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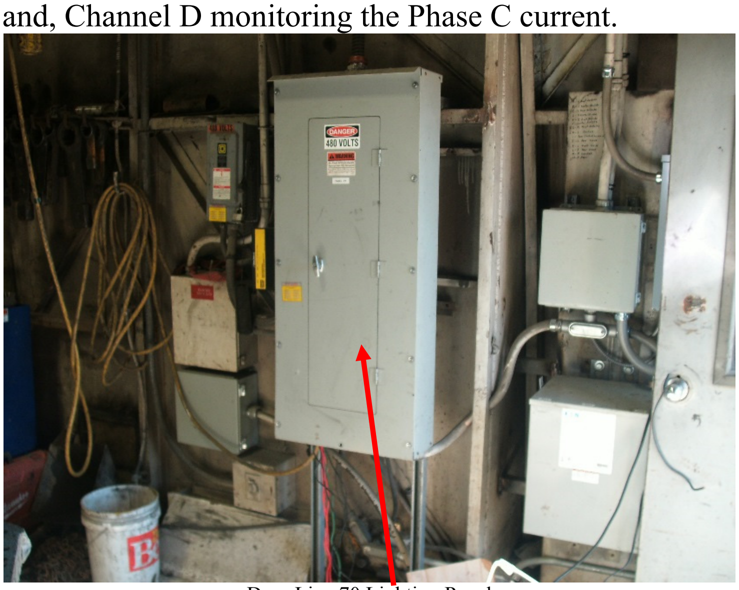
POWER QUALITY STUDY

January 14, 2015, Tom Butcher from Technology Services, Surge Suppression Incorporated, joined , North American Sales Manager – Mining & Energy, and , Chief Technical Officer/Managing Director – Mining & Energy from Company, Inc. We met with , Electrical Supervisor, at the mine in , to conduct a power quality study of the mine's dragline equipment.

There are three draglines at the mine, #70, #1, and #2. had reported that the LED lights on the draglines had been experiencing an unusual rate of failures. The purpose of the power quality study was to monitor the power on the lighting panels at the draglines for any abnormalities that might be causing the failures. Only part of the failures occurred during severe weather. Other times, the failure occurred with no severe weather observed and no other disruptive activity noted. If any problems were noted, we would try to determine whether the source of the problem was from an internal operation of the large motors and drives, or generated on the incoming power lines from the local utility or some other outside source.

We began testing at the lighting control cabinet on Drag Line #70. A Dranetz model 658 Power Quality Analyzer metered the Line side incoming power at the main disconnect switch, to monitor the power for surge activity as well as voltage and current problems. The Dranetz set-up for Test 1 had Channel A monitoring the Phase A to Phase B, 480 Volt power; Channel B monitoring the Phase B to Phase C, 480 Volt power; Channel C monitoring the Phase C to Phase A, 480 Volt power; and, Channel D monitoring the Phase C current.



Drag Line 70 Lighting Panel

Test equipment set-up (Dranetz Power Quality Analyzer and Tablet Computer) at Drag Line 70 Lighting Panel

Monitoring began at approximately 10:17:24 AM to 10:17:25 AM, while Drag Line 70 was running at idle.

The following charts show the summary of events during this monitoring period.

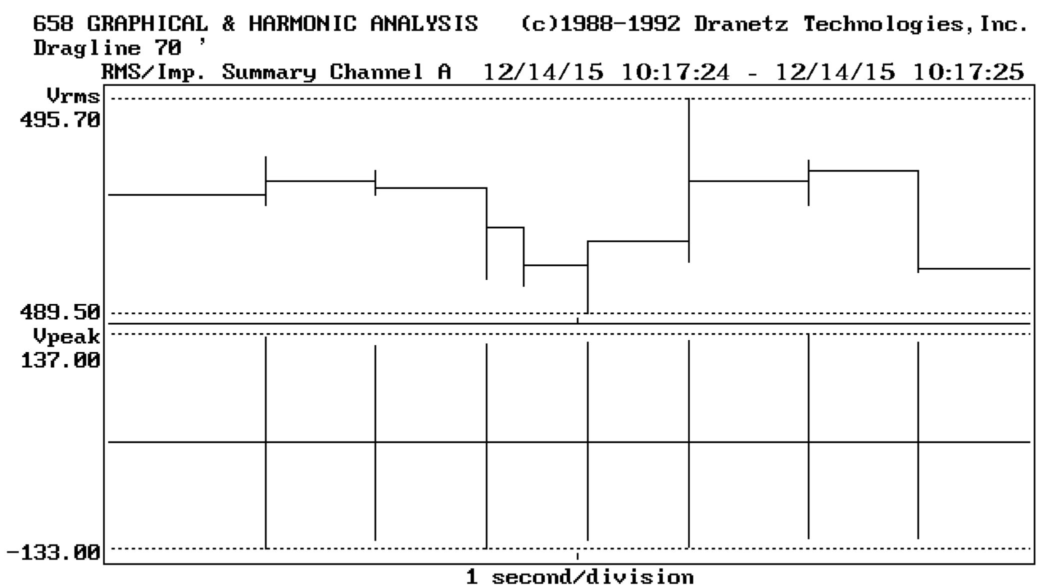


Chart 1

Summary of Phase A to Phase B voltage events during monitoring period for Test 1. Normal voltage variations and multiple transient surge activity ranging from a positive 137 Volts peak (V_{pk}) to a negative 133 V_{pk}.

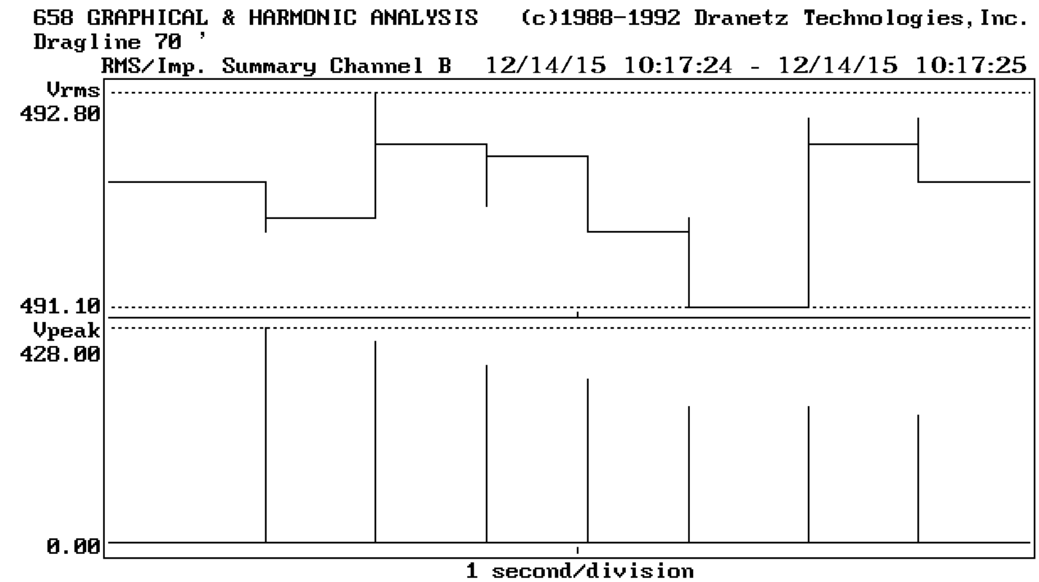


Chart 2

Summary of Phase B to Phase C voltage events during monitoring period for Test 1. Normal voltage variations and multiple transient surge events of up to 428 V_{pk}.

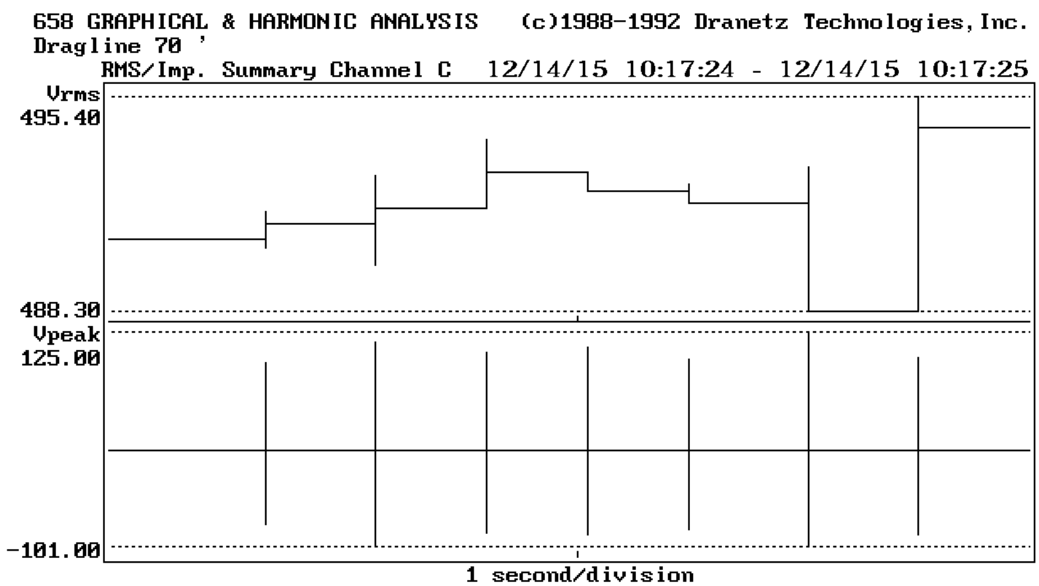


Chart 3

Summary of Phase C to Phase A voltage events during monitoring period for Test 1. Normal voltage variations and transient surge activity ranging from a positive 125 V_{pk} to a negative 101 V_{pk}.

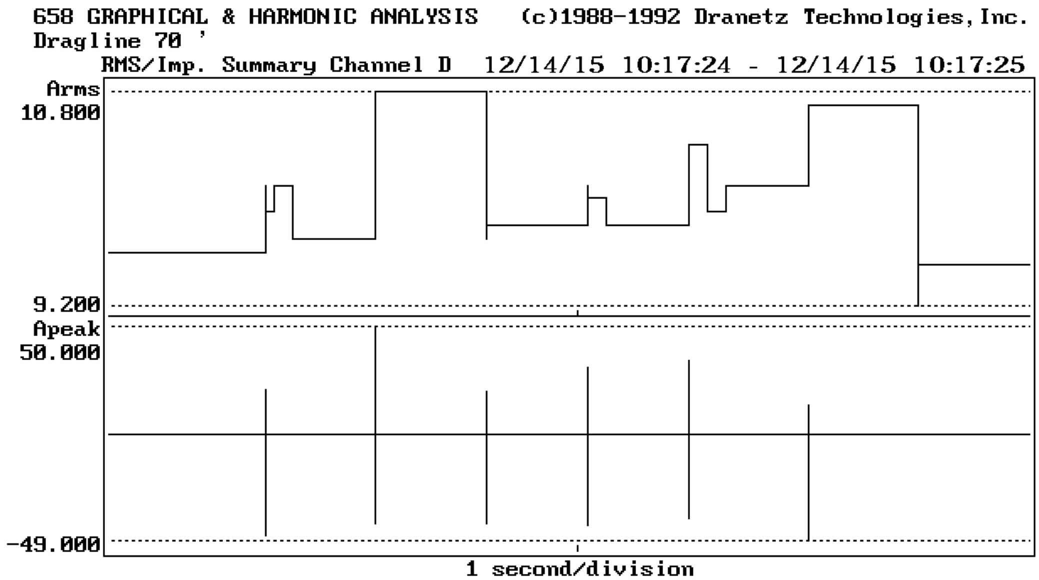


Chart 4

Summary of the Phase C current events during monitoring period for Test 1. The amperage change is normal for the minor changes occurring during the idle period. The surges in current range from a positive 50 Amps peak (A_{pk}) to a negative 49 A_{pk}.

The following charts show monitoring on the Drag Line 70 lighting panel, Channel A, Phase A to Phase B, 480 Volt waveform at 10:17:24.17.

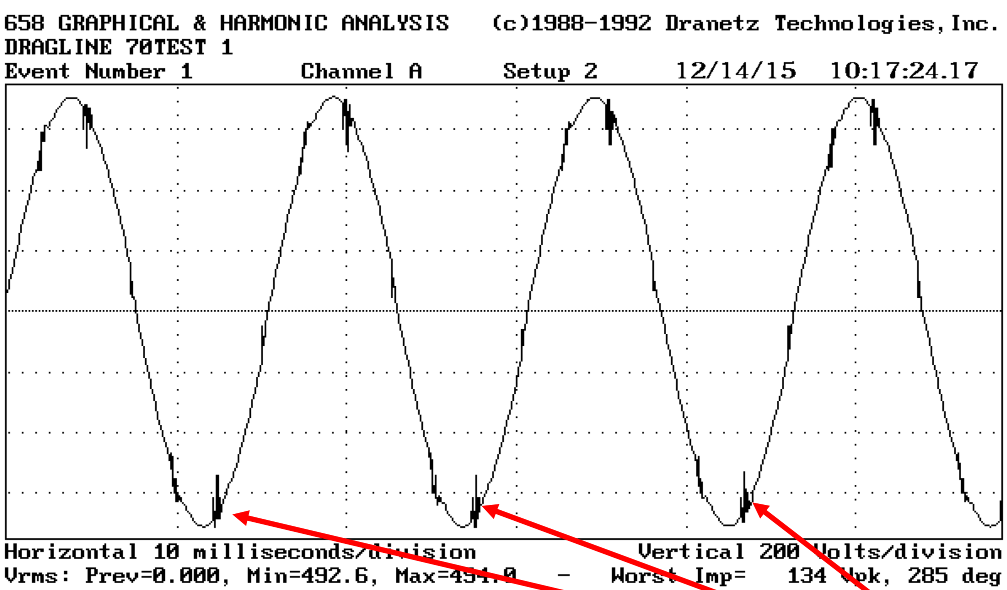


Chart 5

Chart 5 shows the voltage on Phase A to Phase B at 492.6 to 494.0 V_{rms} with repetitive surge activity up to 134 V_{pk}.

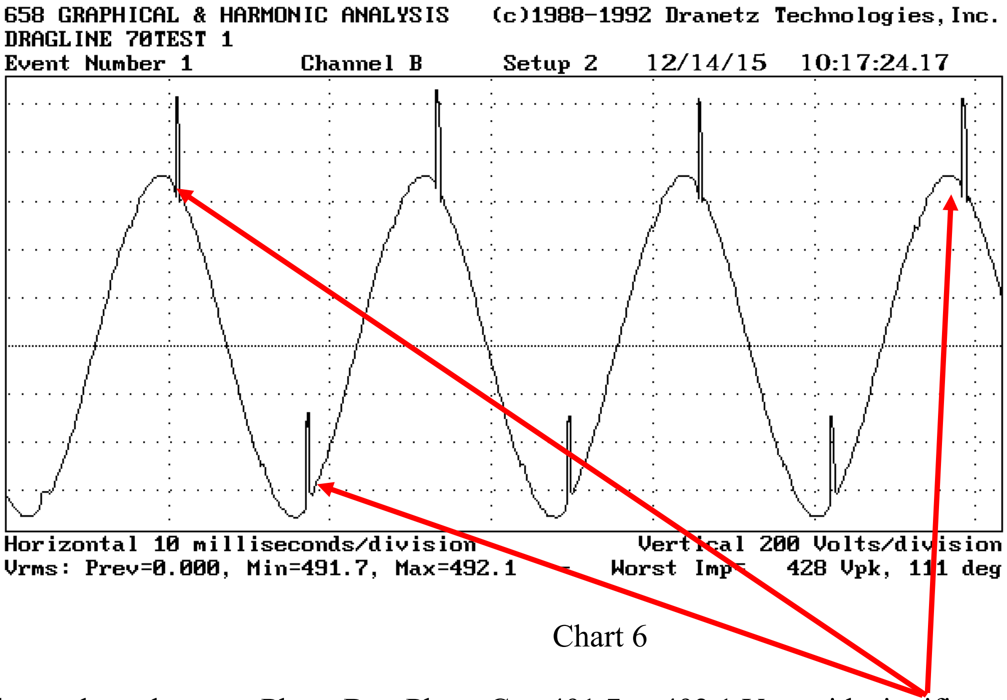


Chart 6

Chart 6 shows the voltage on Phase B to Phase C at 491.7 to 492.1 V_{rms} with significant surge activity occurring twice per cycle up to 428 V_{pk}.

