Power Quality Issues in Grid Connected Wind Farms

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Power Quality Problem?

- Can be defined as:
  - "Any problem in electric power system manifested in

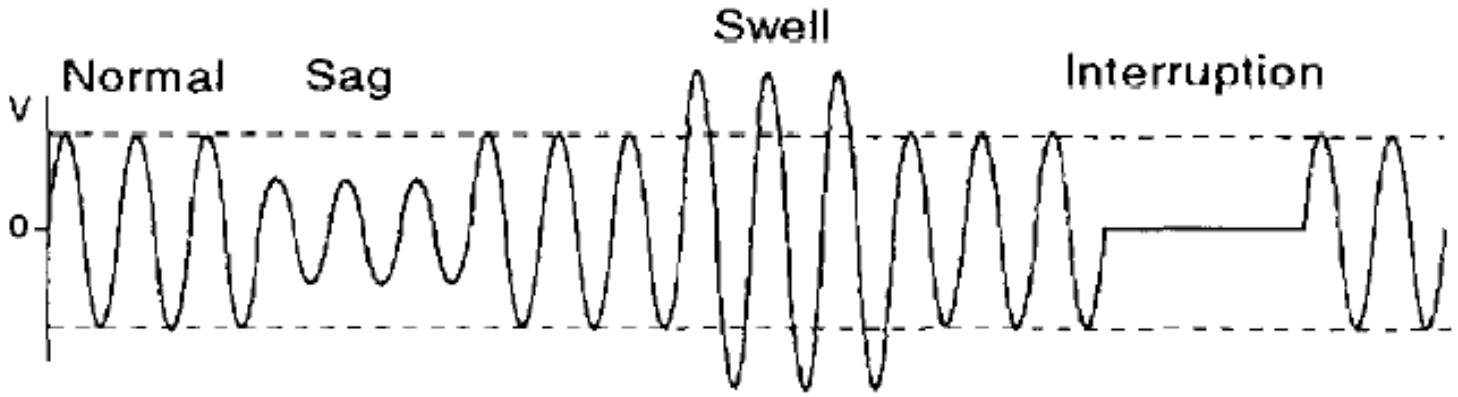
    voltage, current or frequency deviations

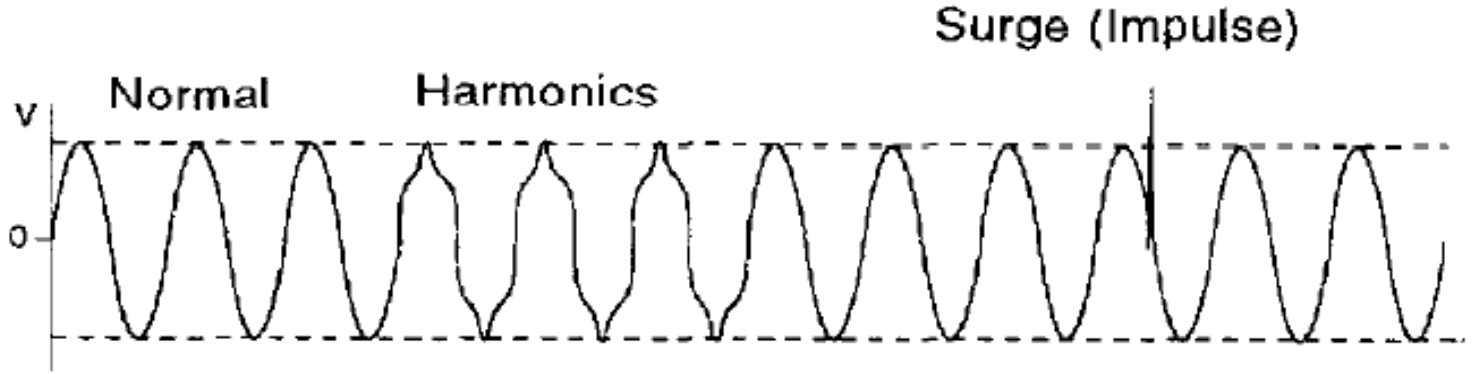
    that results in unsatisfactory operation or failure of electrical equipments"

Quality Power Supply?

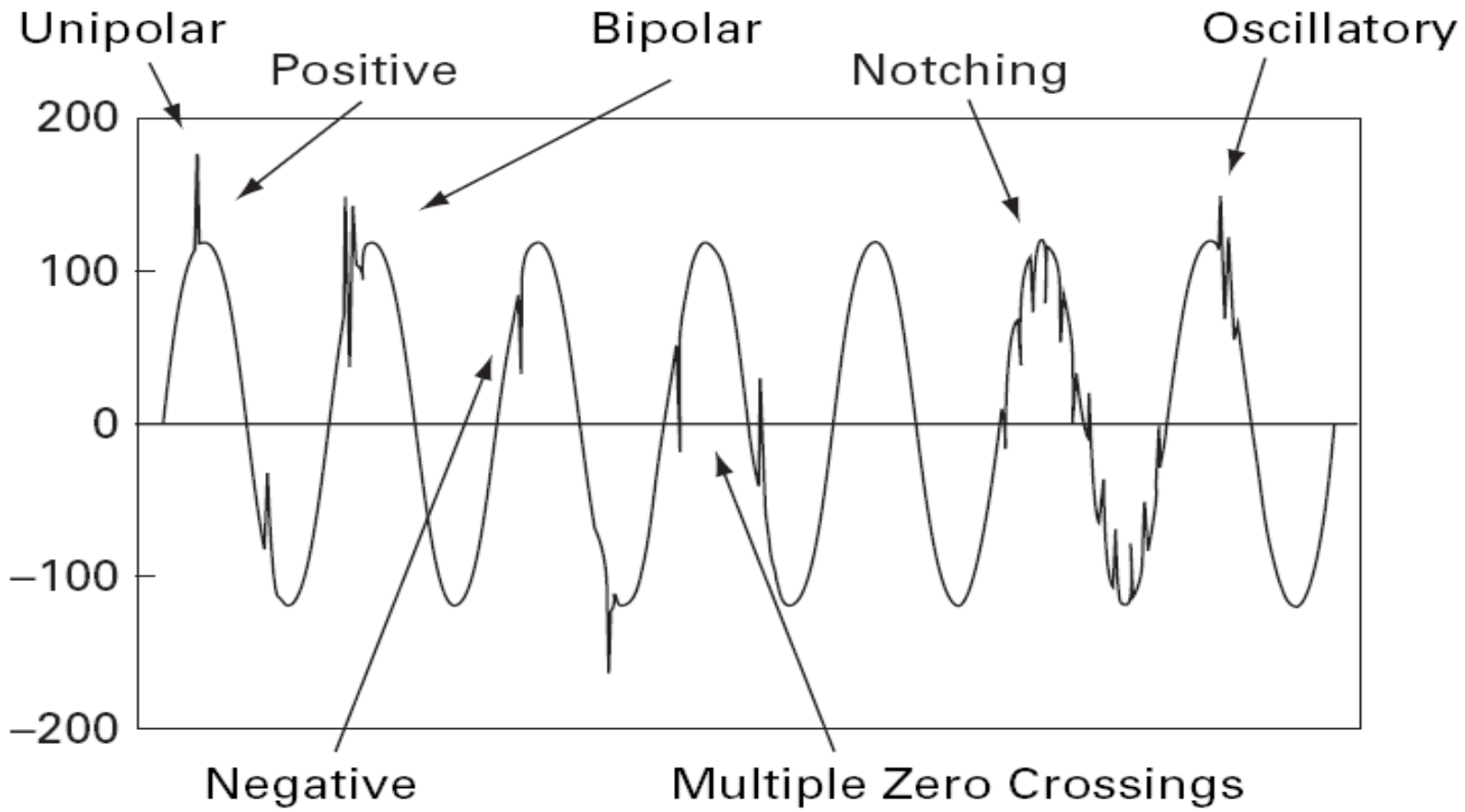
- Refers to:
  - "Uninterrupted supply of power with **sinusoidal** voltage and current waveform
  - at acceptable frequency and voltage magnitude."

Problems with sinusoidal supply





Transients


Unipolar
Positive
Bipolar
Notching
Oscillatory
200
100
0
–100
–200
Negative
Multiple Zero Crossings

Power Quality (PQ) problems- classic definitions

Impulses/Transient: High magnitude for extremely short duration.

Sag: A momentary voltage dip last for a few seconds.

