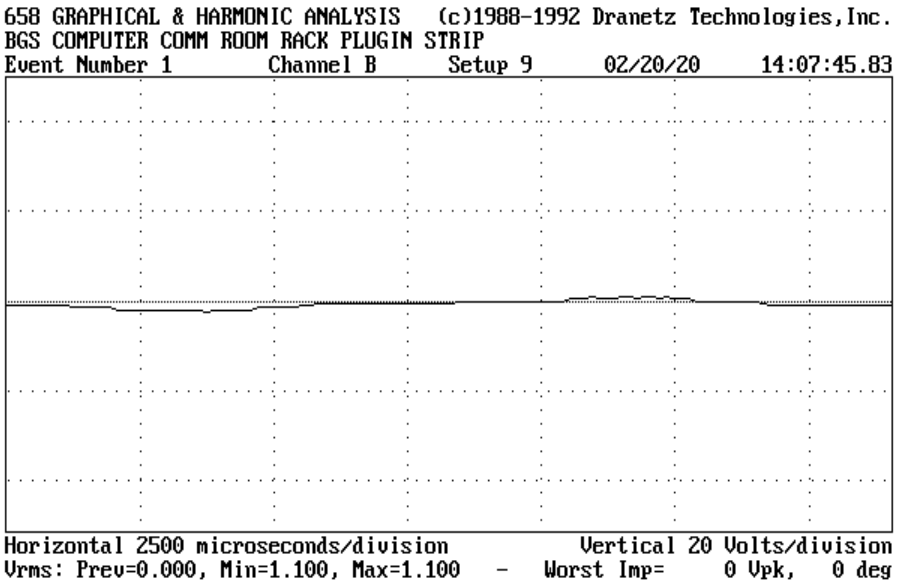


Chart 122

Chart 151 for event #1 shows a stable voltage at 1.100 Vrms and no surge events.

The absence of surge activity at these panels does not remove the need for surge protection. The equipment in the Rack includes computers, network servers, and other equipment specific to the operation. Most of these are linked to the control room monitoring and control panels through data lines. Any surge activity that can cause cumulative or catastrophic damage to the office equipment can potentially travel on the data lines back to the master controls and impact the operational capability of the facility. The proper application of staged surge protection at the Main Distribution Panel, MCCs, Power (Branch) Panels, and if necessary, selected local circuits can reduce and, in most cases, prevent the surge events from reaching levels sufficient to damage the electrical and electronic equipment within the facility.

The application of properly sized and installed SPDs on these panels will further reduce the risk as well as provide the third level of protection from external catastrophic surge events such as lightning or blown transformers.

RECOMMENDATIONS:

MAIN DISTRIBUTION PANEL

To protect the facility electrical distribution system from the constant, cumulative damaging surge events coming into the system from the Mine Power Distribution System, a Surge Protective Device (SPD) should be installed on the Main Distribution Panel. The SPD should be installed as close to the Breaker or Buss as possible, keeping the leads as short and straight as possible, per 2020 National Electrical Code (N.E.C.) 242.24.

If using the Spare breaker at the bottom of the breaker column, install the SPD on the left side of the Main Distribution Panel, directly adjacent to the Spare Breaker, mounting the metal hub on the left side of the SPD and attaching it directly to the right side of the Main Distribution Panel. Run the Phase leads directly to the Spare Breaker lugs. Run the Neutral and Ground leads directly to the Neutral/Ground buss at the rear of the Spare Breaker. Turn on Spare Breaker and relabel as SPD.

Unit to be ordered if Spare Breaker IS USED for installation:

Advantage CHLBM3Y2E32 or SpecPRO CTMB483Y2E32

If the install cannot use the Spare Breaker, then the SPD will need a disconnect in order to connect directly to the Phase Buss and to the Neutral/Ground Buss. The SPD will come already installed inside the disconnect cabinet. Mount the Disconnect Cabinet on the right side of the Main Distribution Panel, just below the Spare Breaker using the metal hub on the left side of the Disconnect. Run the Phase leads to the Phase Buss, tap the buss and using eyelet connectors, bolt the Phase leads to each Phase buss. Using the same connection process, connect the Neutral and Ground leads to the proper lugs.