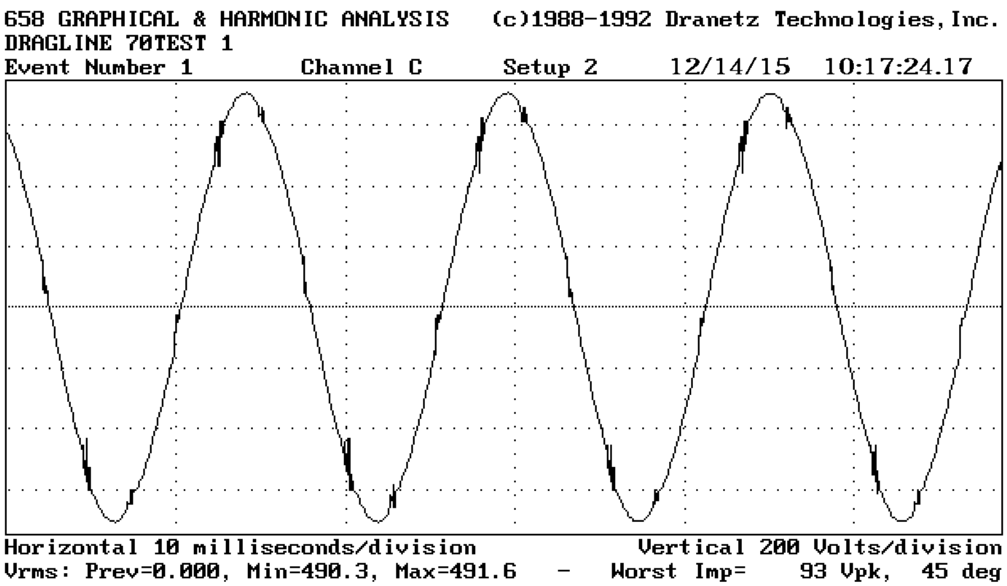


Chart 7

Chart 7 shows the voltage on Phase C to Phase A at 490.3 to 491.6 V_{rms} with surge activity several times per cycle up to 93 V_{pk}.

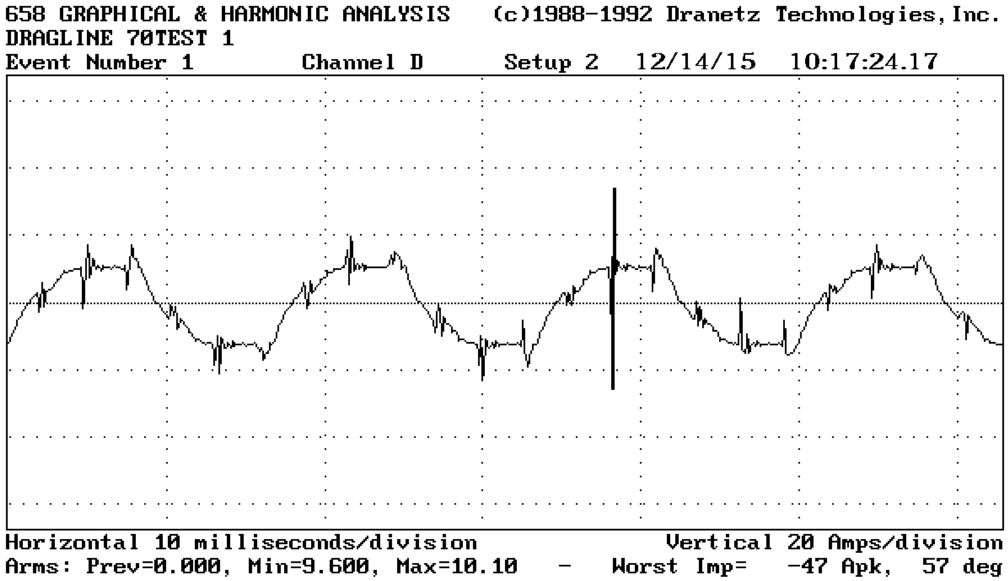


Chart 8

Chart 8 shows the current on Phase C at 9.600 to 10.10 A_{rms} with surge activity occurring multiple times per cycle and one individual current surge of a negative 47 A_{pk}. The smaller distortions in the current waveform are normal for the operation of AC and DC variable speed drives (VFDs). The one larger current spike is most likely from the start of some operation or component that immediately returns to the normal pattern.

The voltage surge activity on the three phase combinations is originating from the operation of the large motor VFDs. The drive rectifiers are turning on and off several times per cycle, drawing current in pulses to convert the AC voltage to DC voltage. At this point, the DC voltage either runs DC voltage motors, or is inverted back to AC voltage at a controlled frequency to run AC voltage motors. The transient surge activity observed on the phases and the current is occurring at least two time per cycle (some phases 4 to 6 times per cycle). At two times per cycle that is 432,000 times per hour that the electronic power supplies for the 480 V_{rms} LED lighting are having to absorb up to 428 V_{pk} surge voltage (4 times/cycle = 864,000/hour and 6 time/cycle = 1,296,000/hour).

Although this type of surge activity is common to VFDs, it is unusual to see such a marked difference in the level of surge between the phase combinations. Phase B to Phase C 480 V_{rms} combination does have a significantly higher surge level than the other two combinations. During the second test on Drag Line 70, the surge activity is more evenly balanced between the three phases. Since Drag Line 70 was in full operation during the second test with the more balanced surge activity, it may not be possible to rebalance the loads during the idle stage to reduce the surge imbalance without creating an imbalance during the operating stage. The more cost efficient solution would be to install frequency responsive surge protection on the LED lighting panel to eliminate the impulse and ring wave surges from the voltage phases.

For Test 2, Drag Line 70 was operating under load. The Dranetz maintained the same set-up on the channels from Test 1. The testing began at 11:24:41 AM and ended at 11:24:55 AM.

The following charts show the summary of events during this monitoring period.

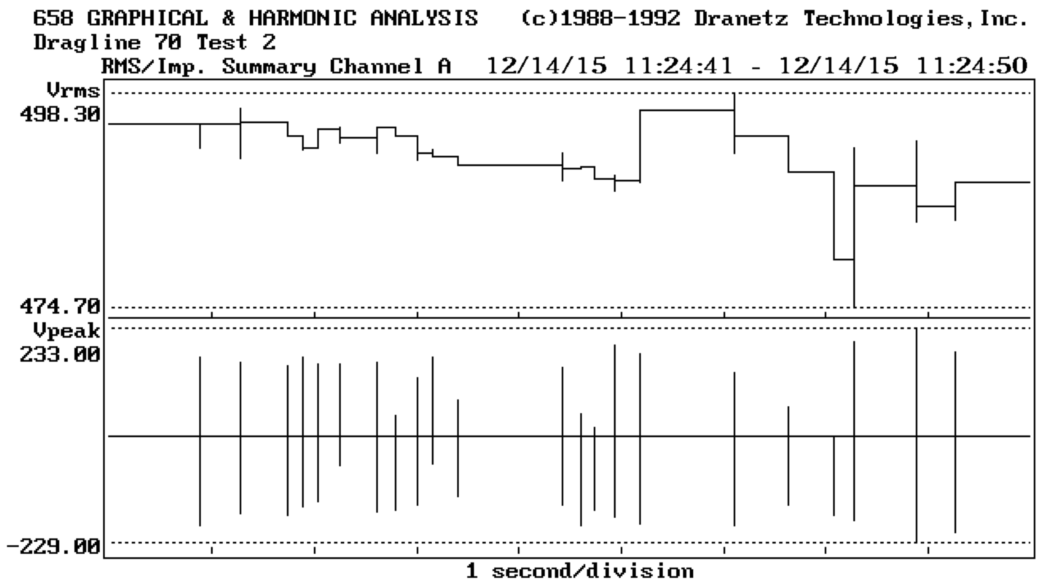


Chart 9

Summary of Phase A to Phase B voltage events during monitoring period for Test 2. The line voltage spiked to a high of 498.30 V_{rms} and to a low 474.70 V_{rms}. Surge events ranged from 233.00 V_{pk} to -229.00 V_{pk}.

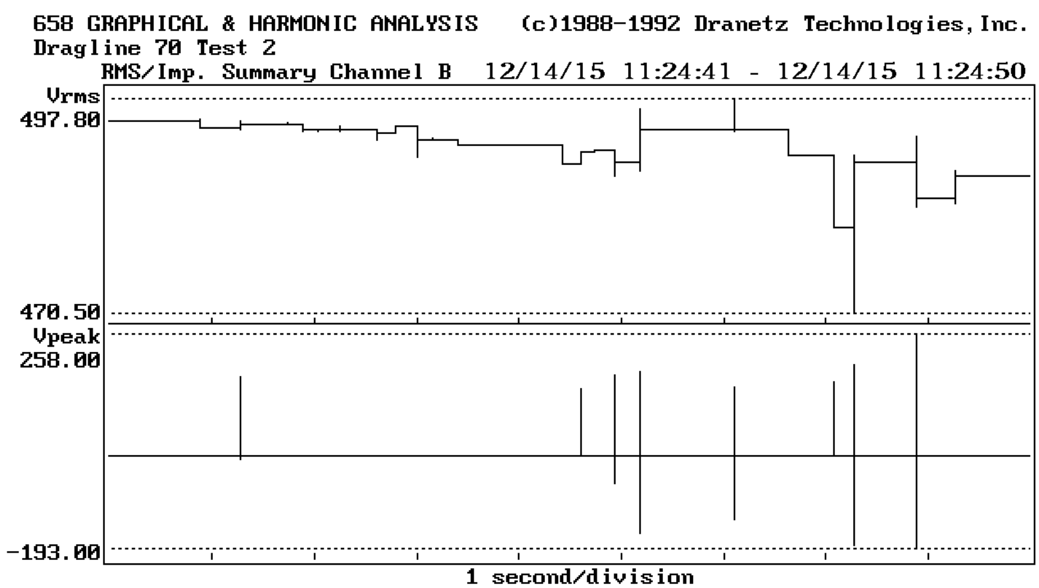


Chart 10

Summary of Phase B to Phase C voltage events during monitoring period for Test 2. The line voltage spiked from a high of 4971.80 V_{rms} to a low of 470.50 V_{rms}. Surge events ranged from 258.00 V_{pk} to -193.00 V_{pk}.

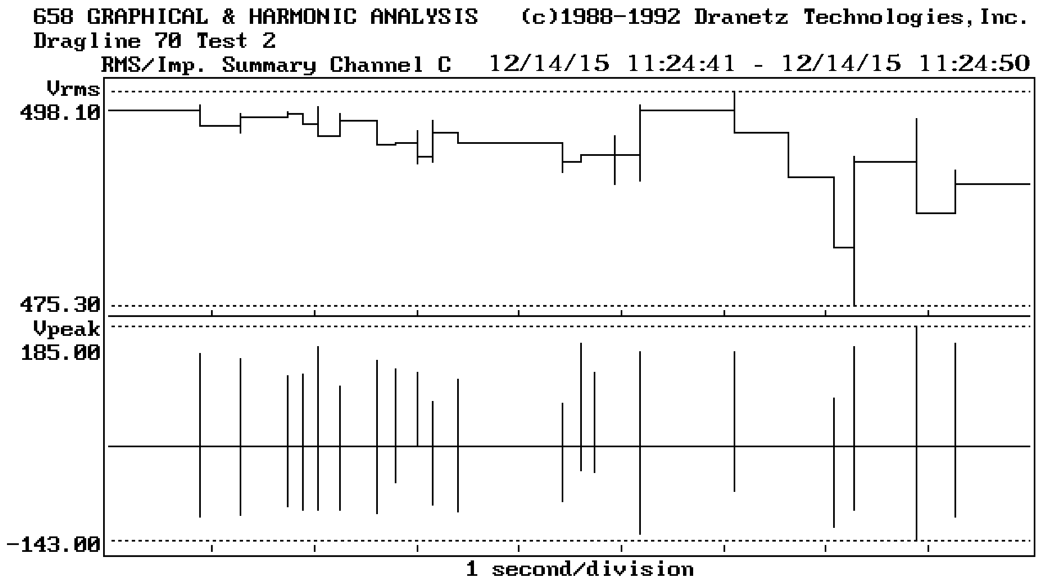


Chart 11

Summary of Phase A to Phase C voltage events during monitoring period for Test 2. The line voltage spiked from a high of 498.10 V_{rms} to a low of 475.30 V_{rms}. Surge events ranged from 185.00 V_{pk} to -143.00 V_{pk}.

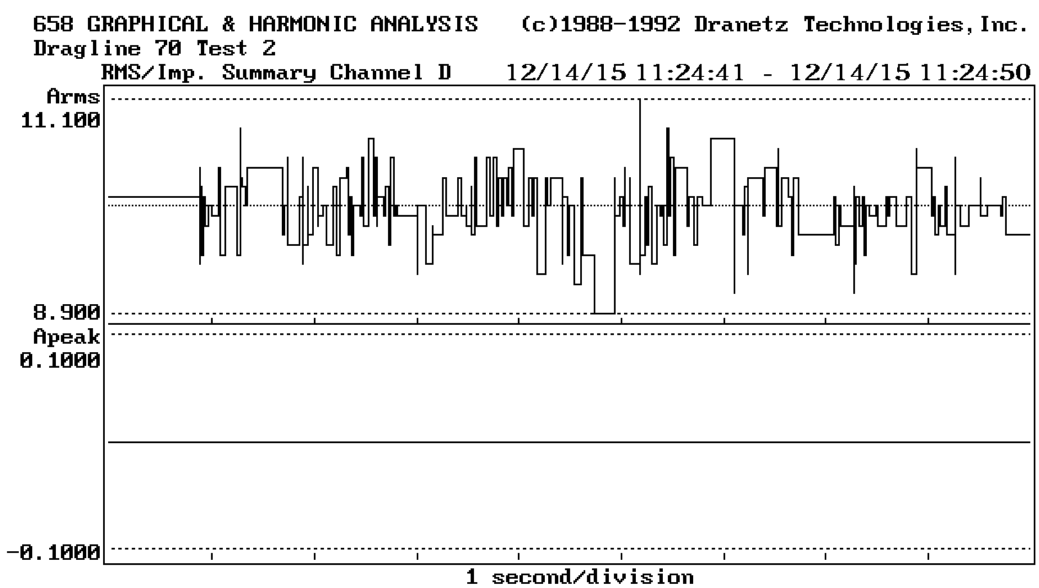


Chart 12

Summary of the Phase C current events during monitoring period for Test 2. The current ranged from a high of 11.100 A_{rms} to a low of 8.900 A_{rms}. There was no surge activity on the current.

The next four charts show the power coming out of the Line Reactor and going to the Allen-Bradley PowerFlex SCR Bus Supply for the DC Bus on Line 1 Concentric. Monitoring started at 11:33:14.