Swell: A momentary voltage rise which last for a few seconds

Over Voltage: A steady state voltage rise last for SEVERAL seconds

Under Voltage: A steady state voltage dip last for SEVERAL seconds

Interruption: A complete loss of voltage for a few seconds to several hours

Flicker: A perceptible change in lamp output due to a sudden change in voltage

Harmonics: The non-fundamental frequency components of a distorted power frequency waveform.

Implication of Poor PQ

- ~~Increased currents & losses in the system~~
- Lower Energy Efficiency
- Blocked capacity
- Additional heating and lower reliability/ life
- Failure of equipment
- Mal-function of equipment
- Poor operational efficiency
- Poor quality of products manufactured

Some typical PQ disturbances

Voltage sags

Major causes: faults, starting of large loads, and

Major consequences: accelerated aging, loss of data or stability, process interrupt, etc.

Capacitor switching transients

Major causes: a power factor correction method

Major consequences: insulation breakdown or sparkover, semiconductor device damage, accelerated aging, loss of data or stability

Harmonics

Major causes: power electronic equipment, arcing, transformer saturation

Major consequences: equipment overheating, high voltage/current, protective device operations

Lightning transients

Major causes: lightning strikes

Major consequences: insulation breakdown or sparkover, semiconductor device damage, accelerated aging, loss of data or stability

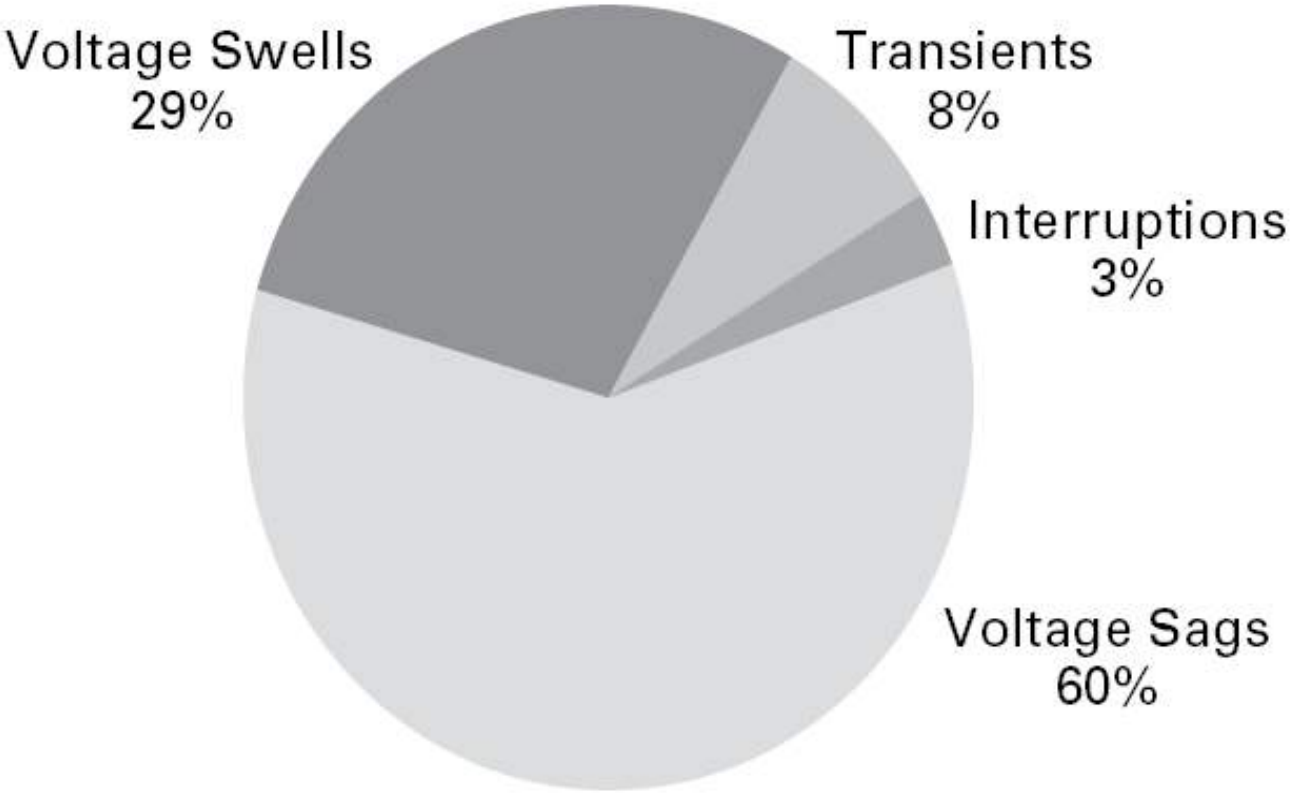
High impedance faults

(One of the most difficult power system protection problems)

Major causes: fallen conductors, trees (fail to establish a permanent return path)

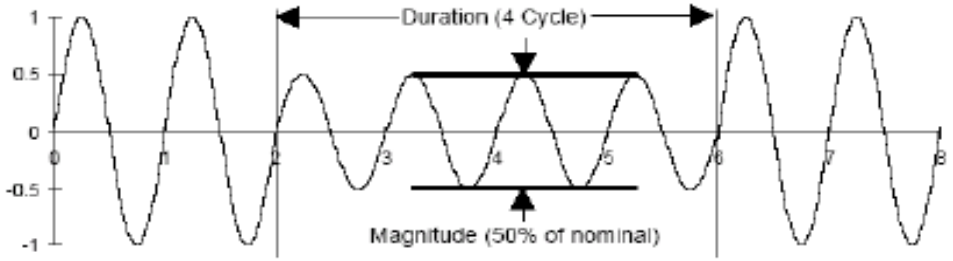
Major consequences: fire, threats to personal safety

Power Quality Issues

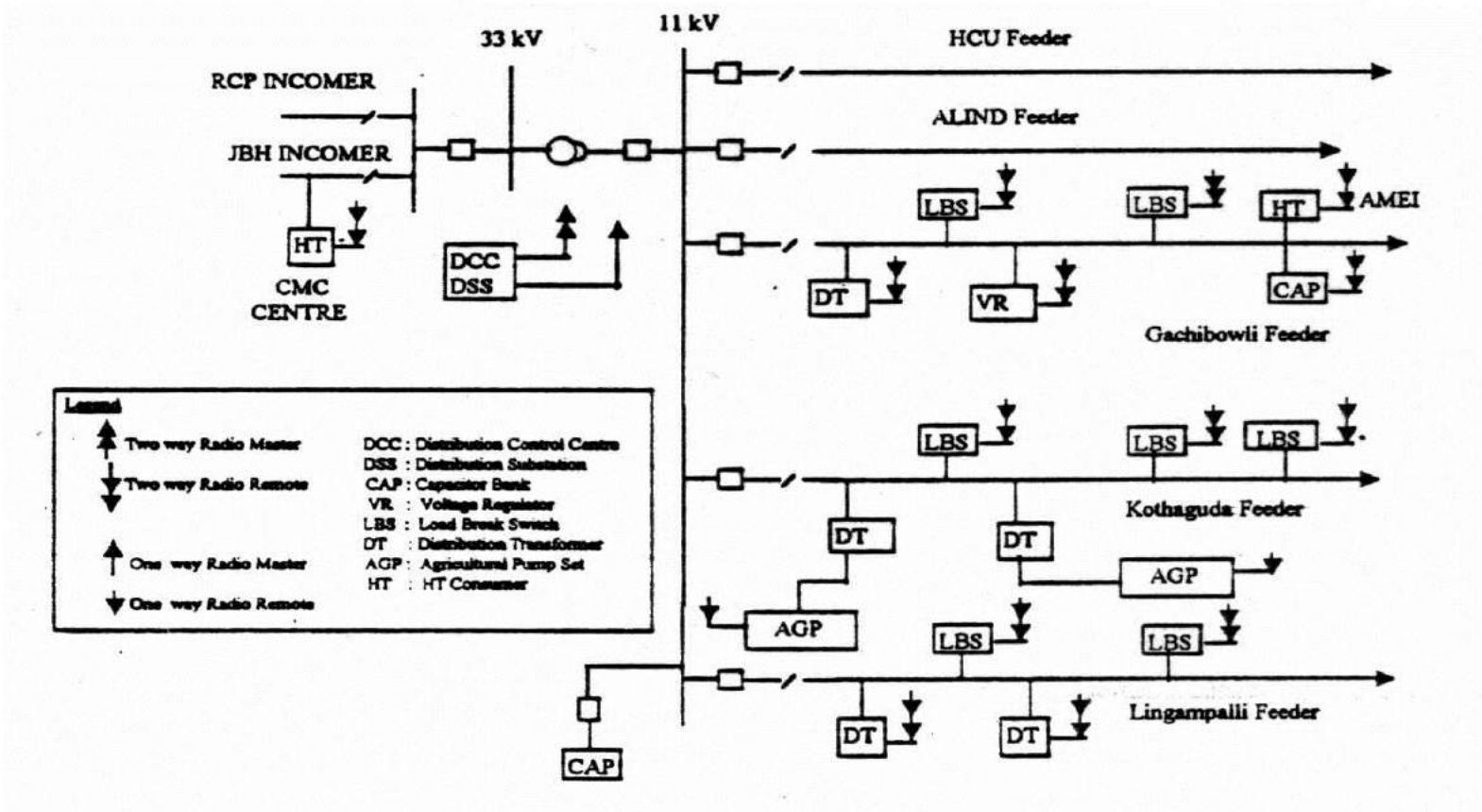


Voltage Sags

- Reduction in the ac voltage, at the power frequency, for durations from a half-cycle to a few seconds.
- Magnitude between 90% and 10%
- Voltage Sag is Characterized by two parameters – Magnitude and Duration
- Power Electronics Loads are Sensitive to Voltage Sags
- Impacts Industrial Customers 7 to 8 Times More Likely Than Outages