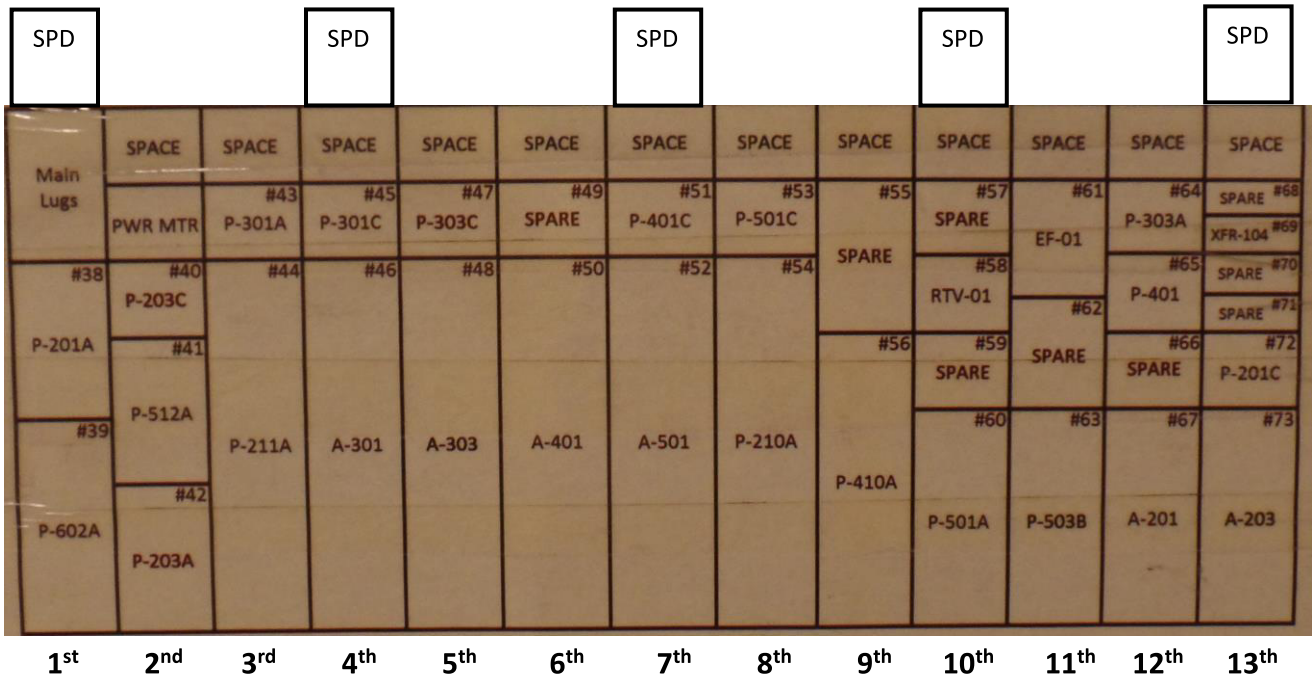
Unit to be ordered if Spare Breaker is NOT USED for installation:

Advantage CHLBM3Y2D6E32 or SpecPRO CTMB483Y2D6E32

MCC 101

All of the Motor Control Centers are receiving repetitive surge activity from the Main Distribution Panel. To prevent long term cumulative damage to the VFDs, motors, controls and other equipment on the MCC 101, and provide a second level of staged protection from lightning and other catastrophic surge events, SPDs should be installed so that each vertical column on the MCC is never any more than one column away from an SPD mounted at the top of the MCC. To accomplish this, the SPDs should be mounted above the first, fourth, seventh, tenth, and thirteenth column. Mount the metal hub on the bottom of the SPD directly to the metal top of the MCC, directly above the connection point on the Phase buss system at the top of the MCC. Connect