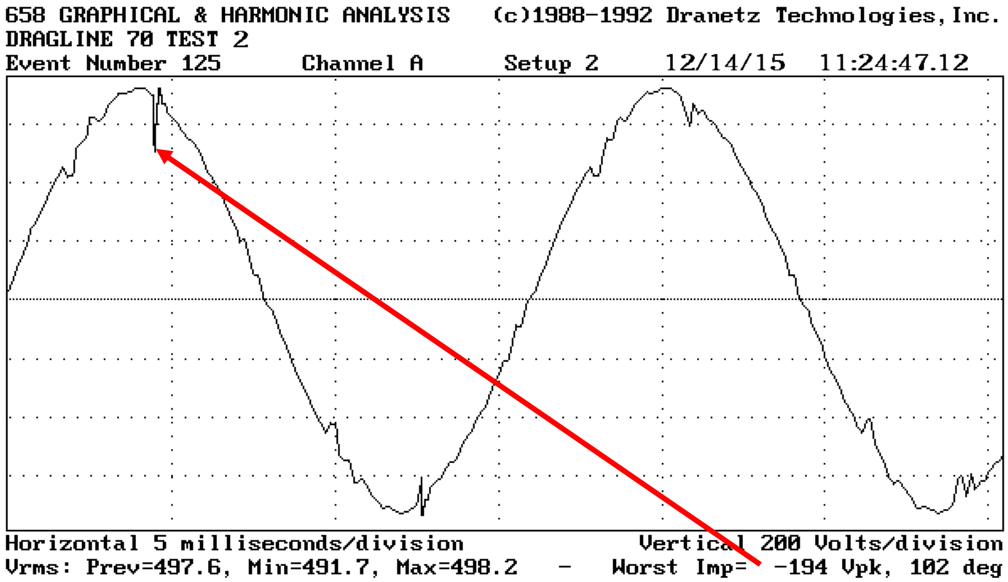


Chart 13

Chart 13 shows the Phase A to Phase B voltage range from a low of 491.7 Vrms to a high of 498.2 Vrms for event 125 at 11:24:47.12, with transients to -194 V_{pk}.

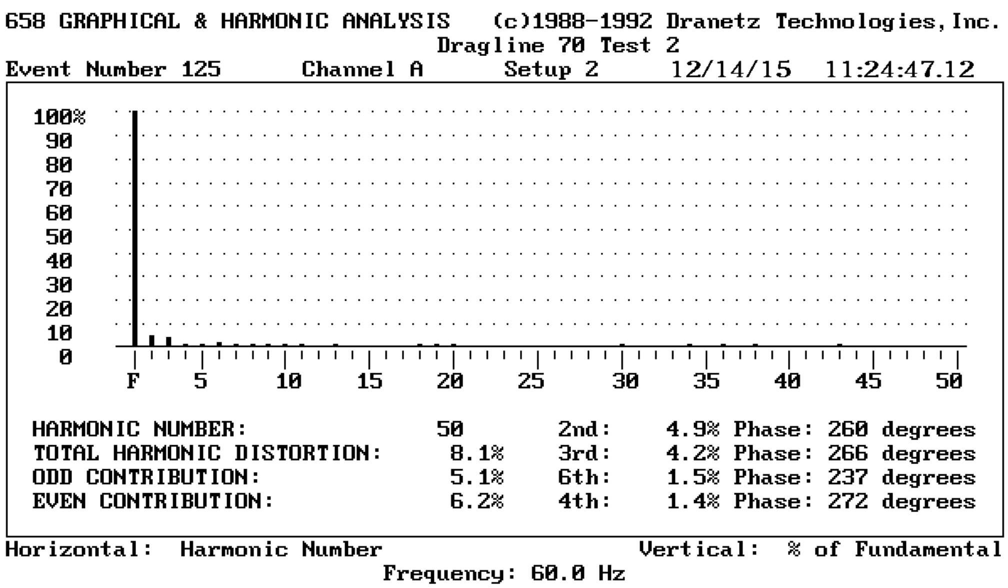


Chart 14

Chart 14 shows the harmonic content for the waveform on Chart 13. The Total Harmonic Distortion (THD) is 8.1%, and the highest individual harmonic distortion is for the 2^{nd} Harmonic at 4.9%. These are both slightly above the maximum allowable levels of 5% THD and 3% individual harmonic distortion under IEEE Standard 519-1992.

It is important to differentiate between true harmonics and transient generated distortion. True harmonic distortion is more of a general, overall distortion of the waveform. The sharp, individual spikes shown in Chart 13 are characteristic of transient distortion. Harmonic filters will not remove the transients shown on Chart 13.

This transient distortion appears to be coming from the operation of the six-pulse rectifier on the large motor VFDs.

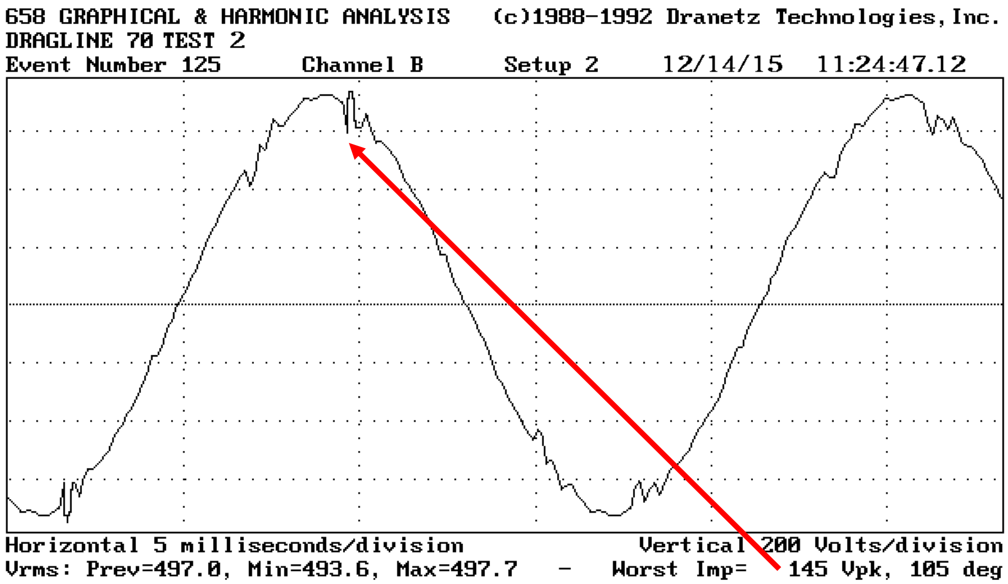


Chart 15

Chart 15 shows the Phase B to Phase C voltage range from a low of 493.6 to a high of 497.7 V_{rms} for the same event, with transients up to 145 Vpk from the waveform.

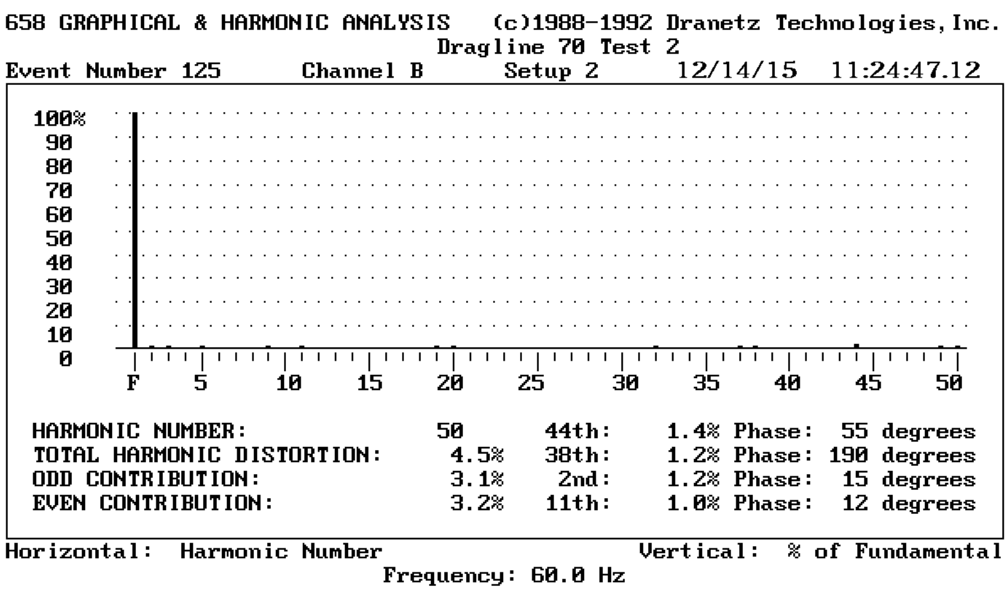


Chart 16

Chart 16 shows the harmonic content for Chart 15. The THD is 4.5% and the highest individual harmonic distortion level is for the 2^{nd} harmonic at 1.4%, well within the allowable standards. The distortions do not have the appearance of true harmonics; rather they appear to be distortions caused by surges from a large motor VFD on another panel in the dragline.

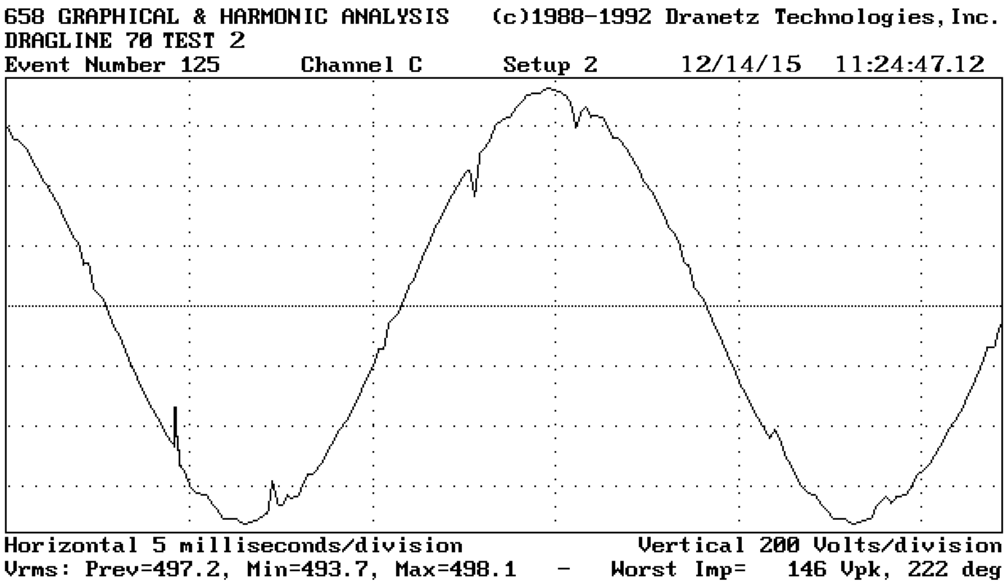


Chart 17

Chart 17 shows the Phase C to Phase A voltage range from a low of 493.7 V_{rms} to a high of 498.1 V_{rms} for the same event, with transients up to 146 V_{pk} from the waveform.

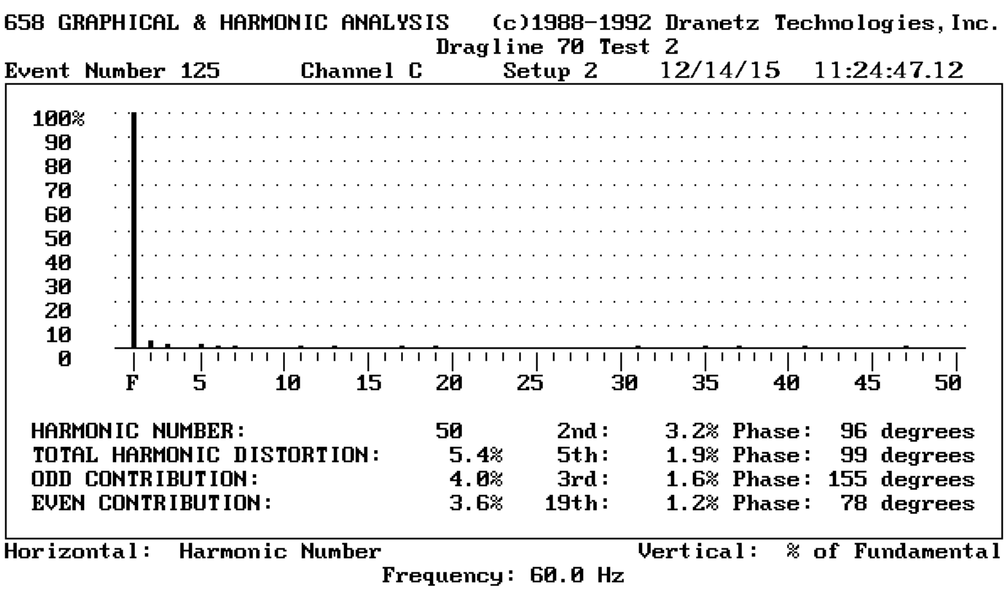


Chart 18

Chart 18 shows the harmonic content for Chart 17. The THD is 5.4% and the highest individual harmonic distortion is for the 2nd harmonic at 3.2%. These levels are slightly above the allowable limits. Once again, the distortion does not appear to be from true harmonics, but rather from surge distortions from a large motor VFD on the system.

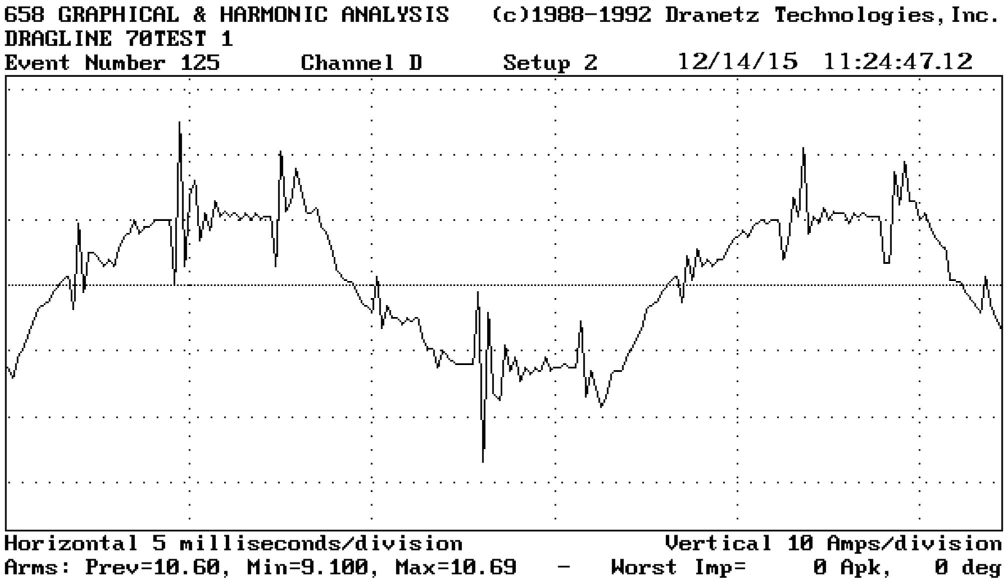


Chart 19

Chart 19 shows the Phase C current range from a low of 9.100 A_{rms} to a high of 10.69 A_{rms} for the same event. The distortion of the current waveform is normal for the non-linear loads such as the VFDs and switch-mode power supplies.