Typical Layout

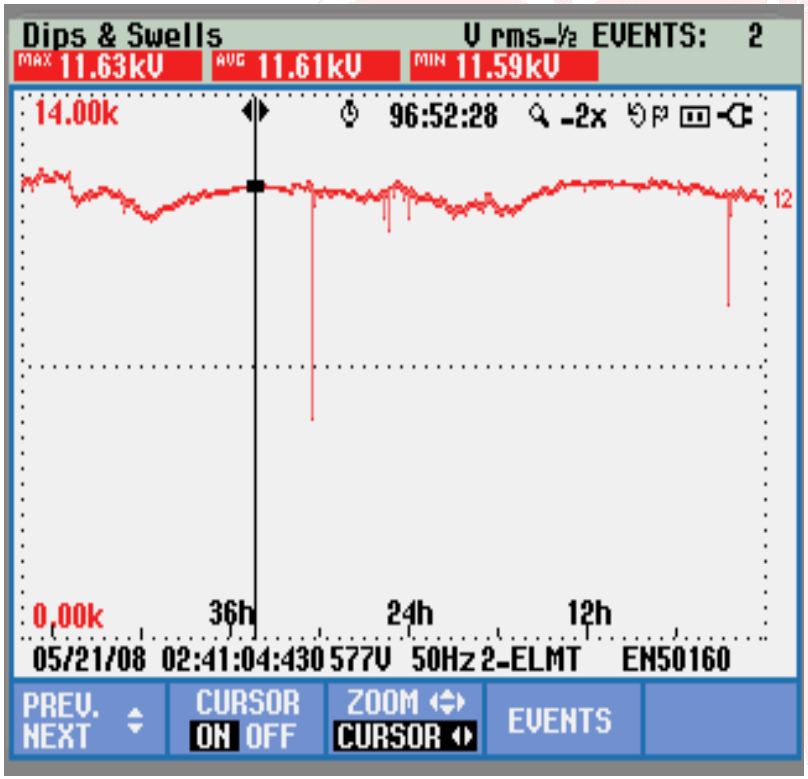


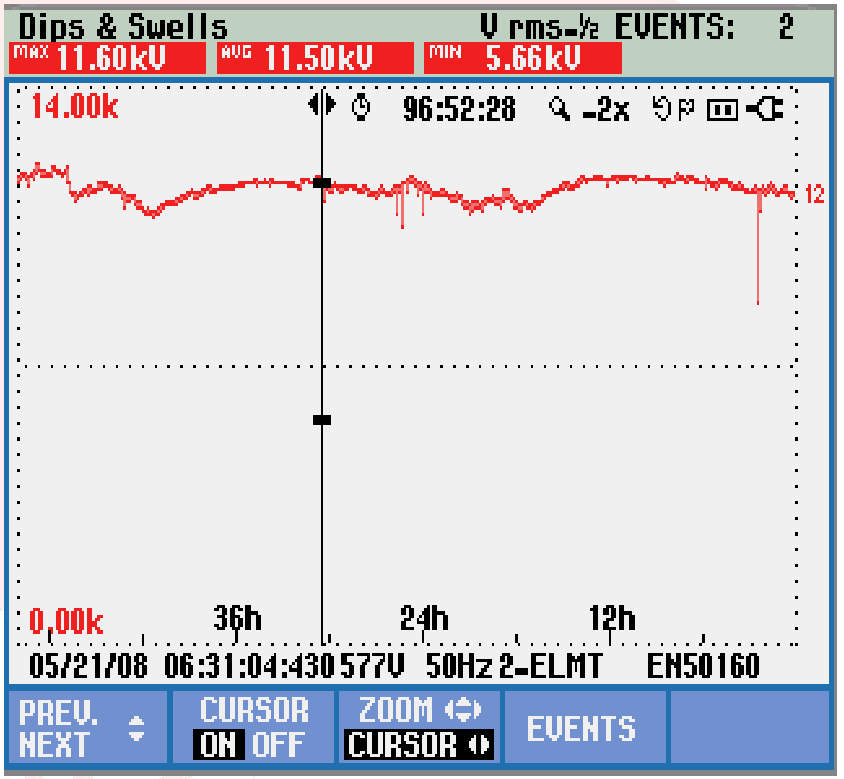
Earth Fault

Case Study
(Voltage Sag in Wind Mills)

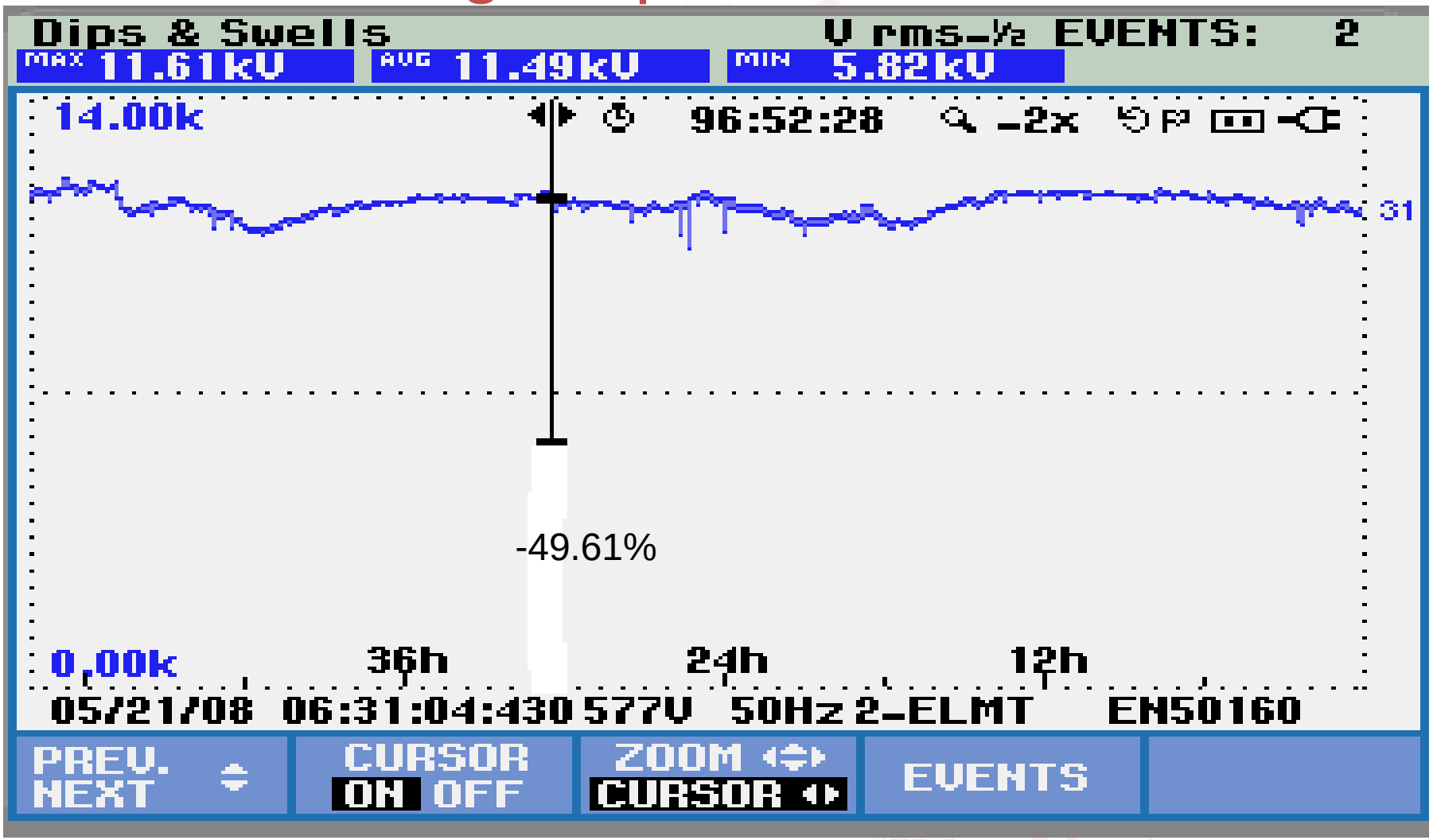
- This is a typical case of Wind Mills tripping due to Voltage Sag
- Voltage Sag caused by tripping of another feeder in the same Sub Station due to earth fault
- Rise in load current experienced
- Suspect of induction Generator aiding the fault