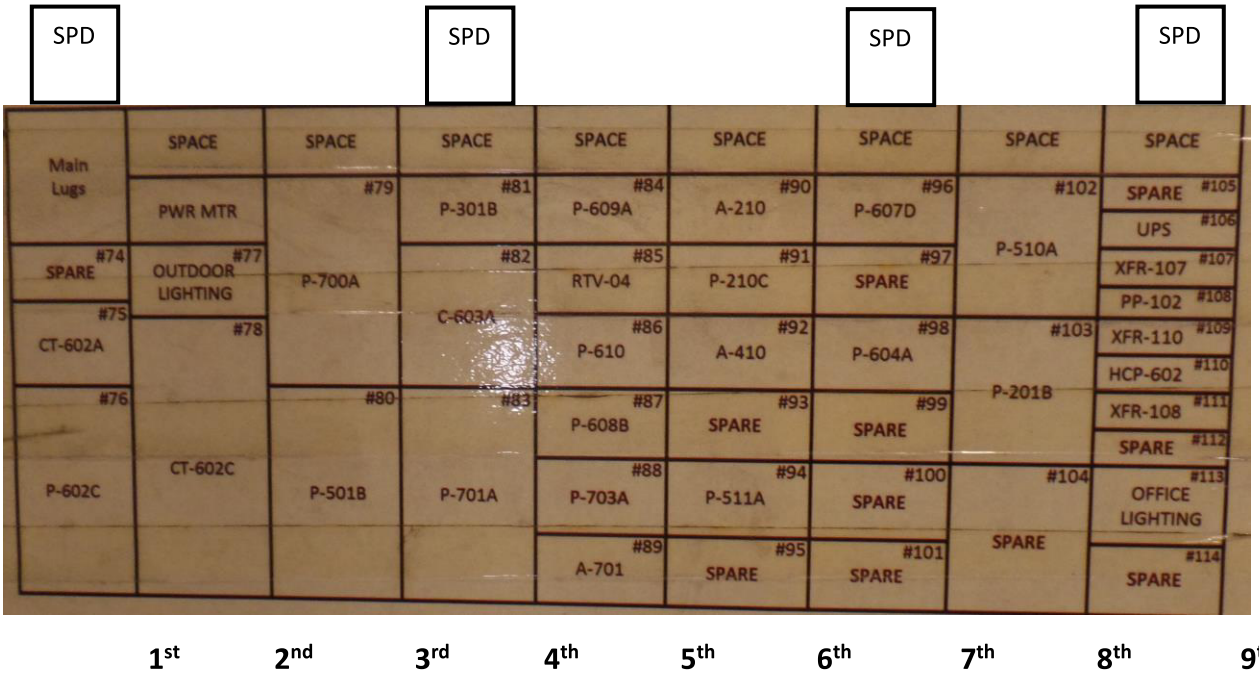
the Phase leads to the respective Phase buss. Connect the Ground lead to the Ground Buss.



Units to be ordered: 5 x Advantage SDLB3N4 or SpecPRO SSMB123N4

MCC 102

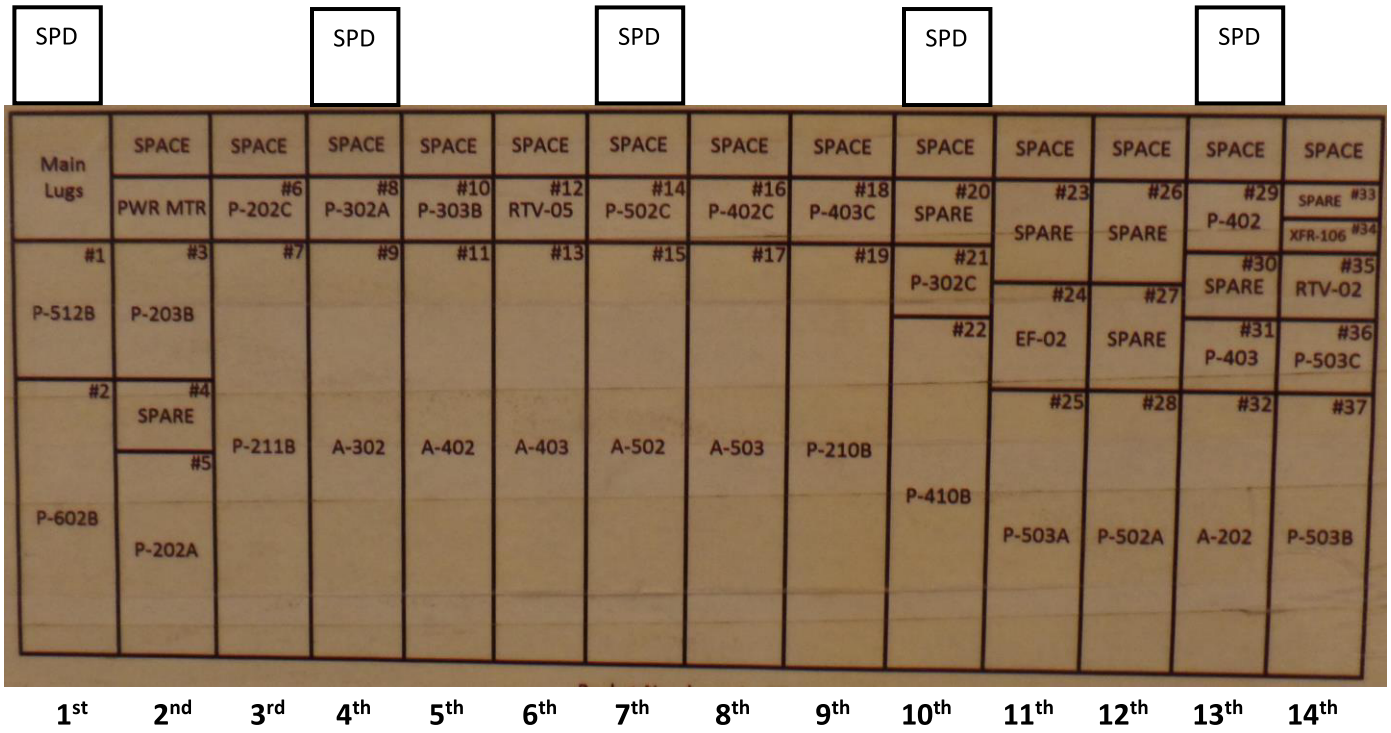
All of the Motor Control Centers are receiving repetitive surge activity from the Main Distribution Panel. To prevent long term cumulative damage to the VFDs, motors, controls and other equipment on the MCC 102, and provide a second level of staged protection from lightning and other catastrophic surge events, SPDs should be installed so that each vertical column on the MCC is never any more than one column away from an SPD mounted at the top of the MCC. To accomplish this, the SPDs should be mounted above the first, fourth, seventh, and ninth column. Mount the metal hub on the bottom of the SPD directly to the metal top of the MCC, directly above the connection point on the Phase buss system at the top of the MCC. Connect the Phase leads to the respective Phase buss. Connect the Ground lead to the Ground Buss.