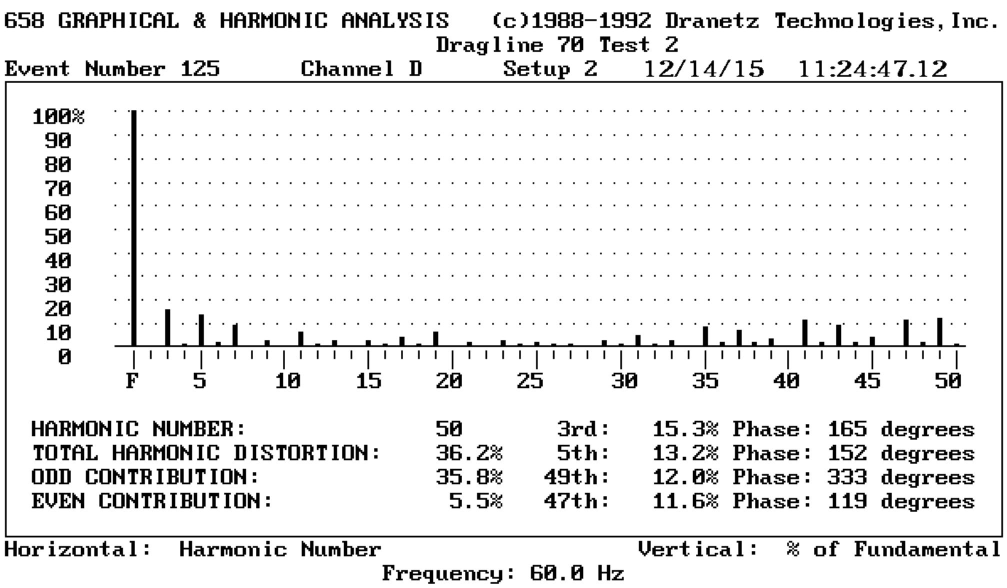


Chart 20

Chart 20 shows the harmonic content for Chart 19. The THD is 36.2% and the highest individual harmonic distortion is for the 3^{rd} harmonic at 15.3%. The power supplies for the LEDs can be contributing to this level of harmonic distortion. Although these levels are above the allowable limits, they are common for non-linear loads and the majority of electronic equipment can operate with these levels of current distortion with no ill effects. If these levels exceed acceptable limits for the operation of the LEDs, a current harmonic filter may be necessary.

After a break for lunch, we moved to Drag Line 2 for two sets of tests at the LED lighting panel. The Dranetz was set-up 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 C current.

The first test commenced at 1:14:56 PM and ended at 1:26:31 PM.

The following charts show the summary of events during this monitoring period.

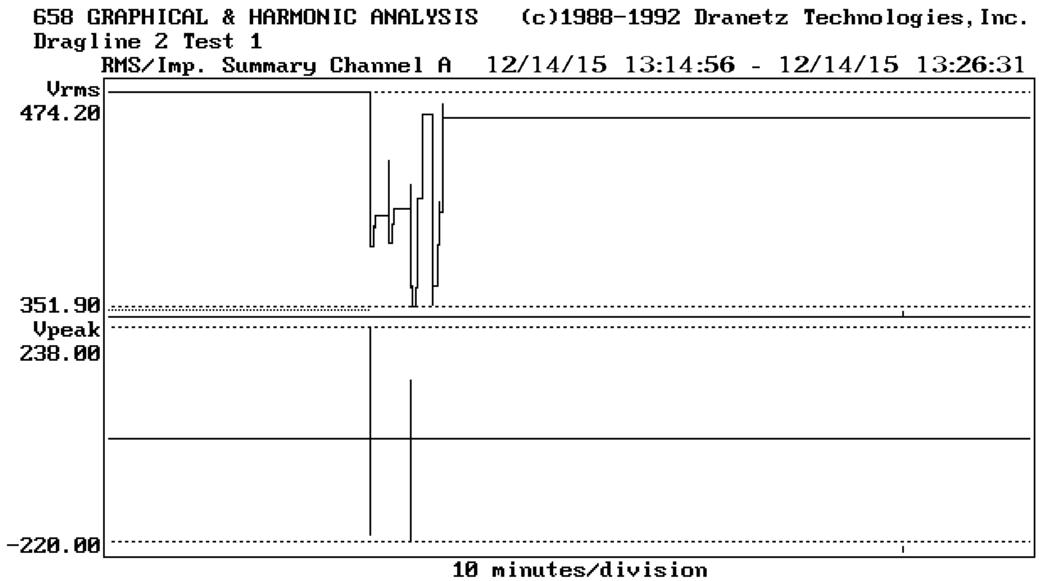


Chart 21

Summary of Phase A to Phase B voltage events during monitoring period for Drag Line 2 Test 1. The line voltage spiked from a high of 474.20 V_{rms} to a low of 351.90 V_{rms} with surge events from 238.00 V_{pk} to -220.00 V_{pk}.

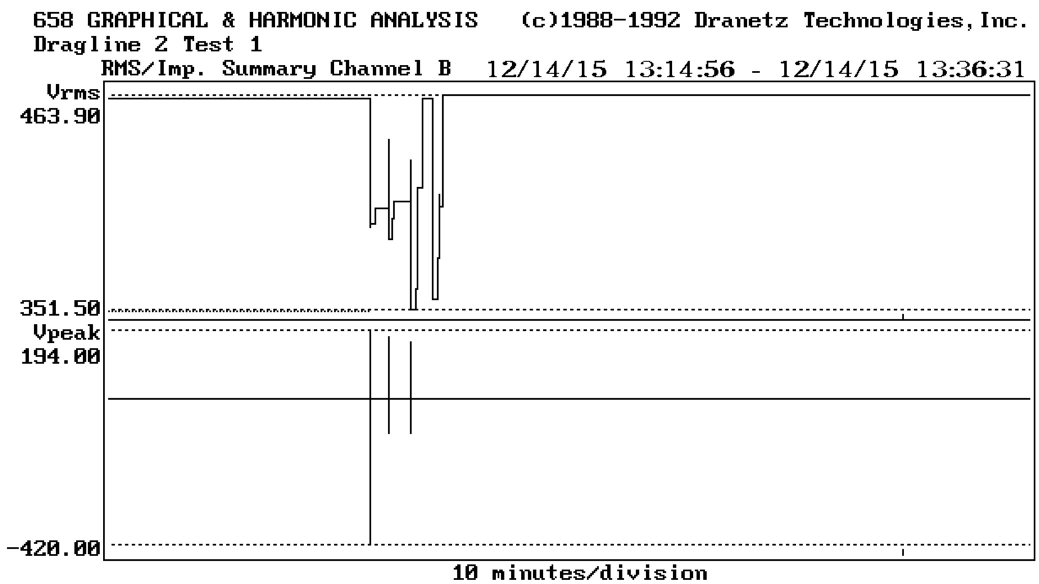


Chart 22

Summary of Phase B to Phase C voltage events during monitoring period for Drag Line 2 Test 1. The line voltage spiked from a high of 463.90 V_{rms} to a low of 351.50 V_{rms} with surge events from 194.00 V_{pk} to -420.00 V_{pk}.

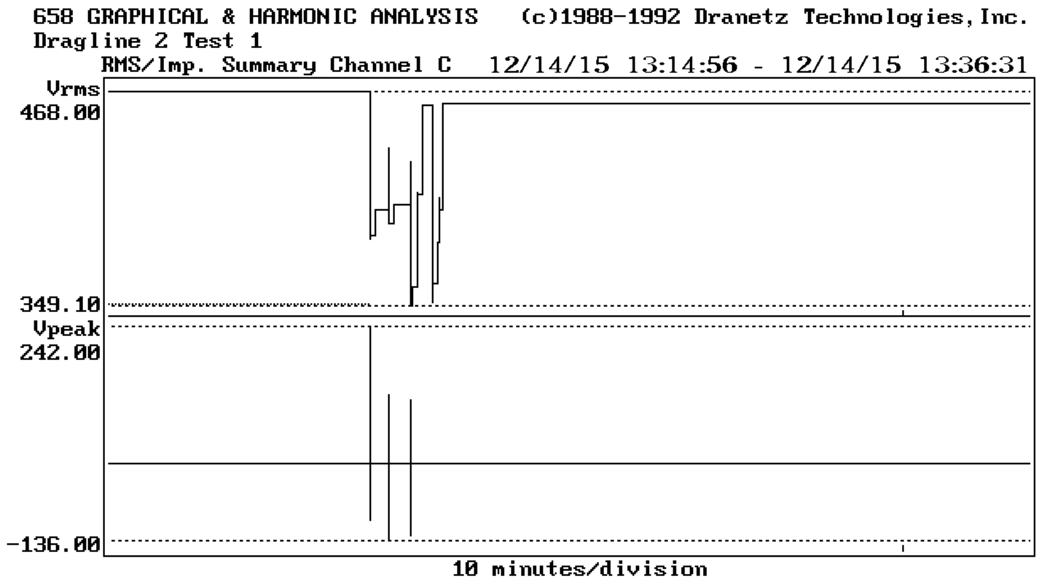


Chart 23

Summary of Phase C to Phase A voltage events during monitoring period for Drag Line 2 Test 1. The line voltage spiked from a high of 468.00 V_{rms} to a low of 349.10 V_{rms} with surge events from 242.00 V_{pk} to -136.00 V_{pk}.

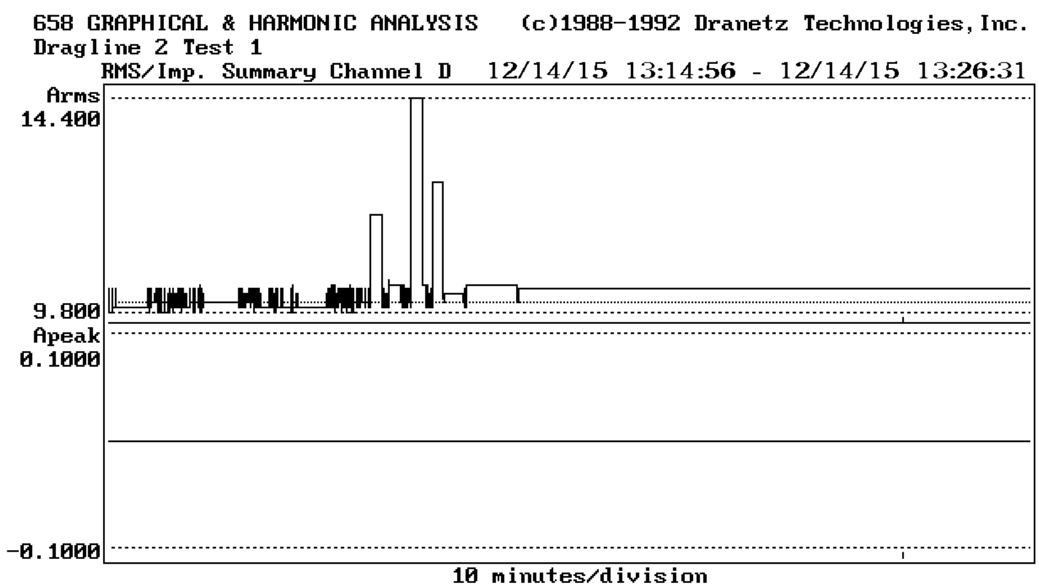


Chart 24

Summary of the Phase C current events during monitoring period for Drag Line 2 Test 1. The current ranged from a high of 14.400 A_{rms} to a low of 9.800 A_{rms}. There were no current surges observed.

The next four charts show the power during start-up of Drag Line 2 on event 805 at 13:18:13.42. This is the first of three start-up events that occurred as components within Drag Line 2 activated.

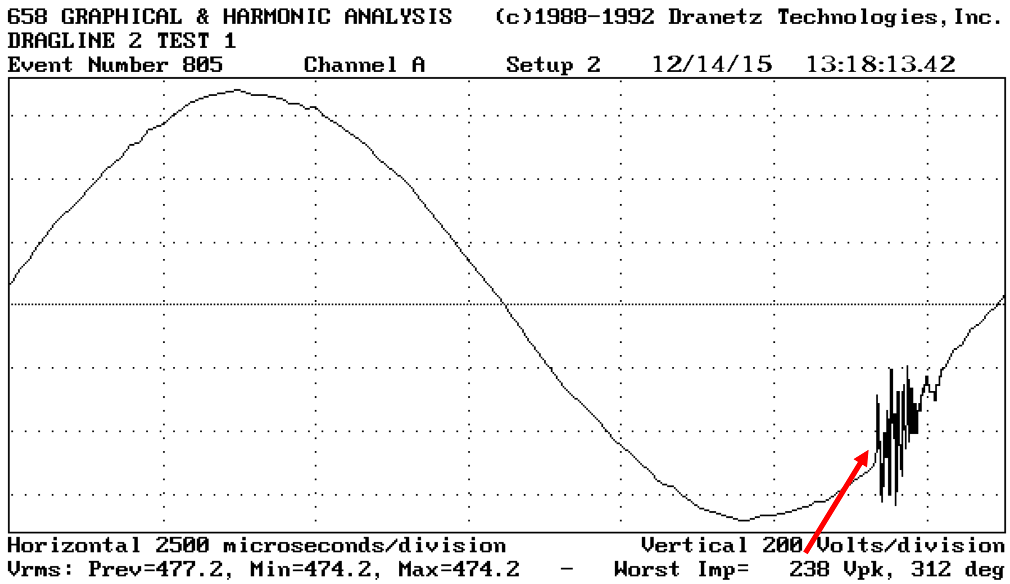


Chart 25

Chart 25 shows the 474.2 V_{rms} Phase A to Phase B voltage during the first start-up event, with up to 238 V_{pk} transient surge events.

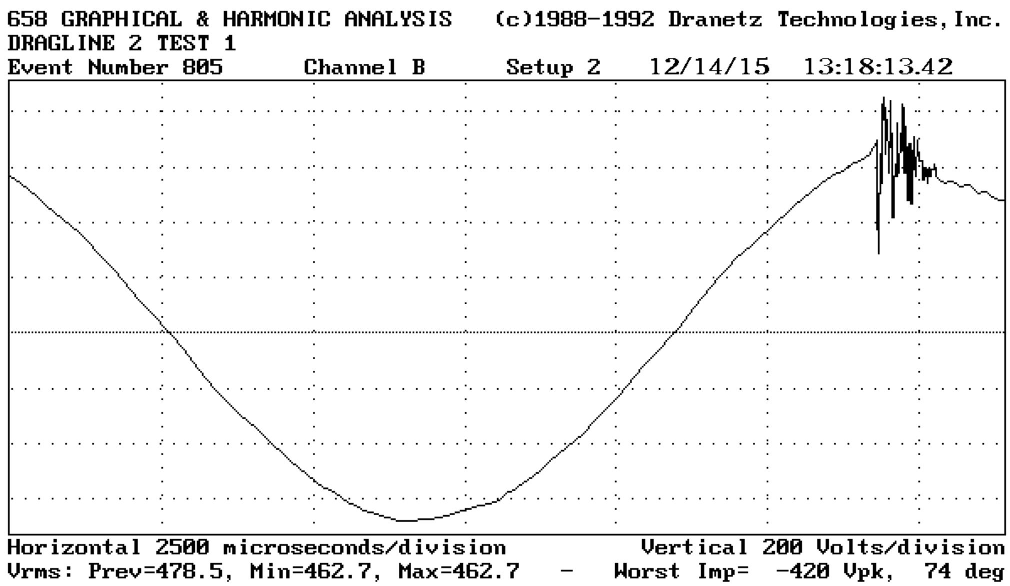


Chart 26

Chart 26 shows the 462.7 V_{rms} Phase B to Phase C voltage during the first start-up event, with up to -428 V_{pk} transient surge events.

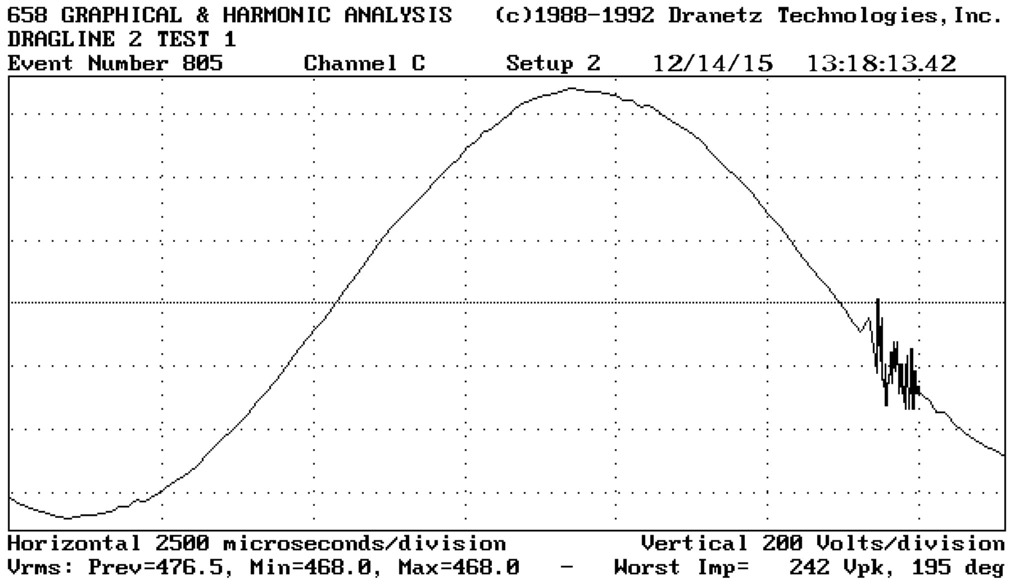


Chart 27

Chart 27 shows the 468.0 V_{rms} Phase C to Phase A voltage during the first start-up event, with up to 242 V_{pk} transient surge events.