Sample Dip

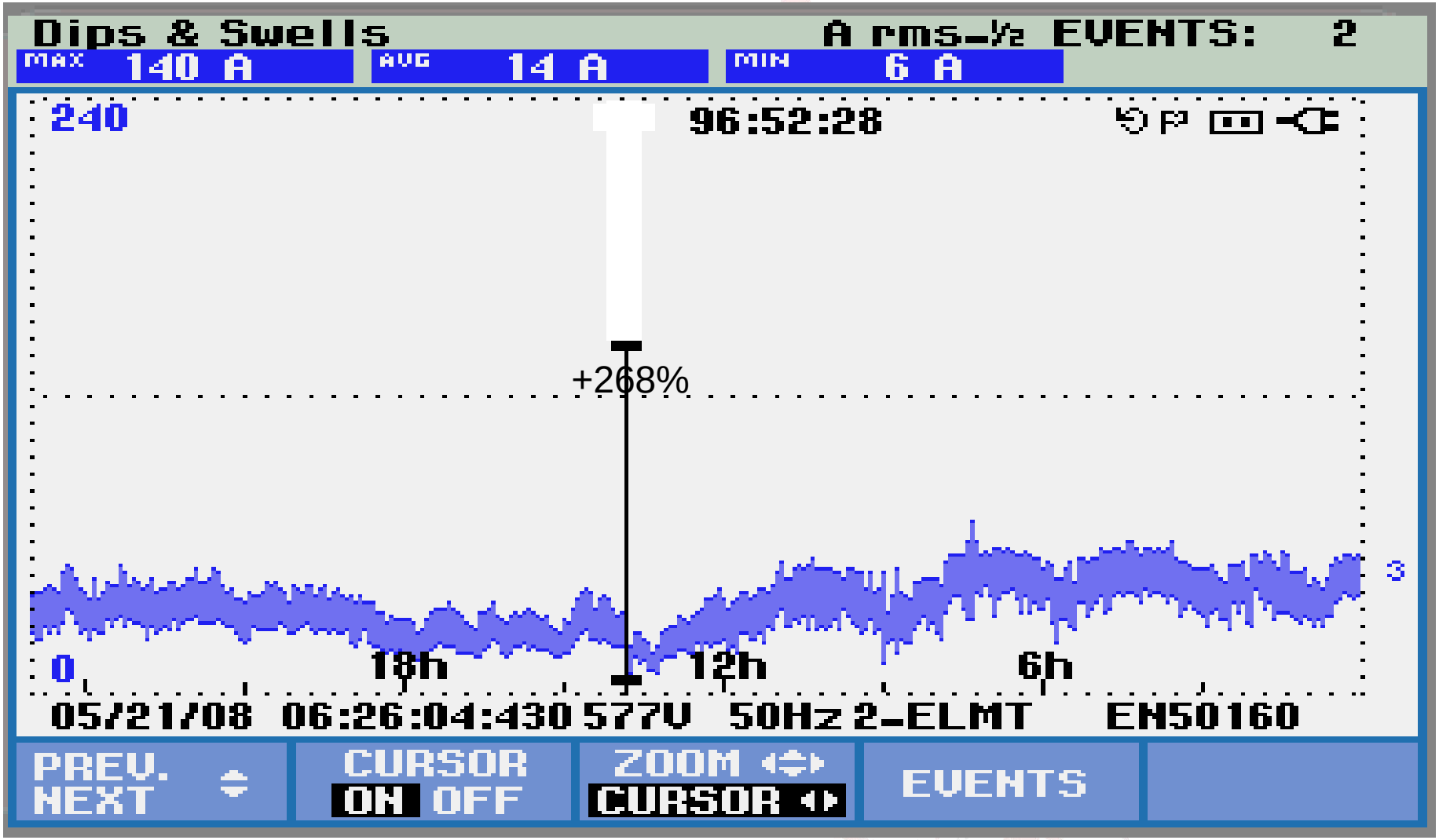

Dips & Swells
V rms-½ EVENTS: 2
MAX 11.63kV
AVG 11.61kV
MIN 11.59kV
14.00k
96:52:28
-2x
12
0.00k
36h
24h
12h
05/21/08 02:41:04:430 577V 50Hz 2-ELMT EN50160
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
EVENTS


Dips & Swells
V rms-½ EVENTS: 2
MAX 11.60kV
AVG 11.50kV
MIN 5.66kV
14.00k
96:52:28
-2x
12
0.00k
36h
24h
12h
05/21/08 06:31:04:430 577V 50Hz 2-ELMT EN50160
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
EVENTS