Units to be ordered: 4 x Advantage SDLB3N4 or SpecPRO SSMB123N4

MCC 103

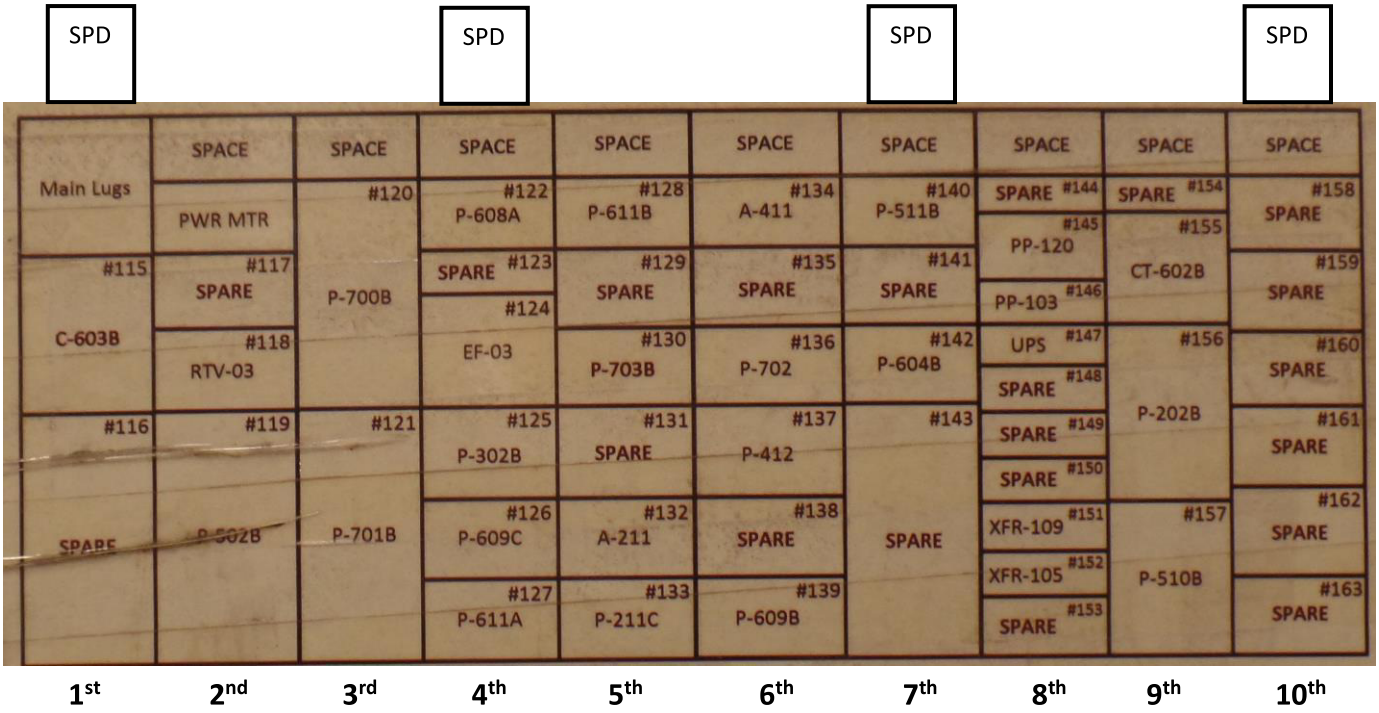
All of the Motor Control Centers are receiving repetitive surge activity from the Main Distribution Panel. To prevent long term cumulative damage to the VFDs, motors, controls and other equipment on the MCC 103, and provide a second level of staged protection from lightning and other catastrophic surge events, SPDs should be installed so that each vertical column on the MCC is never any more than one column away from an SPD mounted at the top of the MCC. To accomplish this, the SPDs should be mounted above the first, fourth, seventh, tenth, and thirteenth column. Mount the metal hub on the bottom of the SPD directly to the metal top of the MCC, directly above the connection point on the Phase buss system at the top of the MCC. Connect the Phase leads to the respective Phase buss. Connect the Ground lead to the Ground Buss.