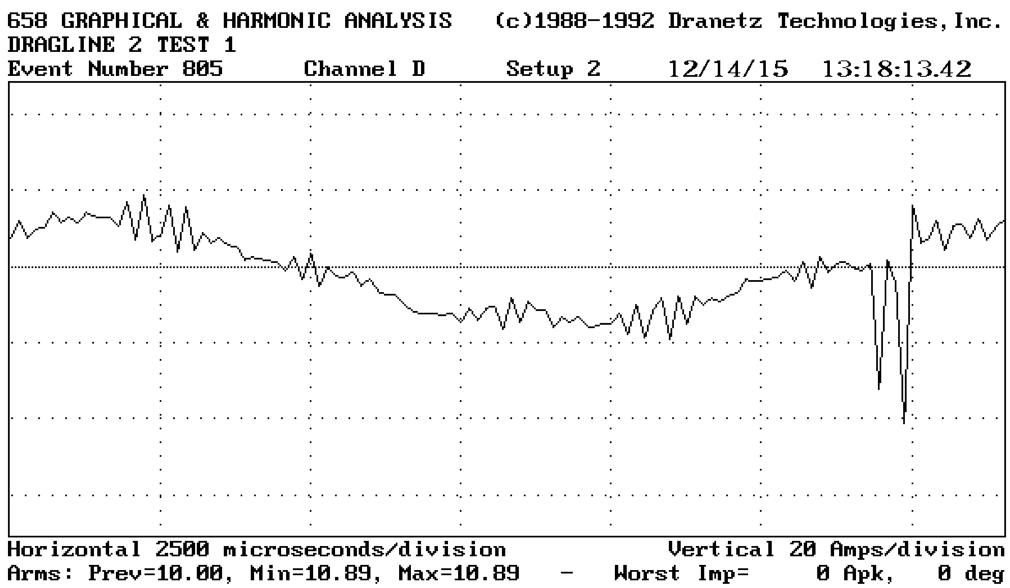


Chart 28

Chart 28 shows the 10.89 A_{rms} current on Phase C during the monitoring of the first start-up event. The smaller current pulses are normal for non-linear loads in that they draw current in pulses to convert the AC voltage to DC voltage within the VFDs and power supplies. The large, double current surge with an initial spike of over 35 A_{pk} and second spike with a return stroke of almost 60 A_{pk} are from the start of a process or component within the dragline start-up procedure.

A second surge occurred during the start-up procedure at 13:18:26.72, event 821, 13.30 seconds after the first start-up event. The next four charts show the power during start-up of Drag Line 2 for the second of three start-up events that occurred as components within Drag Line 2 activated.

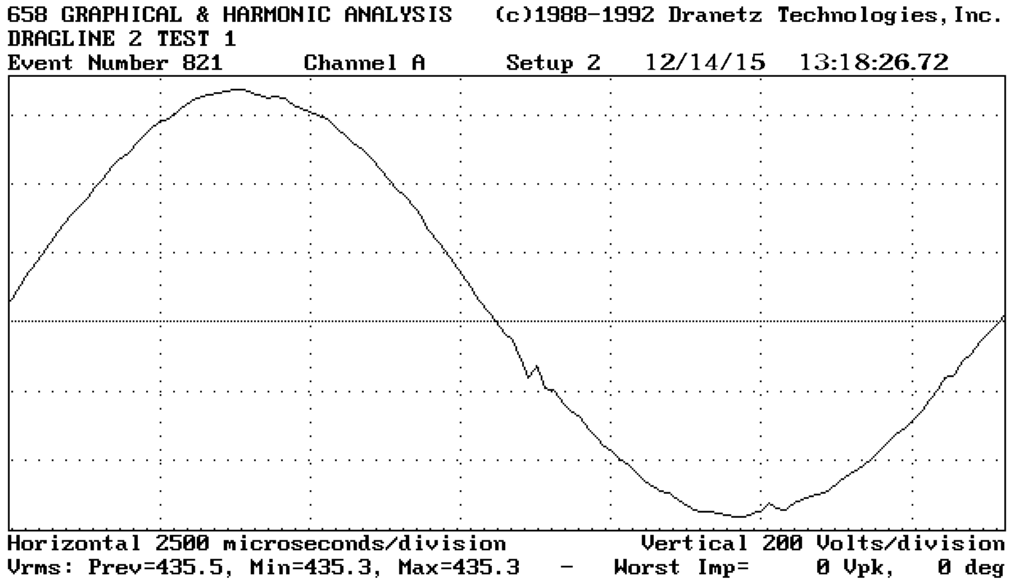


Chart 29

Chart 29 shows the 435.3 V_{rms} Phase A to Phase B voltage during the second start-up event, with a slight distortion, but no measureable transient surge events.

Chart 30

Chart 30 shows the 440.7 V_{rms} Phase B to Phase C voltage during the second start-up event, with up to 173 V_{pk} transient surge events.

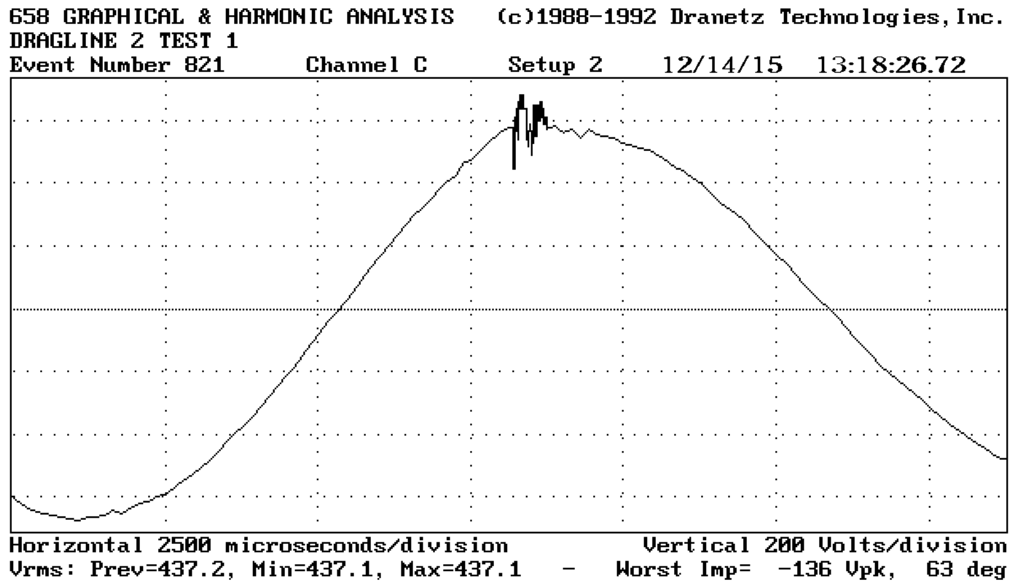


Chart 31

Chart 31 shows the 437.1 V_{rms} Phase C to Phase A voltage during the second start-up event, with up to -136 V_{pk} transient surge events.

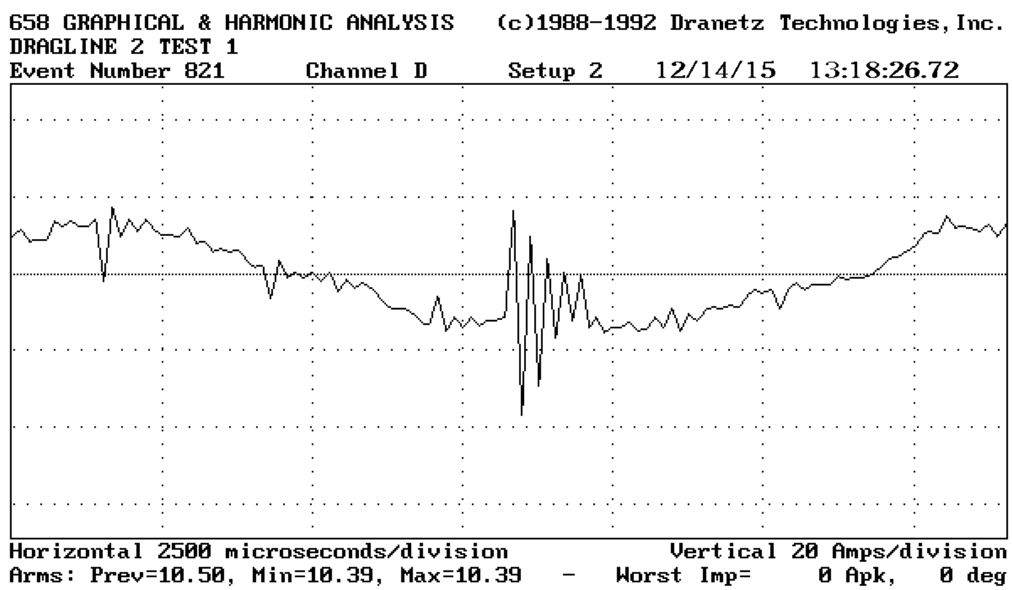


Chart 32

Chart 32 shows the 10.39 A_{rms} current on Phase C during the monitoring of the second start-up event. The large, multiple current surge with an initial spike of over 30 A_{pk} and second spike with a return stroke of almost 55 A_{pk} are from the start of a process or component within the dragline start-up procedure.

A third surge occurred during the start-up procedure at 13:18:44.17, event 863, 17.45 seconds after the second start-up event. The next four charts show the power during start-up of Drag Line 2 for the third of three start-up events that occurred as components within Drag Line 2 activated.

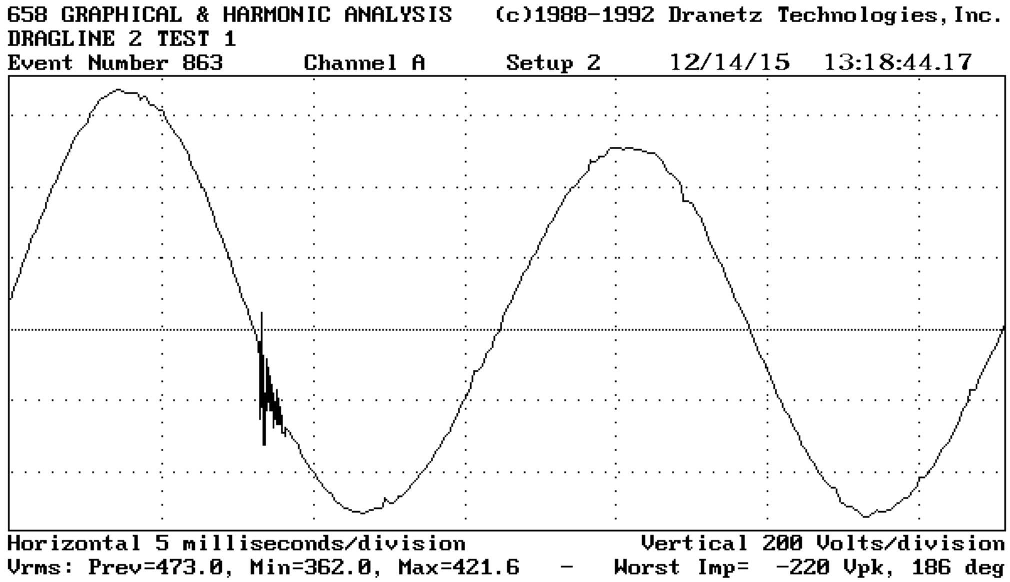


Chart 33

Chart 33 shows the Phase A to Phase B voltage drop from a high of 421.6 V_{rms} to a low of 362.8 V_{rms} during the third start-up event, with up to -220 V_{pk} transient surge events.

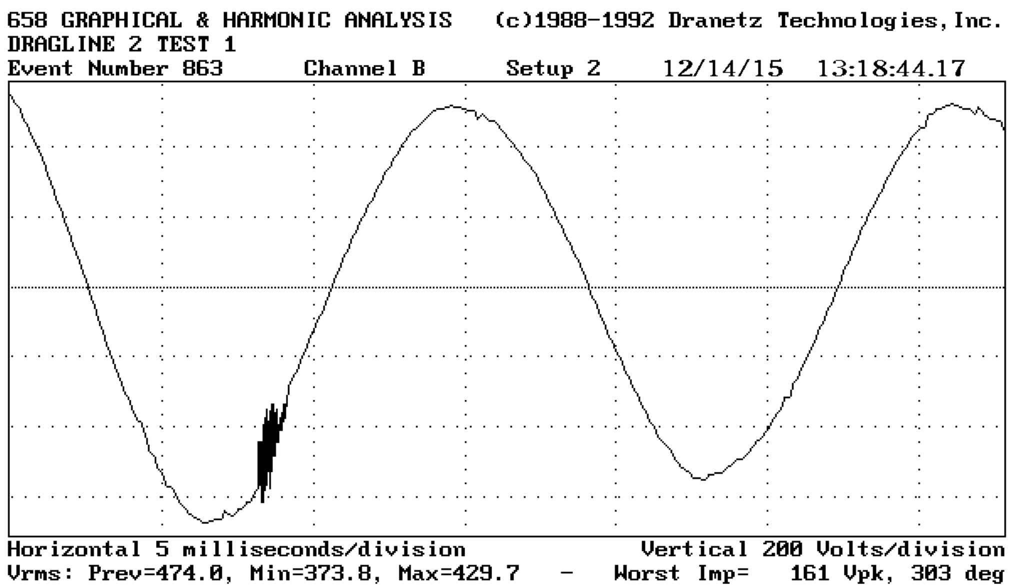


Chart 34

Chart 34 shows the Phase B to Phase C voltage drop from a high of 429.7 V_{rms} to a low of 373.8 V_{rms} during the third start-up event, with up to 161 V_{pk} transient surge events.

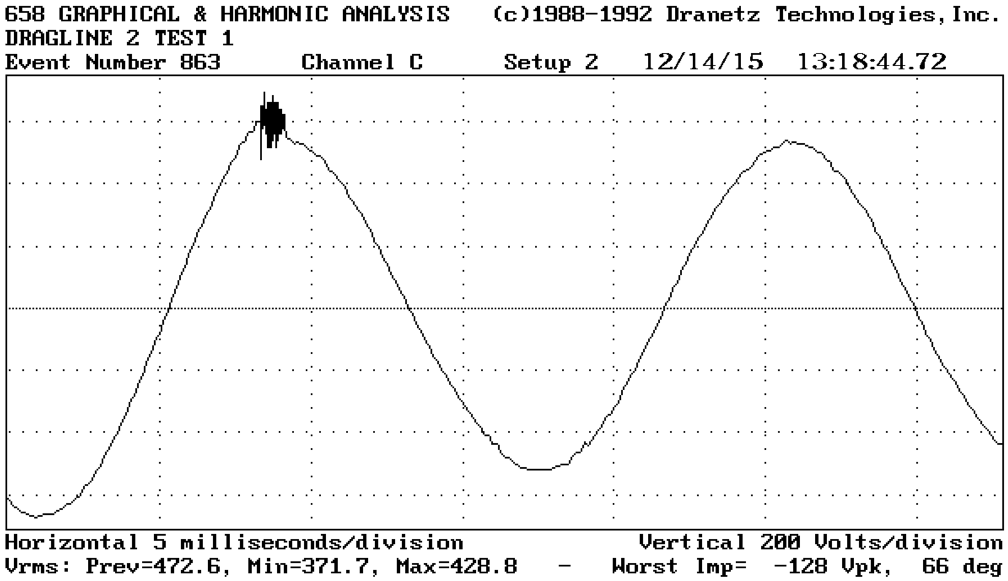


Chart 35

Chart 35 shows the Phase C to Phase A voltage drop from a high of 428.8 V_{rms} to a low of 371.7 V_{rms} during the third start-up event, with up to -128 V_{pk} transient surge events.