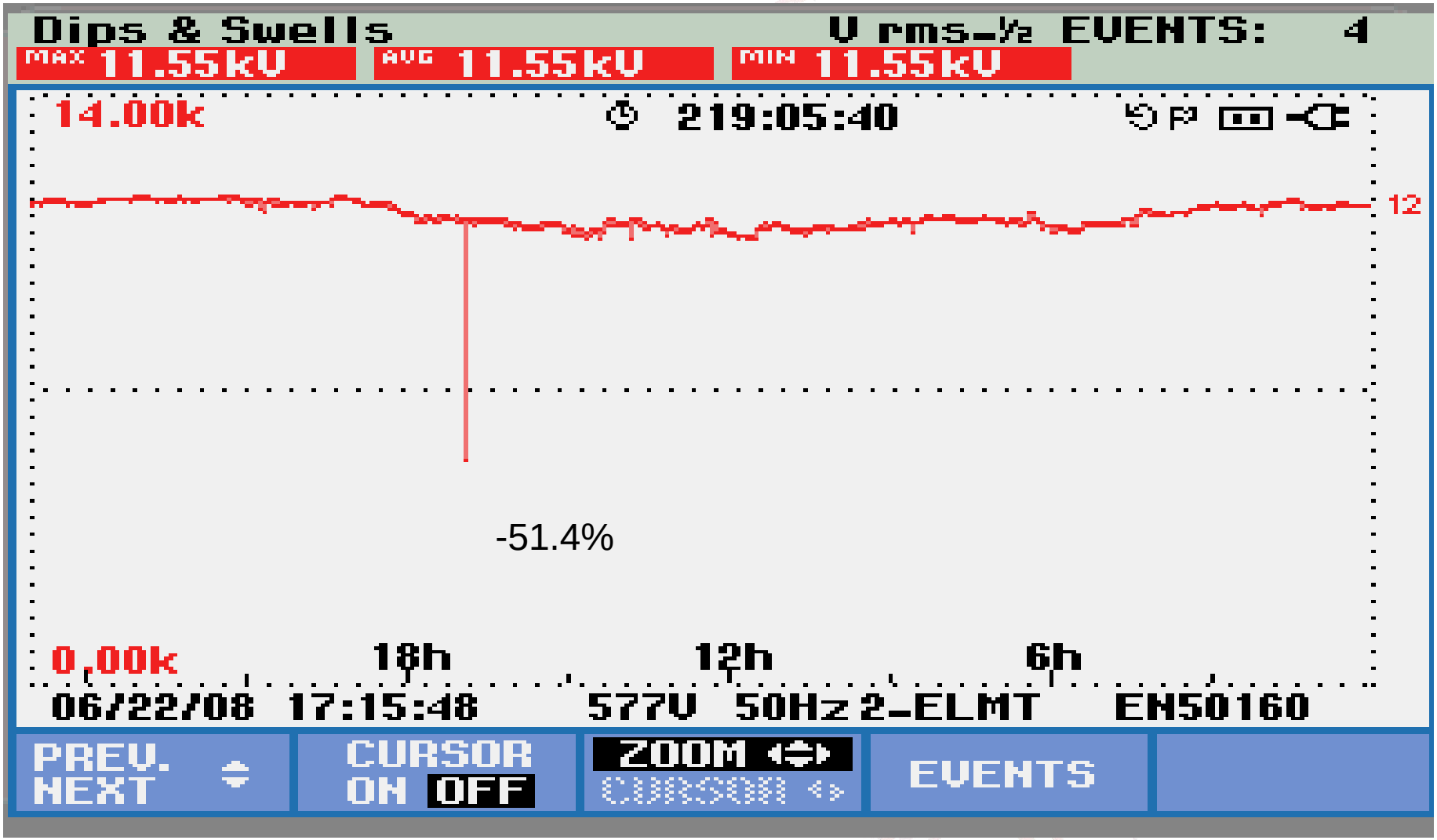
Voltage Dip in WM Feeder



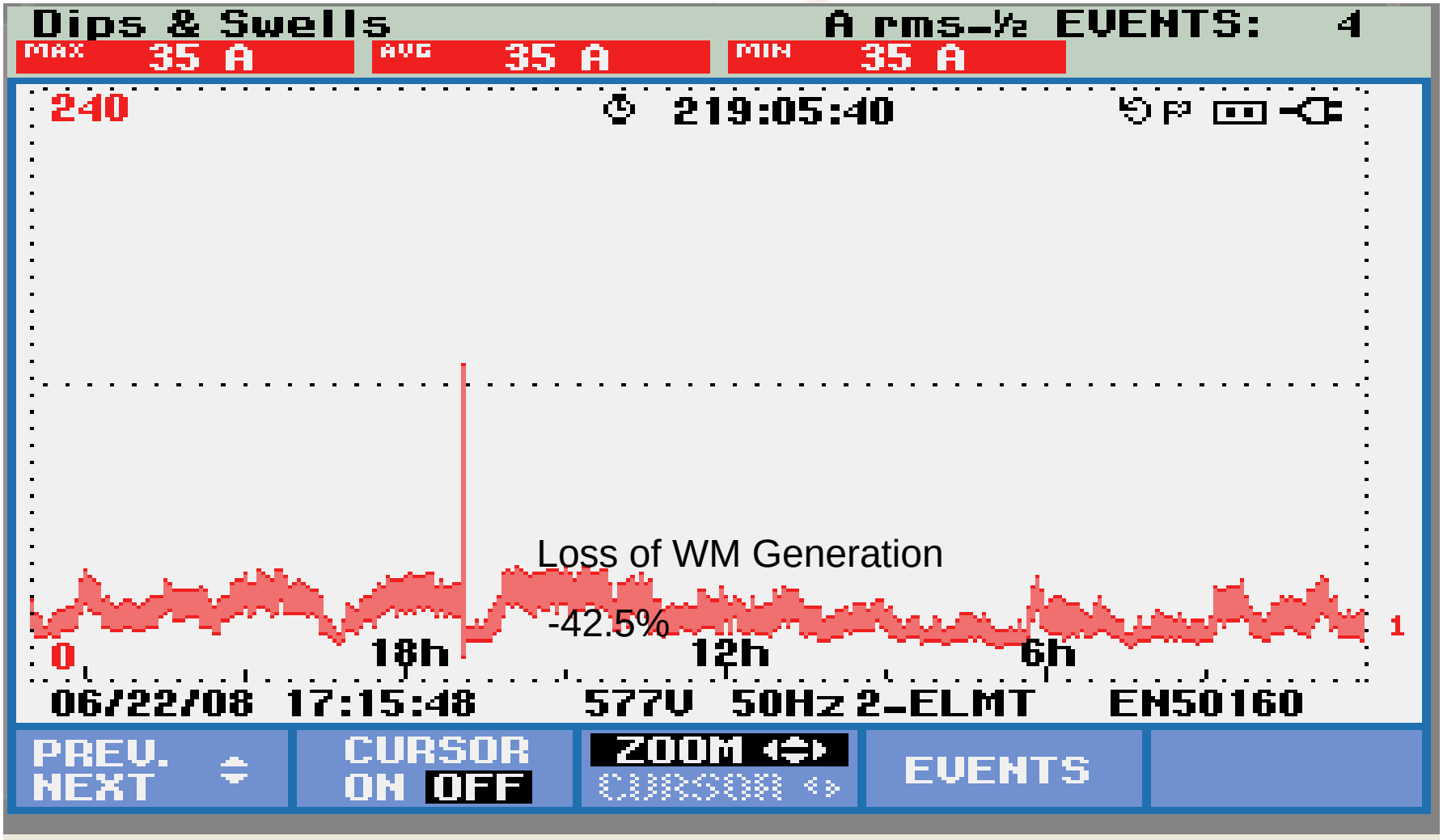
Current rise in WM Feeder



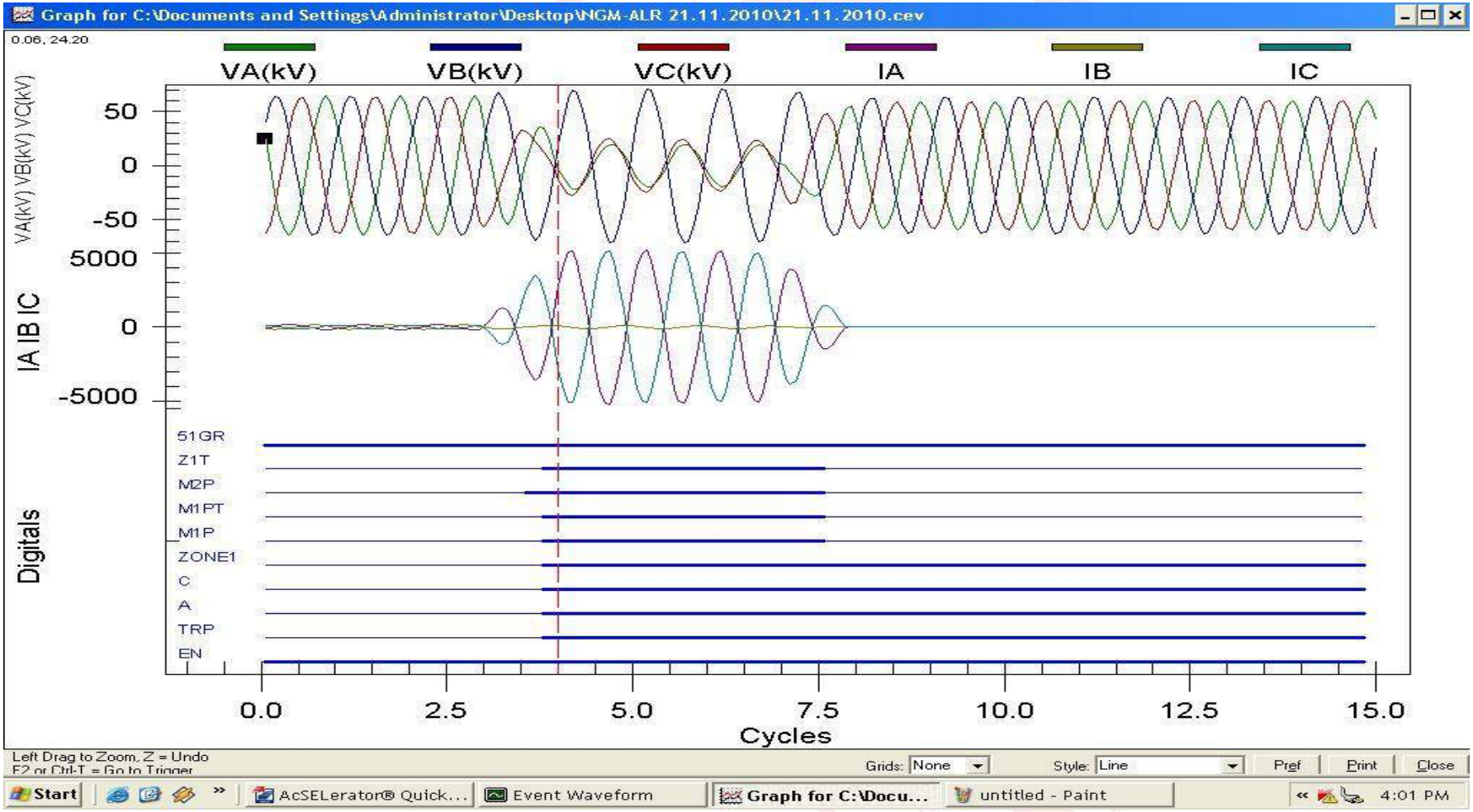
Voltage Dip