Units to be ordered: 5 x Advantage SDLB3N4 or SpecPRO SSMB123N4

MCC 104

All of the Motor Control Centers are receiving repetitive surge activity from the Main Distribution Panel. To prevent long term cumulative damage to the VFDs, motors, controls and other equipment on the MCC 103, and provide a second level of staged protection from lightning and other catastrophic surge events, SPDs should be installed so that each vertical column on the MCC is never any more than one column away from an SPD mounted at the top of the MCC. To accomplish this, the SPDs should be mounted above the first, fourth, seventh, and tenth column. Mount the metal hub on the bottom of the SPD directly to the metal top of the MCC, directly above the connection point on the Phase buss system at the top of the MCC. Connect the Phase leads to the respective Phase buss. Connect the Ground lead to the Ground Buss.



Units to be ordered: 4 x Advantage SDLB3N4 or SpecPRO SSMB123N4

VFD Control Voltage

There are 30 Variable Frequency Drives on the 4 MCCs. Each VFD has a 480 V to 120 V Step-Down Transformer fed from the VFD's Main Lugs. The 120 V, 1 Ø, is used to power the control circuits and processors within the VFD. The surge activity present on the Main Buss of each MCC and any surge events being generated by the VFD rectifiers, has the potential to create cumulative damage over time to the circuits and components within the VFD controls. In addition, the history of lightning and other catastrophic surge events at the facility requires a third level of protection beyond the Main Distribution Panel and MCC Main Buss SPDs to provide the staged reduction of the large surges to non-destructive levels at the electronic circuit boards and components. To accomplish this, a series type, Frequency Response Circuitry SPD should be installed on the load side of the 480 V to 120 V Step-Down Transformer.

Units to be ordered: 30 x USPT1P1

Power Panel PP-LA, PP-LB, PP-102, PP-105

The four Power Panels within the Main Electrical Room are all 120/208 V, 3 Ø, 4-Wire, Wye, 225 Amp panels. They all have a mix of electrical and electronic loads. The continuous, cumulative level surge events present on the MCCs, as well as the larger impulse surges from lightning, other catastrophic events, and major motor switching can all travel down-line through the transformers and into the Power Panels to create at least cumulative damage to the connected electrical and electronic equipment. The installation of a third level, Frequency Response Circuitry SPD on each Power Panel will provide the necessary final protection to reduce the potentially catastrophic surges to non-destructive levels.

Units to be ordered: 4 x Advantage CDLB3Y1 or SpecPRO CSMB123Y1

Power Panel IT/Telecom

The IT/Telecom Power Panel is a 120/240 V, Split-Phase, 3-Wire system powering the network servers and computers in the Rack in the IT/Telecom Room off the Conference Room. This is extremely sensitive and vulnerable equipment that does not tolerate surge activity. There is no surge protection on this Power Panel. There is an urgent need for a Frequency Response Circuitry SPD at this Power Panel to provide the third level of protection for the sensitive electronics that are critical for facility operations.

Unit to be ordered: Advantage CKLB1S1 or SpecPRO CSMB81S1

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Senior Member *IEEE*

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