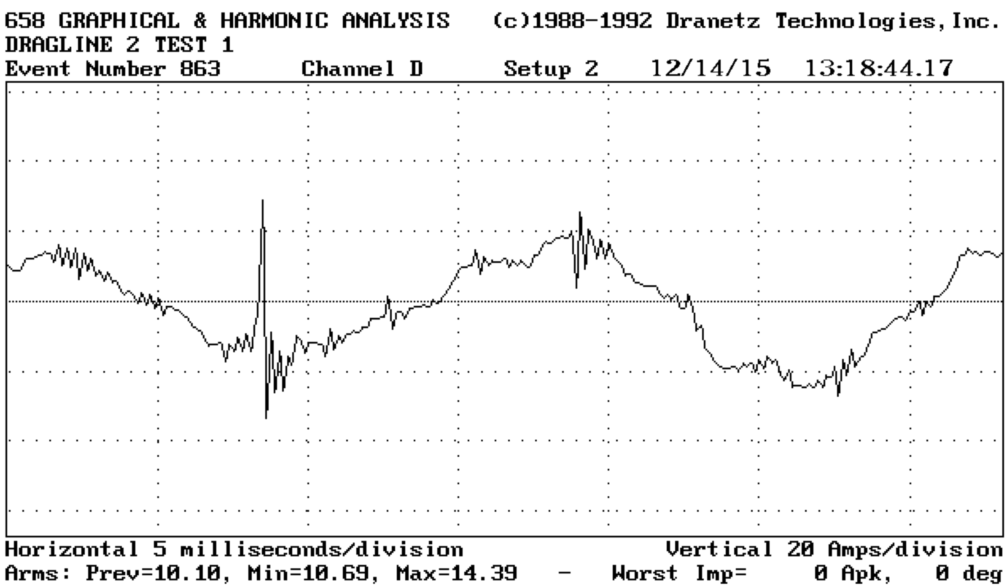


Chart 36

Chart 36 shows the 10.69 A_{rms} current on Phase C rising to 14.39 A_{rms} during the monitoring of the third start-up event. The large current surge with an initial spike of over 40 A_{pk} and second spike with a return stroke of over 60 A_{pk} are from the start of a process or component within the dragline start-up procedure. The increase in current, although relatively small, coincides with an almost 60 V_{rms} drop in voltage on all three phases.

The three start-up events are producing surge activity at the LED lighting panel. This surge activity, although not catastrophic, is excess, waste energy that has to go somewhere in the system to dissipate. This surge energy is on the LED lighting panel circuits, and is going to the power supplies and LED lights. It is much too short duration (less than 500 millionths of a second) and much too fast rise time (around .5 millionths of a second) for the power supplies or LEDs to use this energy properly. The energy meets resistance within the LED components and converts to heat. This repetitive surge activity will eventually create "hot spots" on the circuits and components of the LEDs, with the potential to lead to early failure.

The next four charts show the power during the commencement of drag operations at 13:26:30.30, on event 960. This event repeats continuously during the remainder of Test 1.

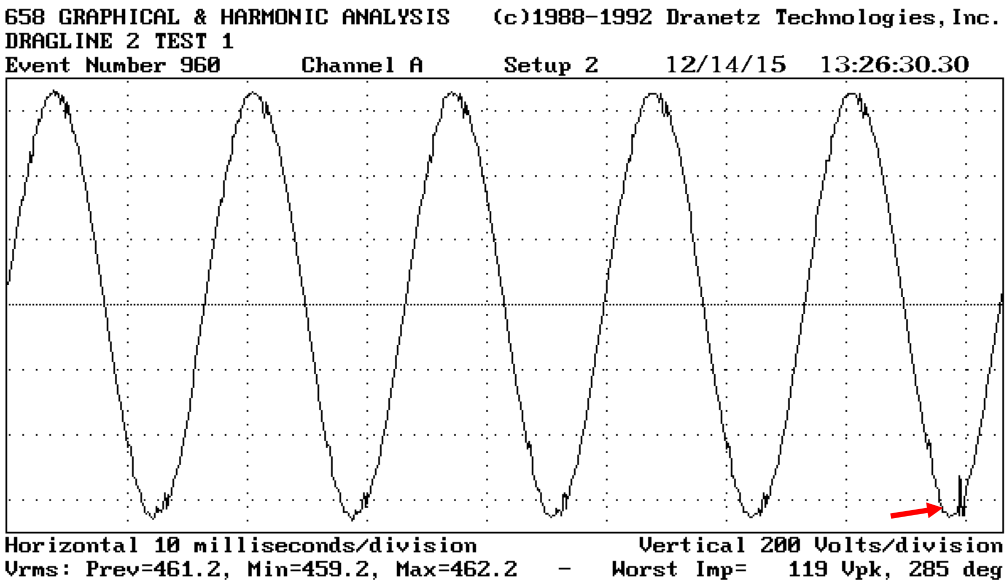


Chart 37

Chart 37 shows the Phase A to Phase B voltage ranging from 459.2 V_{rms} to 462.2 V_{rms} during the monitoring of the run, with transient surges up to 119 V_{pk} off the sine wave.

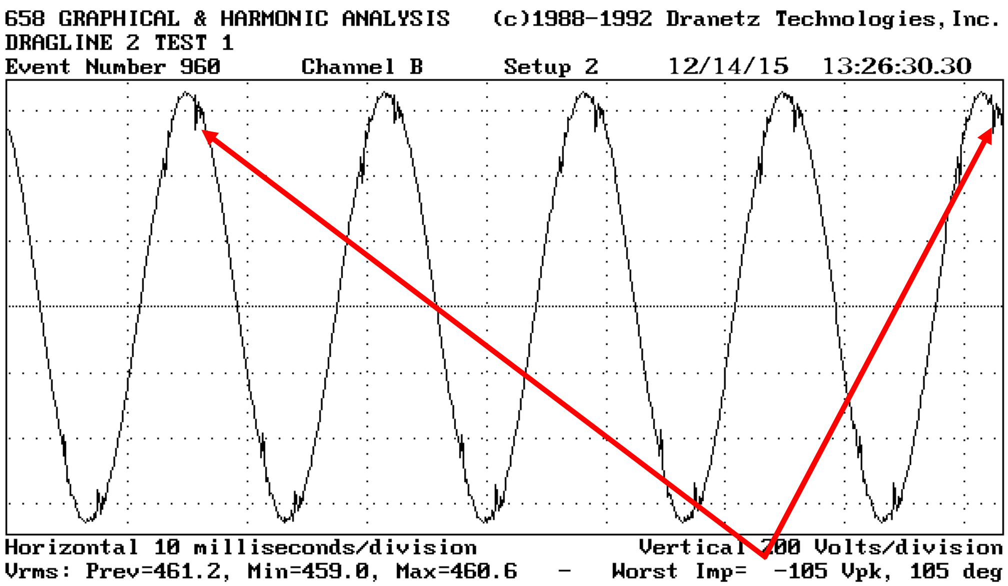
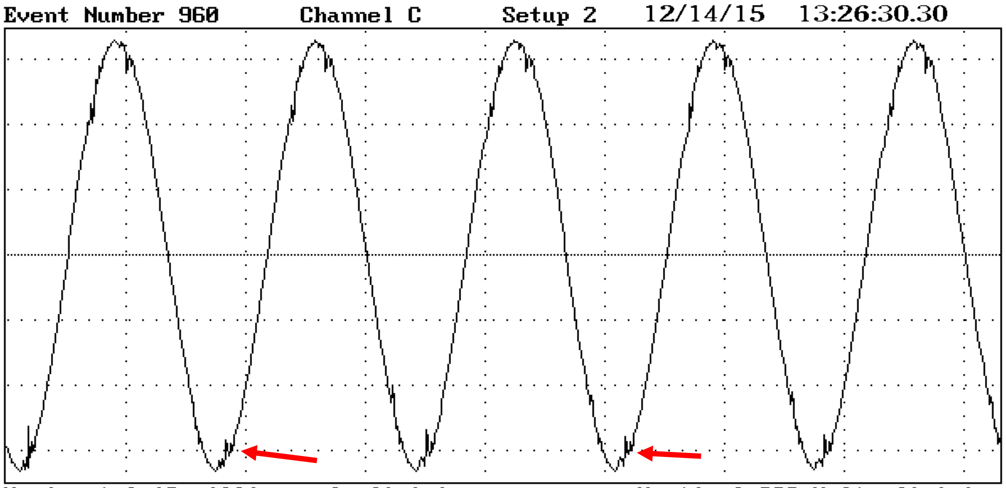


Chart 38

Chart 38 shows the Phase B to Phase C voltage ranging from 459.0 V_{rms} to 460.6 V_{rms} during the monitoring of the run, with transient surges up to -105 V_{pk} off the sine wave.

658 GRAPHICAL & HARMONIC ANALYSIS (c)1988-1992 Dranetz Technologies, Inc.
DRAGLINE 2 TEST 1
Event Number 960 Channel C Setup 2 12/14/15 13:26:30.30

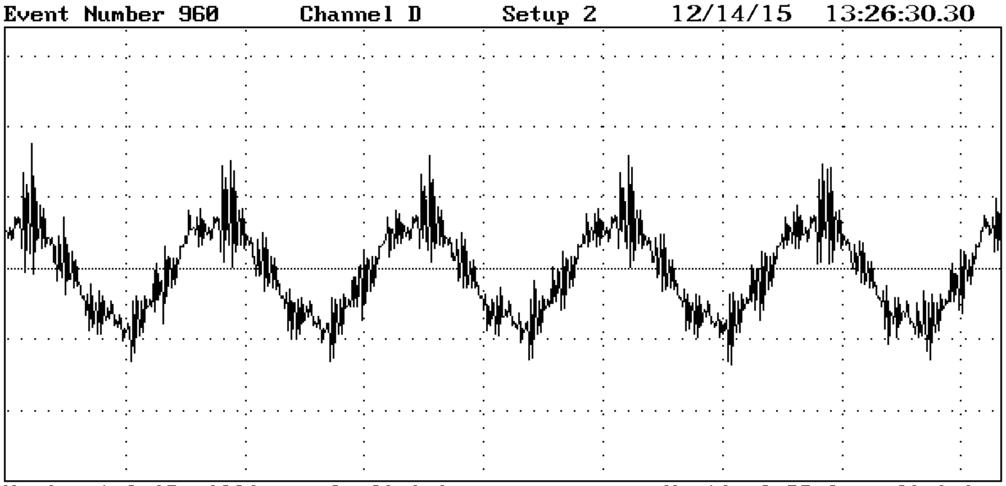


Horizontal 10 milliseconds/division Vertical 200 Volts/division
Vrms: Prev=459.5, Min=458.2, Max=459.2 - Worst Imp= 135 Vpk, 285 deg

Chart 39

Chart 39 shows the Phase C to Phase A voltage ranging from 458.2 V_{rms} to 459.2 V_{rms} during the monitoring of the run, with transient surges up to 135 V_{pk} off the sine wave.

658 GRAPHICAL & HARMONIC ANALYSIS (c)1988-1992 Dranetz Technologies, Inc.
DRAGLINE 2 TEST 1
Event Number 960 Channel D Setup 2 12/14/15 13:26:30.30



Horizontal 10 milliseconds/division Vertical 20 Amps/division
Arms: Prev=12.10, Min=11.69, Max=12.00 - Worst Imp= 0 Apk, 0 deg

Chart 40

Chart 40 shows the current on Phase C changing slightly from 11.69 A_{rms} to 12.00 A_{rms} during the monitoring of the run with no current spikes noted. The current pulses are normal for non-linear loads in that they draw current in pulses to convert the AC voltage to DC voltage within the multiple large motor drives on Drag Line 2. The six groups per cycle are representative of 6-pulse rectifier VFDs. The number of pulses per group are from the multiple drives controlling the various functions during the dragging operation. The one concern is the unusually large pulses at the same point on the positive side of the waveform. This could indicate a problem with a rectifier on one of the drives.

Test 2 on Drag Line 2 retained the same set-up for the Dranetz power quality analyzer and started with Drag Line 2 in full operation. Testing commenced at 13:39:36 and filled the memory of the Dranetz in twelve seconds, at 13:39:48.

The following charts show the summary of events during this monitoring period.

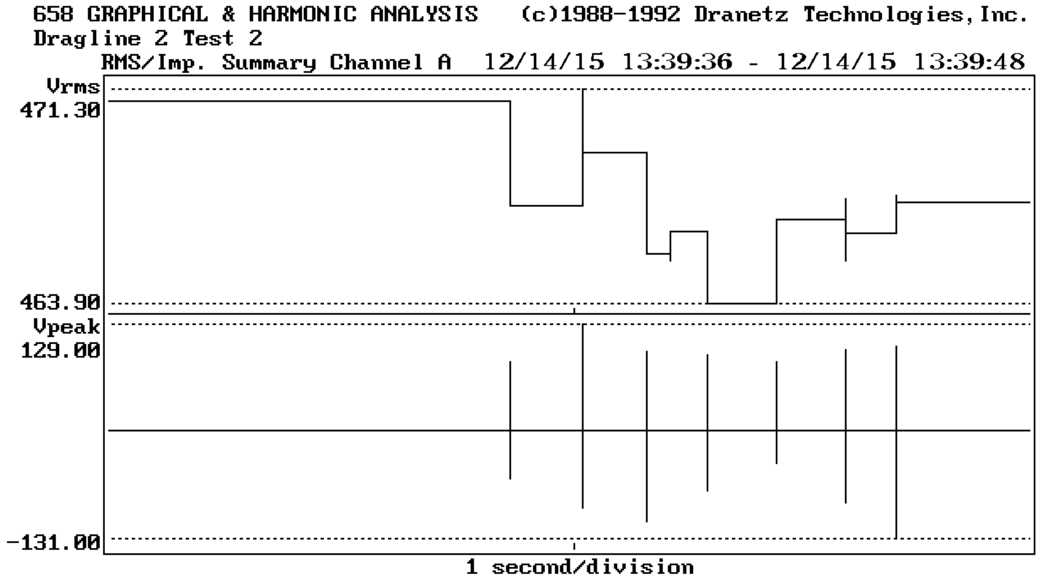


Chart 41

Summary of Phase A to Phase B voltage events during monitoring period for Drag Line 2 Test 2. The line voltage spiked from a high of 471.30 V_{rms} to a low of 463.90 V_{rms} with surge events from 129.00 V_{pk} to -131.00 V_{pk}.