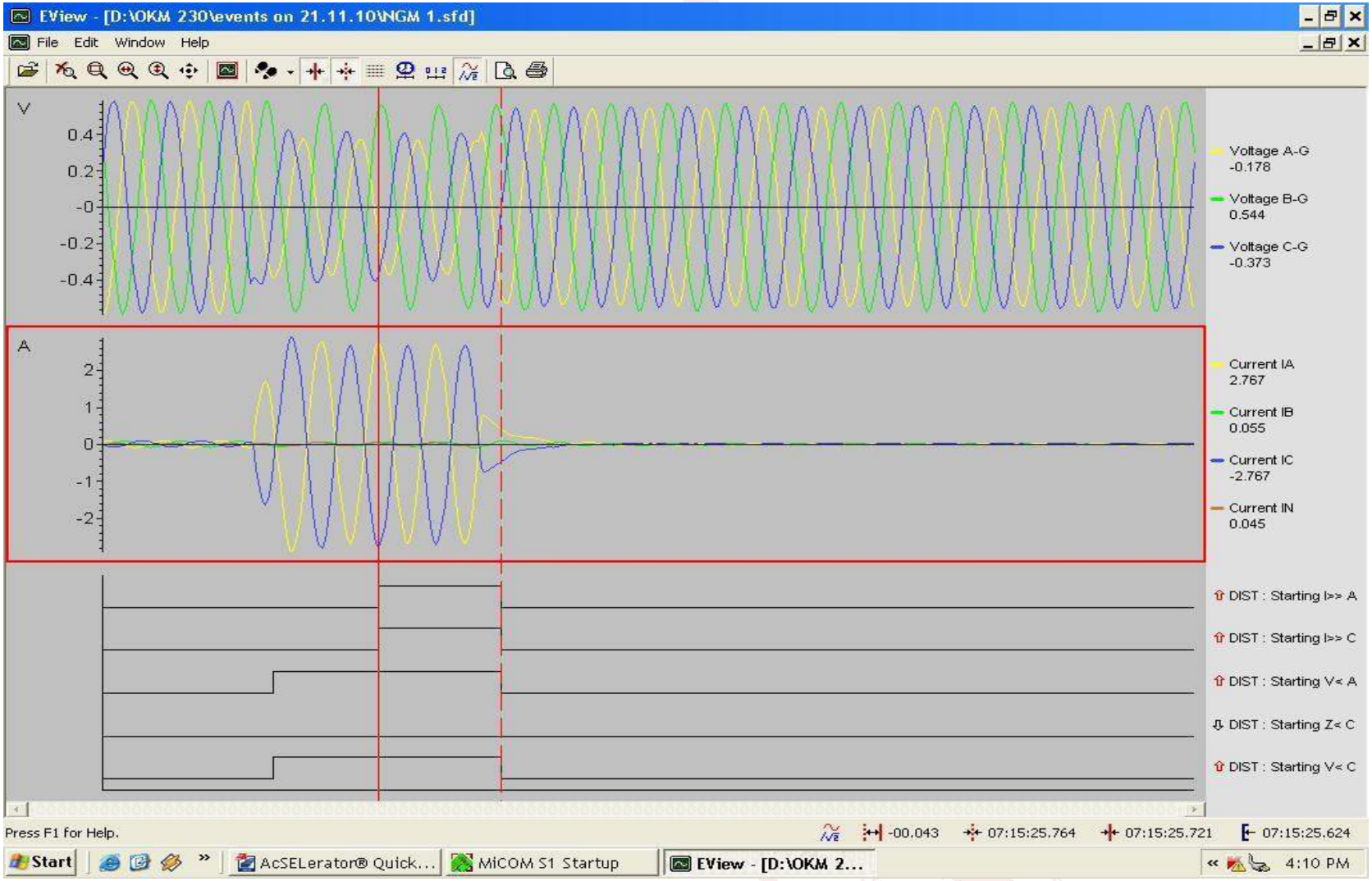

Dips & Swells
V rms-½ EVENTS: 4
MAX 11.55kV
AVG 11.55kV
MIN 11.55kV
14.00k
219:05:40
12
-51.4%
0.00k
18h
12h
6h
06/22/08 17:15:48
577V 50Hz 2-ELMT EN50160
PREV.
NEXT
CURSOR
ON OFF
ZOOM
EVENTS