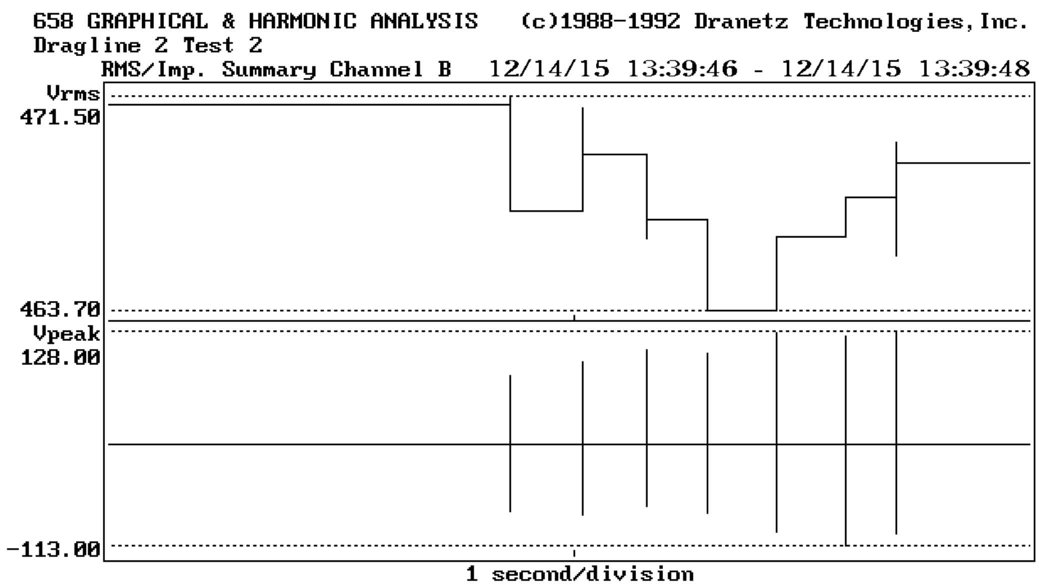


Chart 42

Summary of Phase B to Phase C voltage events during monitoring period for Drag Line 2 Test 2. The line voltage spiked from a high of 471.50 V_{rms} to a low of 463.70 V_{rms} with surge events from 128.00 V_{pk} to -113.00 V_{pk}.

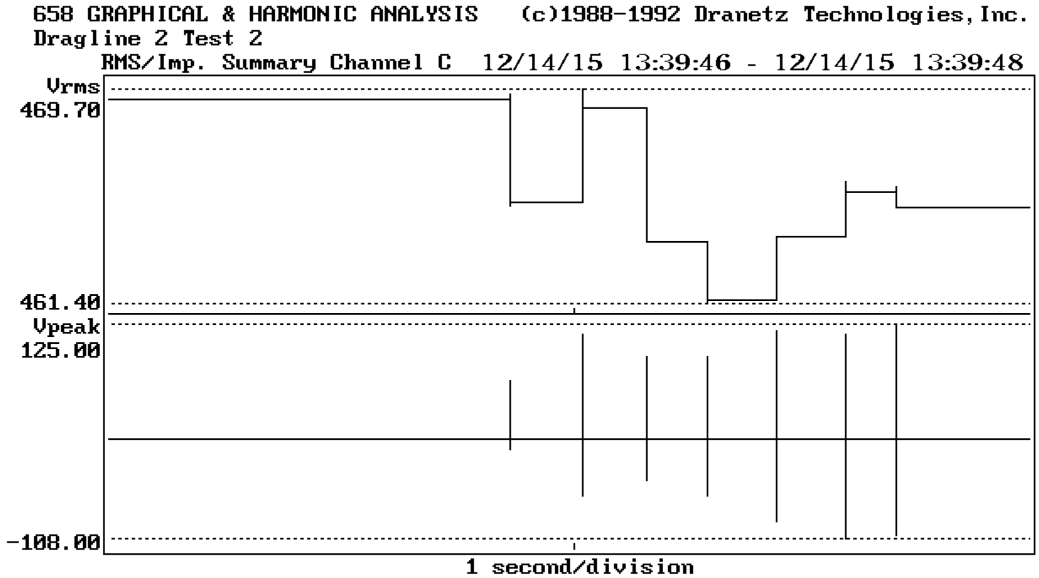


Chart 43

Summary of Phase C to Phase A voltage events during monitoring period for Drag Line 2 Test 2. The line voltage spiked from a high of 469.70 V_{rms} to a low of 461.40 V_{rms} with surge events from 125.00 V_{pk} to -108.00 V_{pk}.

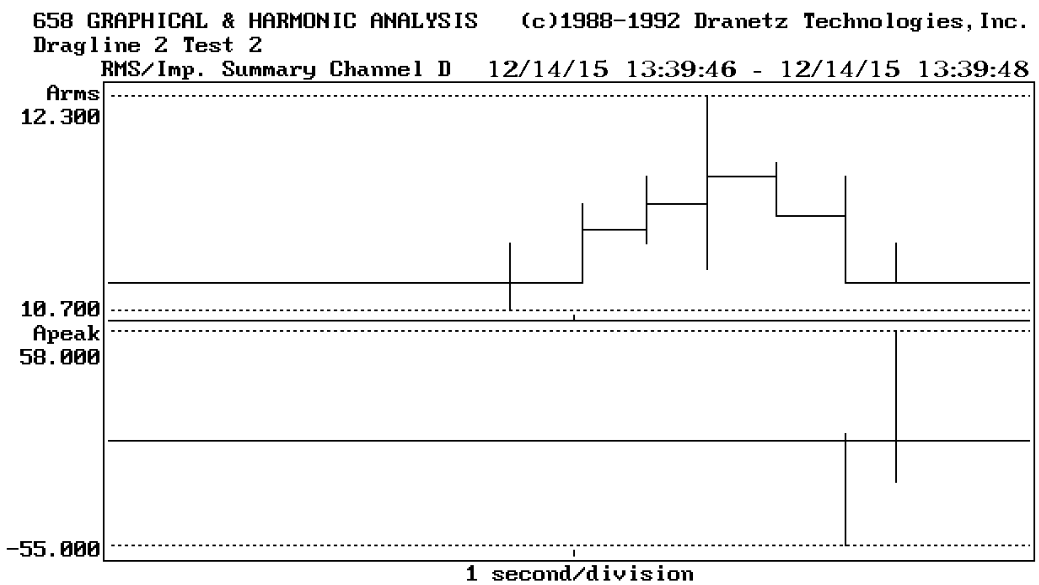


Chart 44

Summary of the Phase C current events during monitoring period for Drag Line 2 Test 2. The current ranged from a high of 12.300 A_{rms} to a low of 10.700 A_{rms}, with surge events from 58.00 A_{pk} to -55.00 A_{pk}.

The next ten charts show the power during Test 2 on Drag Line 2 for event 8 at 13:39:47.71, with a two-chart example of true harmonics from **XYZ Foods** power quality study.

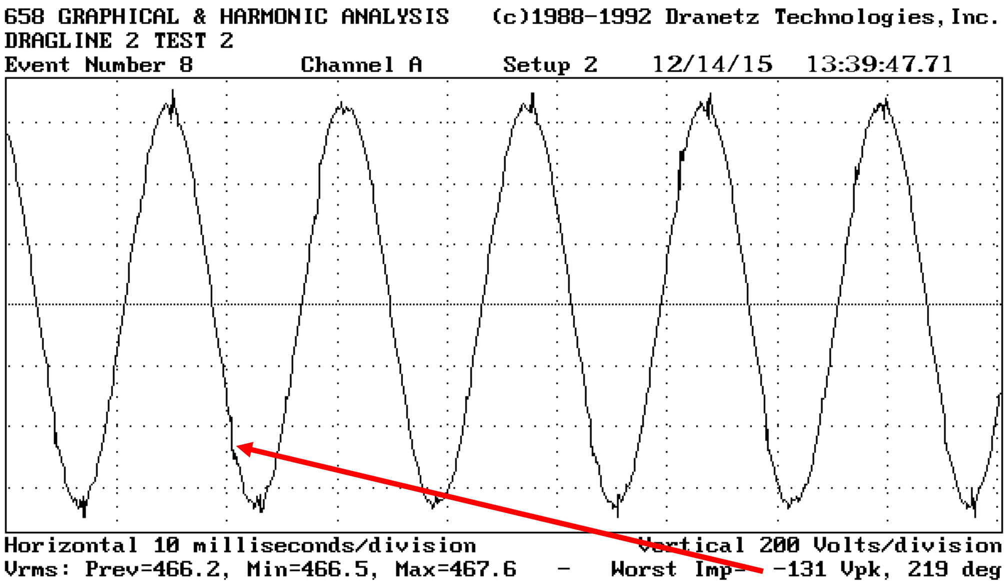


Chart 45

Chart 45 shows the Phase A to Phase B voltage with a low of 466.5 V_{rms} and a high of 467.6 V_{rms} during the event, with up to -131 V_{pk} transient surge events.

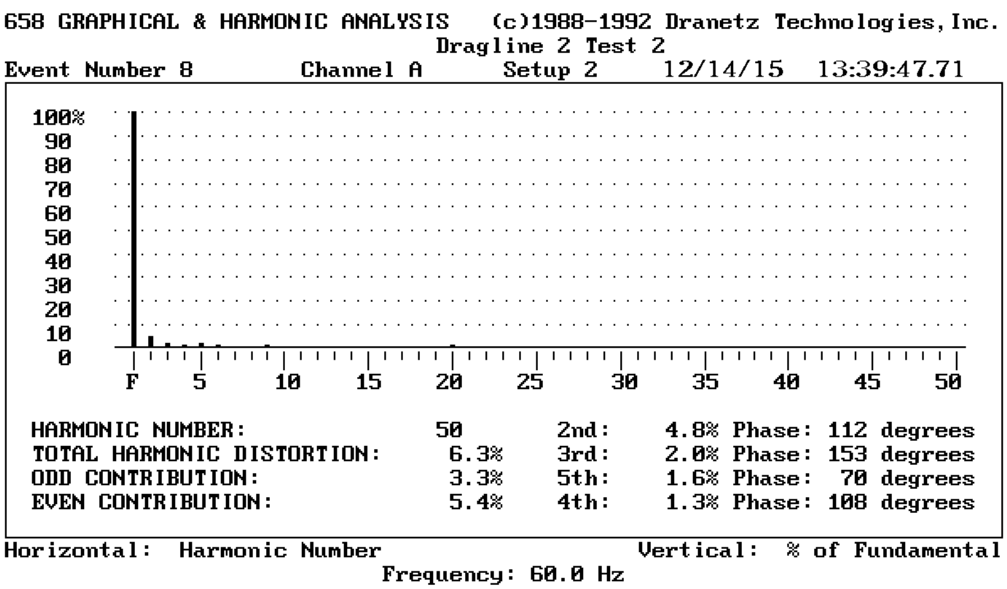


Chart 46

Chart 46 shows the harmonic content for the waveform on Chart 45. The Total Harmonic Distortion (THD) is 6.3%, and the highest individual harmonic distortion is for the 2^{nd} Harmonic at 4.8%. These are both slightly above the maximum allowable levels of 5% THD and 3% individual harmonic distortion under IEEE Standard 519-1992.

It is important to differentiate between true harmonics and transient generated distortion. True harmonic distortion is more of a general, overall distortion of the waveform. The sharp, individual spikes on the relatively sinusoidal waveforms shown in Chart 45 are characteristic of transient distortion. Harmonic filters will not remove the transients shown on Chart 45.

This transient distortion appears to be coming from the operation of the six-pulse rectifier on the large motor VFDs.

True harmonic distortion would give the voltage waveform a significantly more distorted appearance, such as this chart from a study at XYZ Foods :

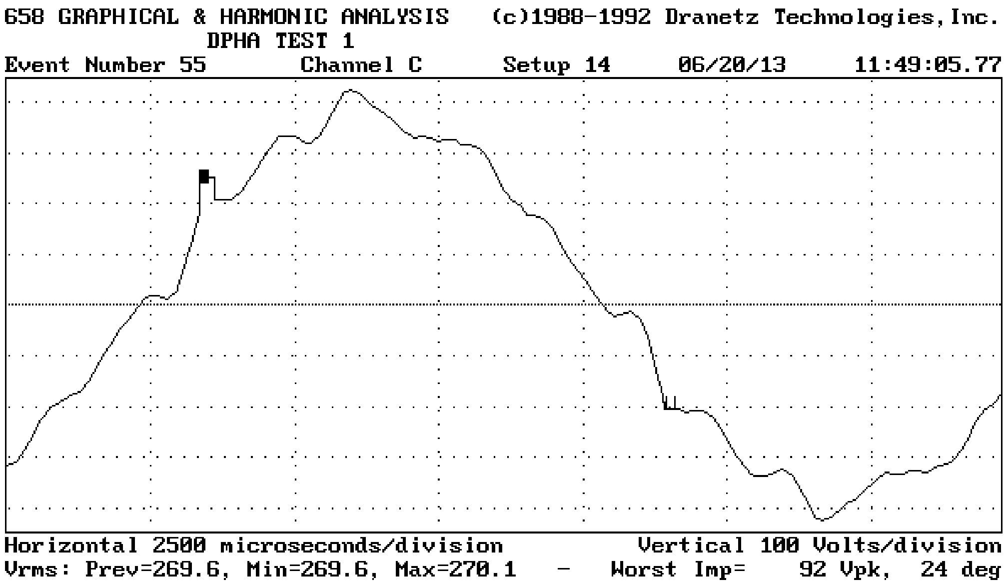


Chart 47

Chart 47 shows the Phase C to Neutral voltage only varies from a low of 269.6 V_{rms} to a high of 270.1 V_{rms}, a difference of 0.5 V_{rms}. The limited surge activity, occurring at the same location on the positive and negative portions of the waveform are up to 92 V_{pk}. The distortions are smooth, not spiked as with surges.

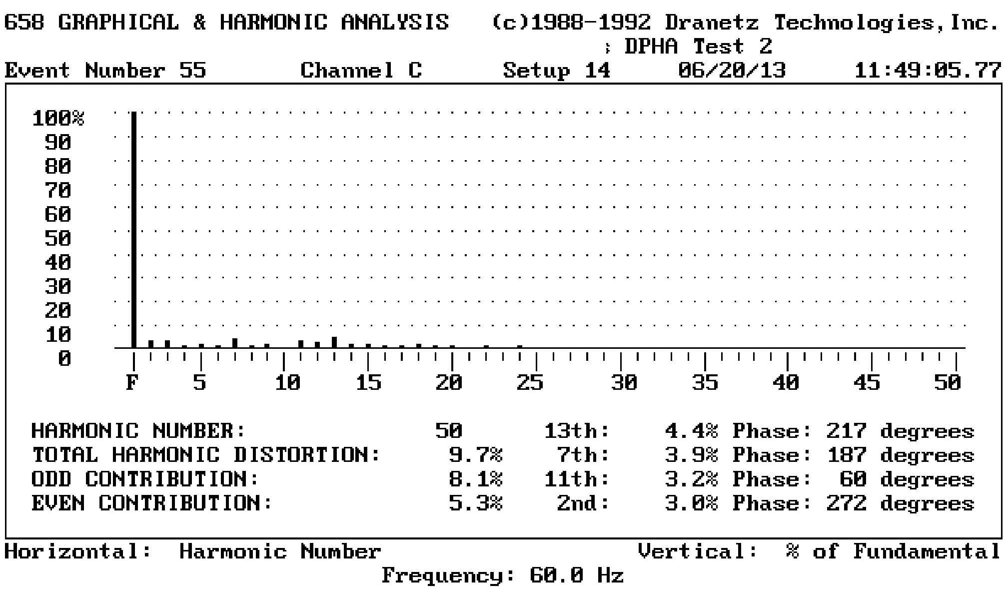


Chart 48

Chart 48 shows the harmonic content for the waveform on Chart 47 from XYZ Foods. The Total Harmonic Distortion (THD) is 9.7%, and the highest individual harmonic distortion is for the 13th Harmonic at 4.4%. These are both slightly above the maximum allowable levels of 5% THD and 3% individual harmonic distortion under IEEE Standard 519-1992. Although the harmonic levels are similar, notice the significant difference between the two waveforms. The Sun Gold Foods chart 47 distortion is from harmonics. The Drag Line 2 chart 45 distortion is from surges.