Tripping of WM Due to Sag

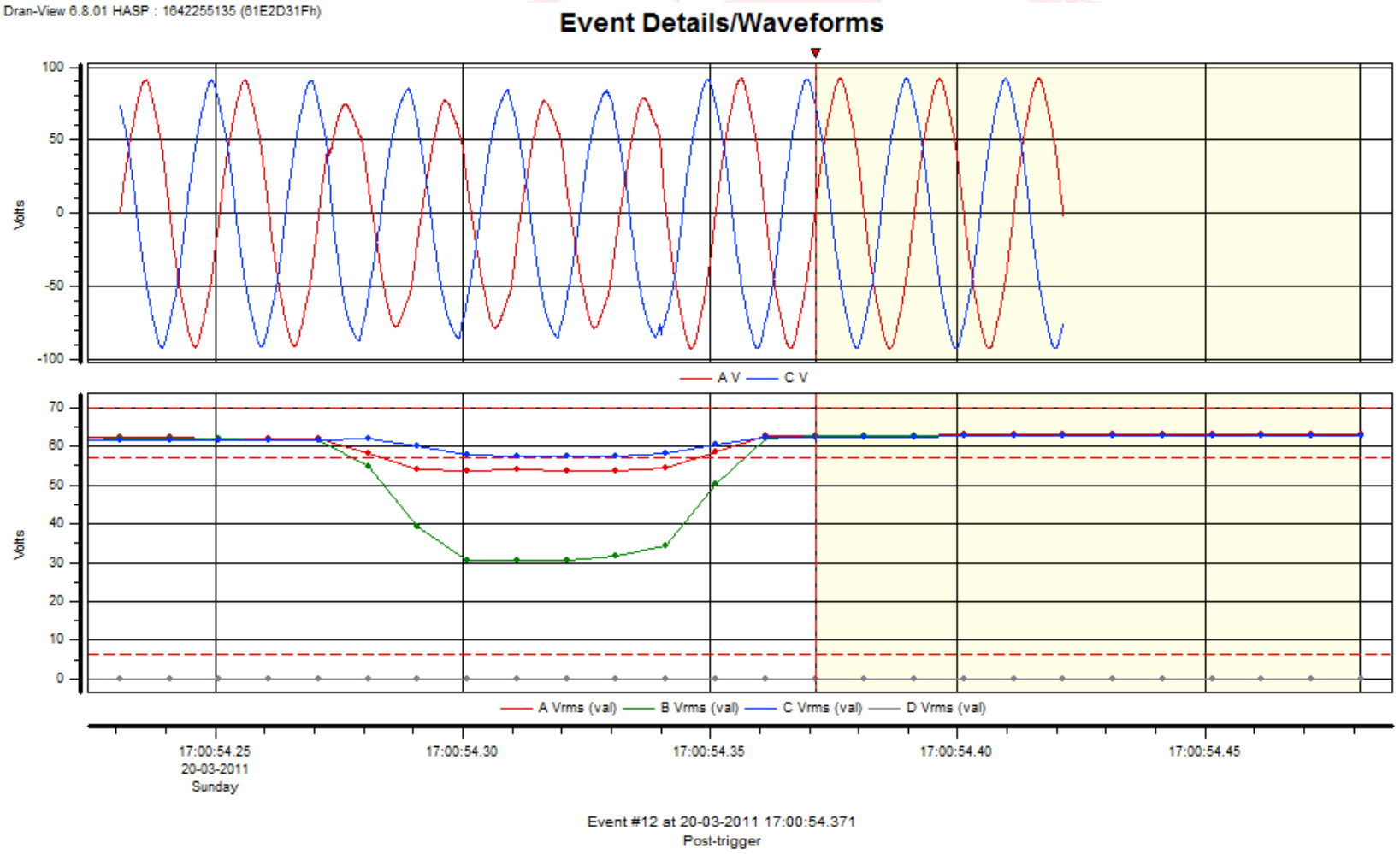


Grid Disturbance in 110 kV SS

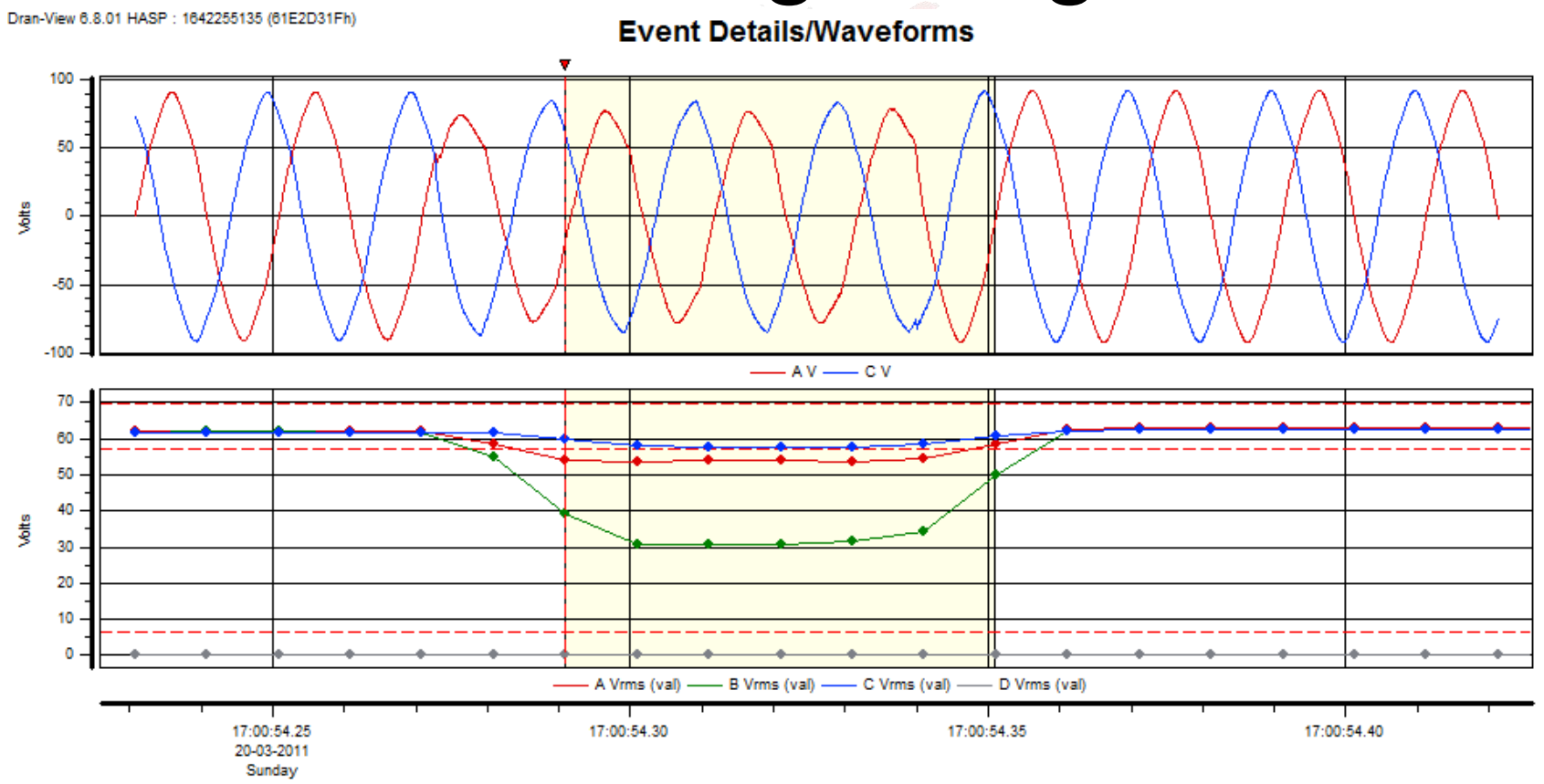



EView - [D:\OKM 230\events on 21.11.10\NGM 1.sfd]
File Edit Window Help
V
0.4
0.2
-0
-0.2
-0.4
Voltage A-G
-0.178
Voltage B-G
0.544
Voltage C-G
-0.373
A
2
1
0
-1
-2
Current IA
2.767
Current IB
0.055
Current IC
-2.767
Current IN
0.045
DIST : Starting I>> A
DIST : Starting I>> C
DIST : Starting V< A
DIST : Starting Z< C
DIST : Starting V< C
Press F1 for Help.
-00.043
07:15:25.764
07:15:25.721
07:15:25.624
Start
AcSELerator® Quick...
MiCOM S1 Startup
EView - [D:\OKM 2...
4:10 PM

Voltage Sag


Dran-View 6.8.01 HASP : 1642255135 (61E2D31Fh)
Event Details/Waveforms
Volts
100
50
0
-50
-100
A V
C V
Volts
70
60
50
40
30
20
10
0
A Vrms (val)
B Vrms (val)
C Vrms (val)
D Vrms (val)
17:00:54.25
20-03-2011
Sunday
17:00:54.30
17:00:54.35
17:00:54.40
17:00:54.45
Event #12 at 20-03-2011 17:00:54.371
Post-trigger

Voltage Sag

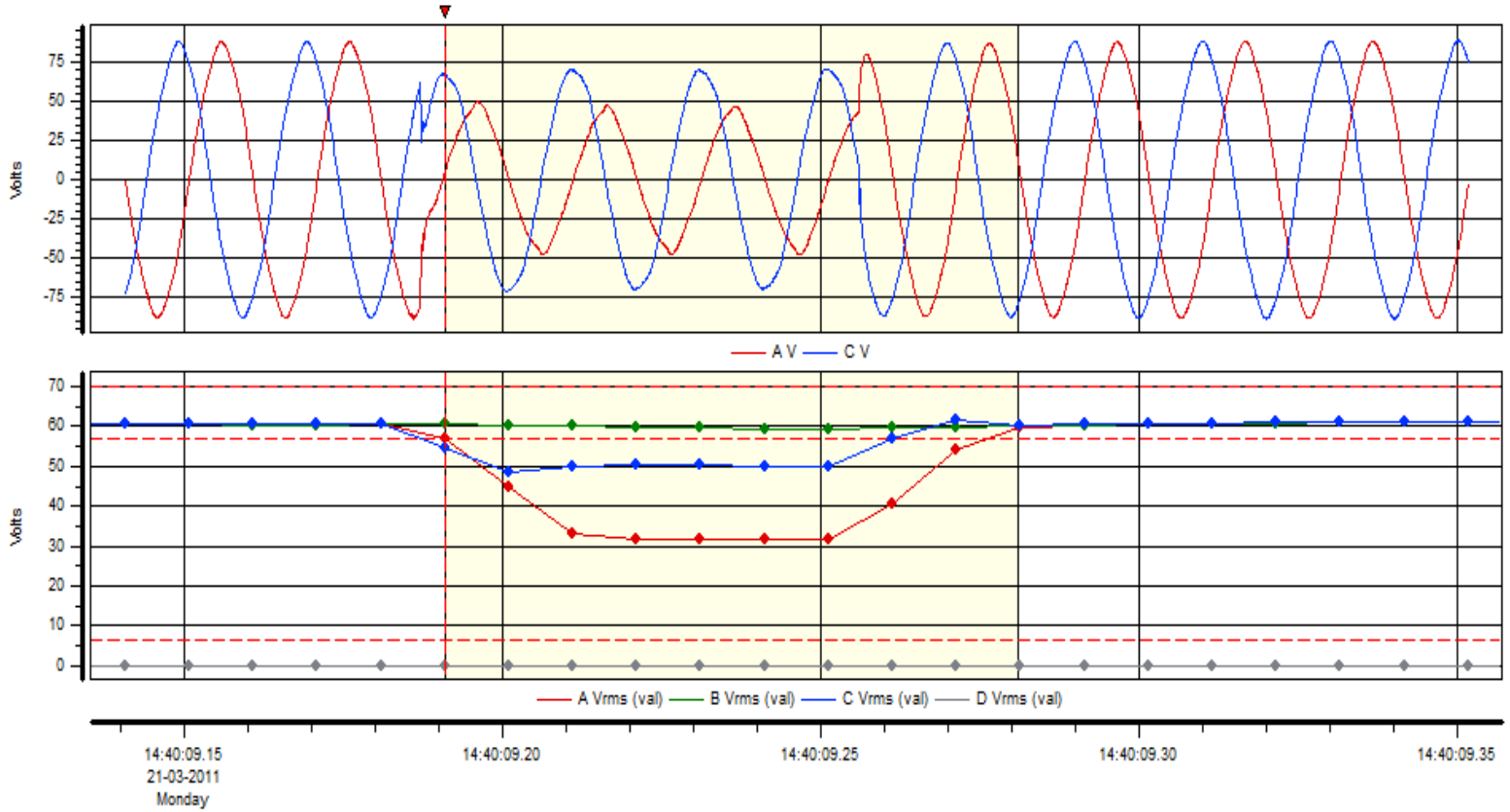


Event #8 at 20-03-2011 17:00:54.290
AVrms Instantaneous Sag
CATEGORY: Short Duration Instantaneous Sag

Threshold crossed	57.14 V
Magnitude	53.52 V
MaxRMS	54.25 V
Duration	0.06019 Sec.