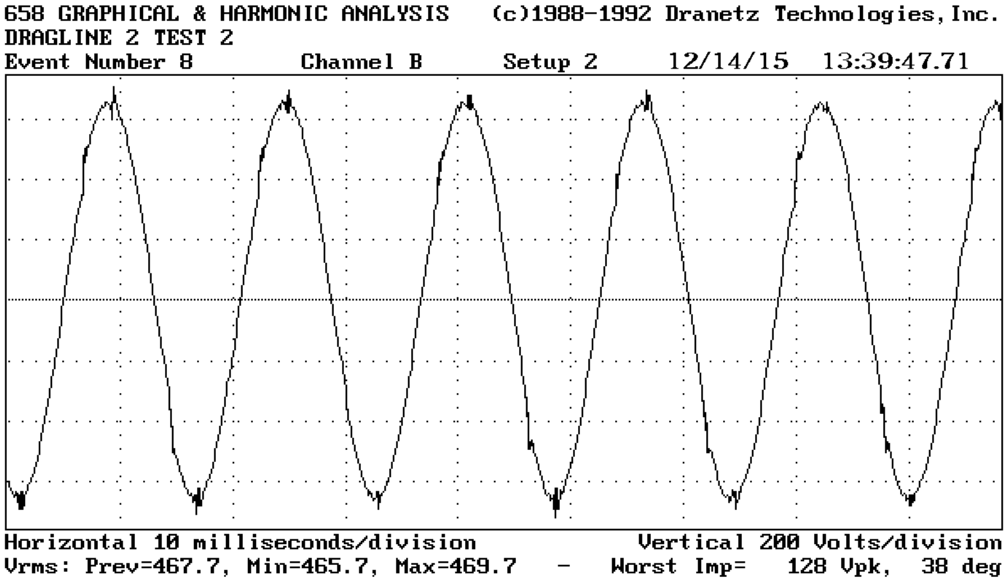


Chart 49

Chart 49 shows the Phase B to Phase C voltage with a low of 465.7 V_{rms} and a high of 469.7 V_{rms} during the event, with up to 128 V_{pk} transient surge events.

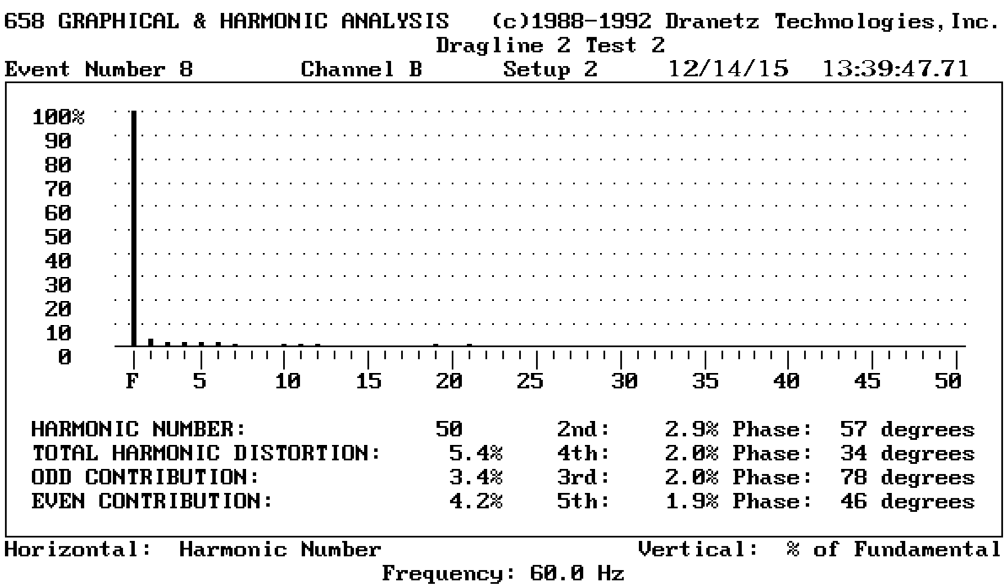


Chart 50

Chart 50 shows the harmonic content for the waveform on Chart 49. The Total Harmonic Distortion (THD) is 5.4%, and the highest individual harmonic distortion is for the 2^{nd} Harmonic at 2.9%. These are both slightly above the maximum allowable levels of 5% THD and 3% individual harmonic distortion under IEEE Standard 519-1992.

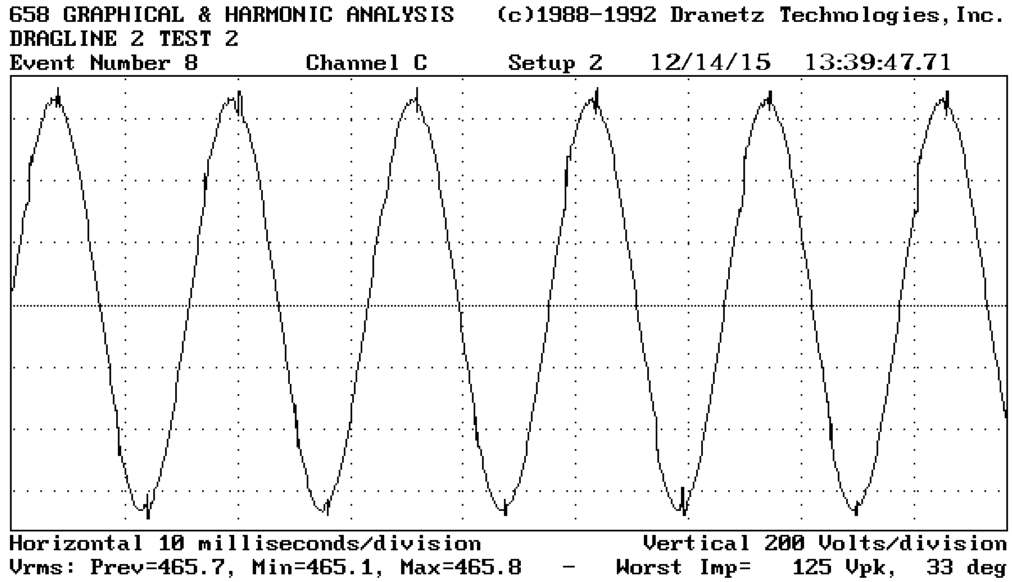


Chart 51

Chart 51 shows the Phase C to Phase A voltage with a low of 465.1 V_{rms} and a high of 465.8 V_{rms} during the event, with up to 125 V_{pk} transient surge events.

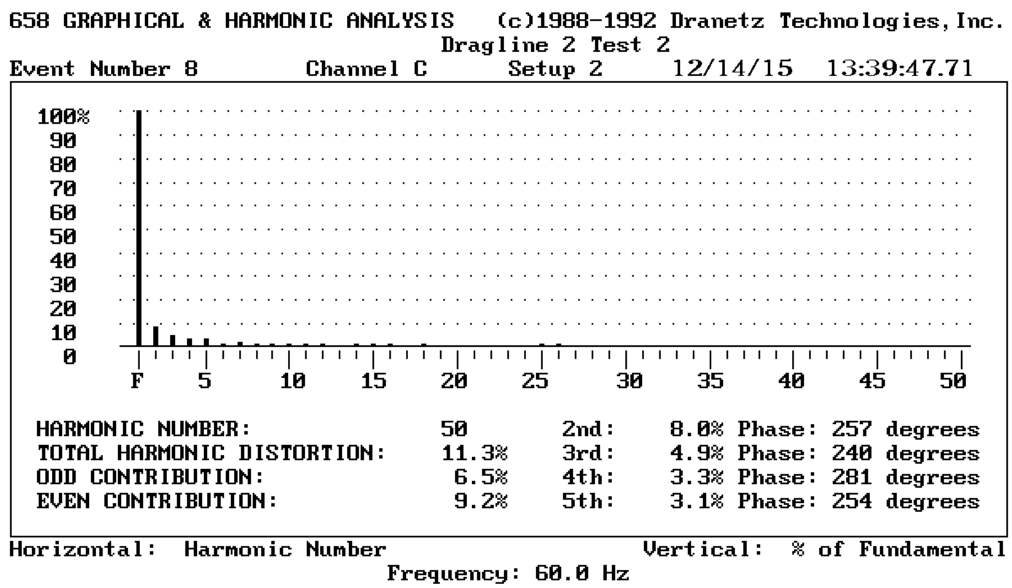


Chart 52

Chart 52 shows the harmonic content for the waveform on Chart 51. The Total Harmonic Distortion (THD) is 11.3%, and the highest individual harmonic distortion is for the 2nd Harmonic at 8.0%. These are both slightly above the maximum allowable levels of 5% THD and 3% individual harmonic distortion under IEEE Standard 519-1992.

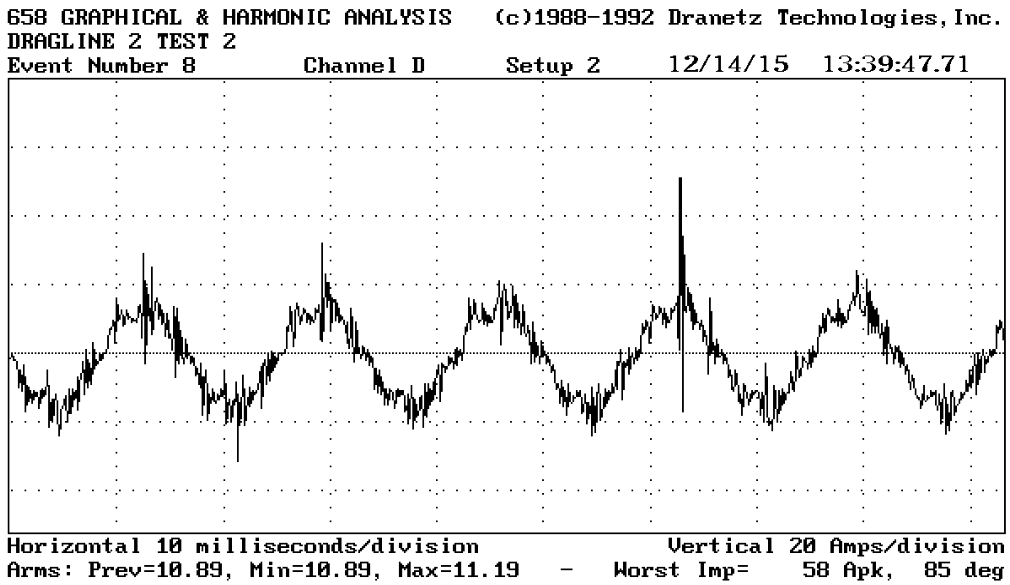


Chart 53

Chart 53 shows the current on Phase C changing slightly from 10.89 A_{rms} to 11.19 A_{rms} during the monitoring of the run with current spikes up to 58 A_{pk}. The smaller current pulses are normal for non-linear loads in that they draw current in pulses to convert the AC voltage to DC voltage within the VFDs and power supplies. The large, double current surge with an initial spike of over 35 A_{pk} and second spike with a return stroke of almost 60 A_{pk} are from the start of a process or component within the dragline start-up procedure. As mentioned previously, there does appear to be an uncharacteristically large pulse at the same point on the positive waveform. Because the current does not increase appreciably and the voltage does not drop, it would appear this large pulse is not associated with the start-up of a large motor drive. This is further reason to check the drive rectifier to make sure a problem is not developing toward a failure.

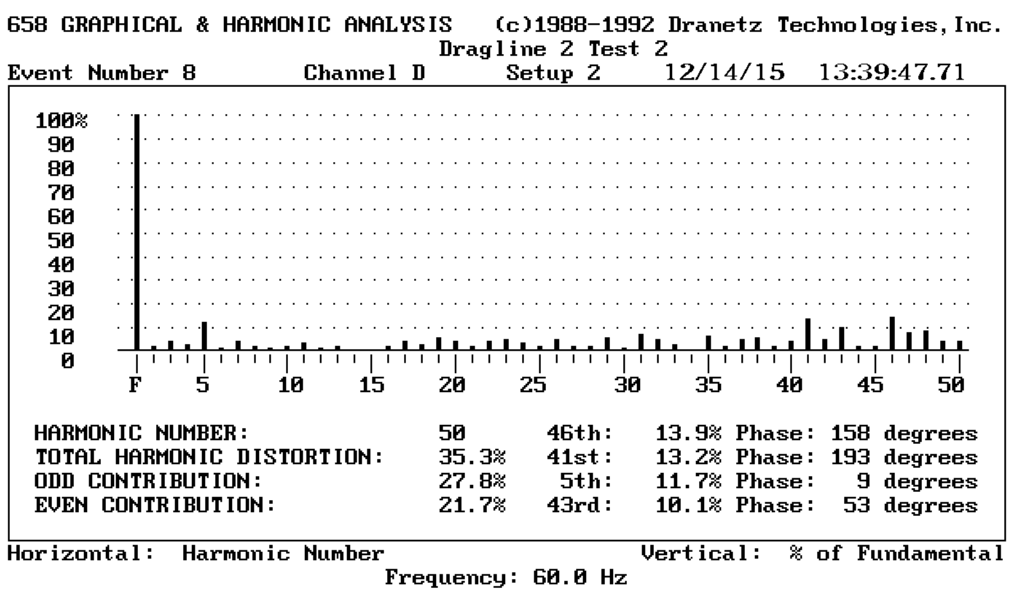


Chart 54

Chart 54 shows the harmonic content for Chart 53. The THD is 35.3% and the highest individual harmonic distortion is for the 46^{th} harmonic at 13.9%. The power supplies for the LEDs can be contributing to this level of harmonic distortion. Although these levels are above the allowable limits, they are common for non-linear loads and many electronic devices can operate with these levels of current distortion with no ill effects. If these levels exceed acceptable limits for the operation of the LEDs, a current harmonic filter may be necessary.

Drag Line 1 testing was on Tuesday, December 15, 2015. The electrical technicians who were assisting us with the testing transported the Dranetz power quality analyzer in its travel case from Drag Line 2 to the office on Monday afternoon and then out to Drag Line 1 on Tuesday morning. Due to rough roads, the case bounced around the bed of the pickup truck transporting the equipment and ourselves to and from the test sites. Apparently, the bouncing was severe enough to damage the Dranetz during the transfer from Drag Line 2 to Drag Line 1. At start-up, the Dranetz failed its internal diagnostic test, and would not open the analysis package. We were unable to test Drag Line 1. According to the electrical technicians on site, Drag Line 1 is identical to Drag Line 2, with the exception of only a partial conversion to the newer LED lighting.

RECOMMENDATIONS:

1. Both Drag Line 70 and Drag Line 2 exhibited surge activity at the LED lighting panels. There is no reliable surge protection at these panels with the ability to remove the impulse and ring wave surges present. The repetitive nature of the surges from the VFDs and other electronic sources within both Drag Lines would result in cumulative damage over time to the power supplies and LED lights themselves. Because of the harsh nature of the electrical environment, and the potential for lightning activity from storms at the mine site, we would normally recommend a tiered coverage of Surge Protective Devices (SPDs) at the service entrance, distribution panels and the LED lighting panel. Since we are only working with the LED lighting panel, we would recommend a more robust SPD at that location because it will be the only SPD and not part of a coordinated system.

   Drag Line 70, Drag Line 2, and, by reference, Drag Line 1 should have a CDLB3N4-D3, 480 V_{rms}, 3 Phase, 3 Wire, Delta, 60 kA per mode SPD with NEMA 4X enclosure and rotary disconnect installed on each LED lighting panel.

2. Verify that the level of harmonics on the current waveform are within tolerance for the LED lighting. The voltage "harmonic" levels are actually surge induced and would not be attenuated by a harmonic filter. If the current harmonics levels are beyond tolerance for the LED lighting, contact a harmonic specialist for the proper tuned harmonic filter for the specific harmonic problem.

3. The abnormally large current pulses at the top of the current waveform on Drag Line 2, along with the occasional spike several times the normal amplitude, may indicate a developing problem with some equipment within Drag Line 2. A likely source could be a rectifier within one of the VFDs. A technician should check this.