Dran-View 6.8.01 HASP : 1642255135 (61E2D31Fh)

Event Details/Waveforms



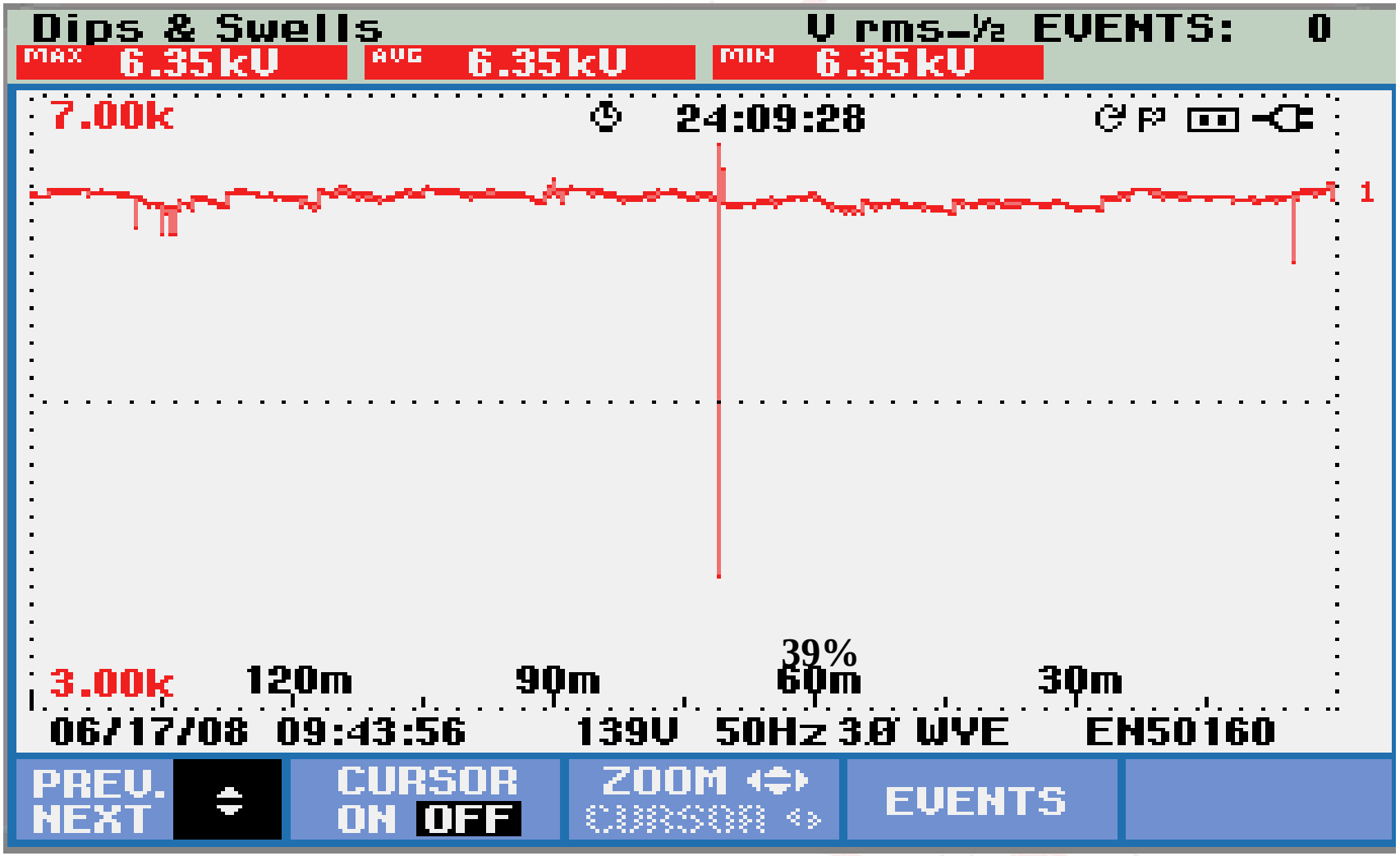
Event #13430 at 21-03-2011 14:40:09.191
AVrms, CVrms Instantaneous Sag
CATEGORY: Short Duration Instantaneous Sag

	AV	CV
Threshold crossed (V)	57.14	57.14
Magnitude (V)	31.53	48.65
MaxRMS (V)	54.22	57.1
Duration (sec.)	0.09036	0.09036

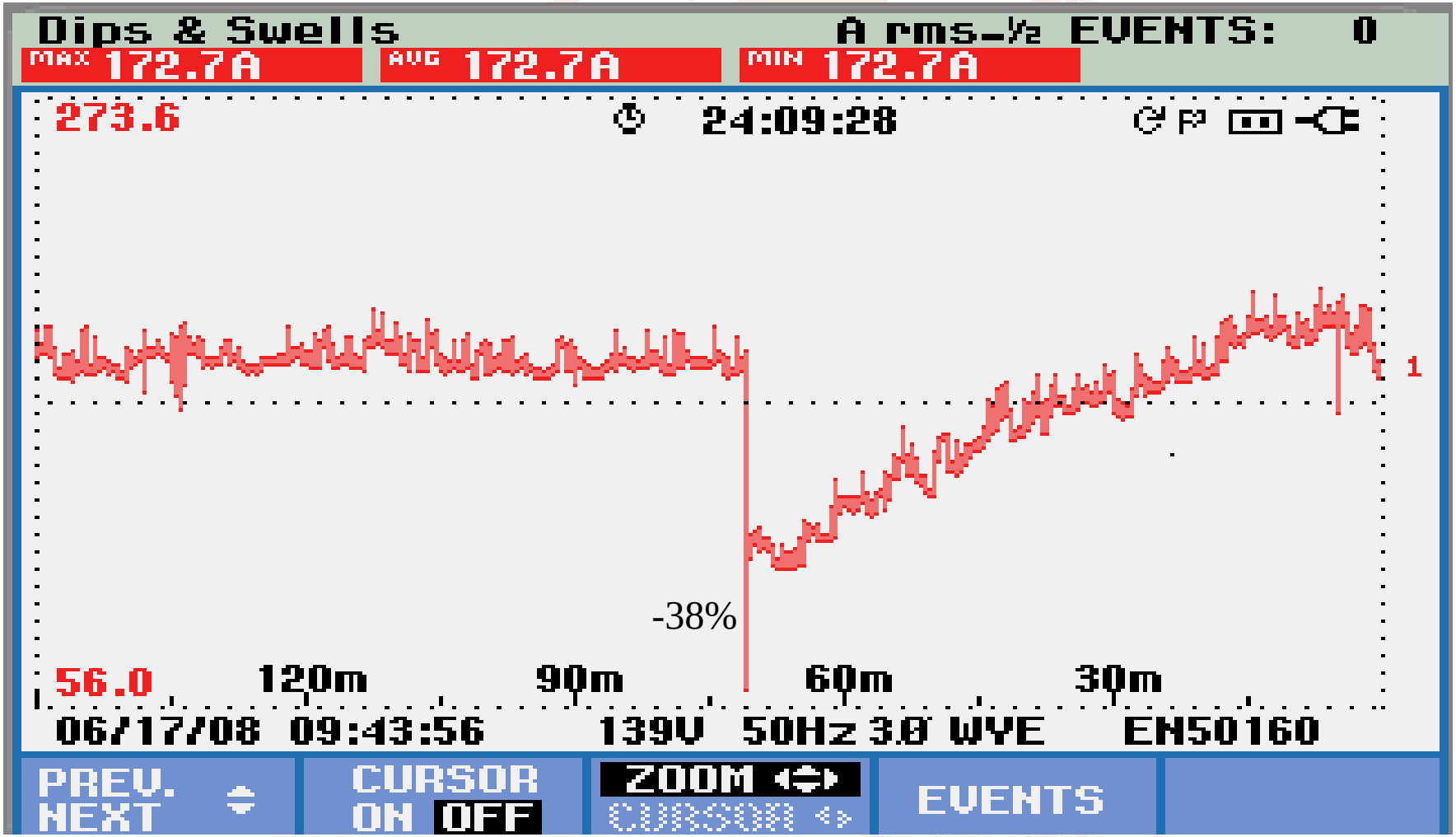
Case Studies (Voltage Sag)

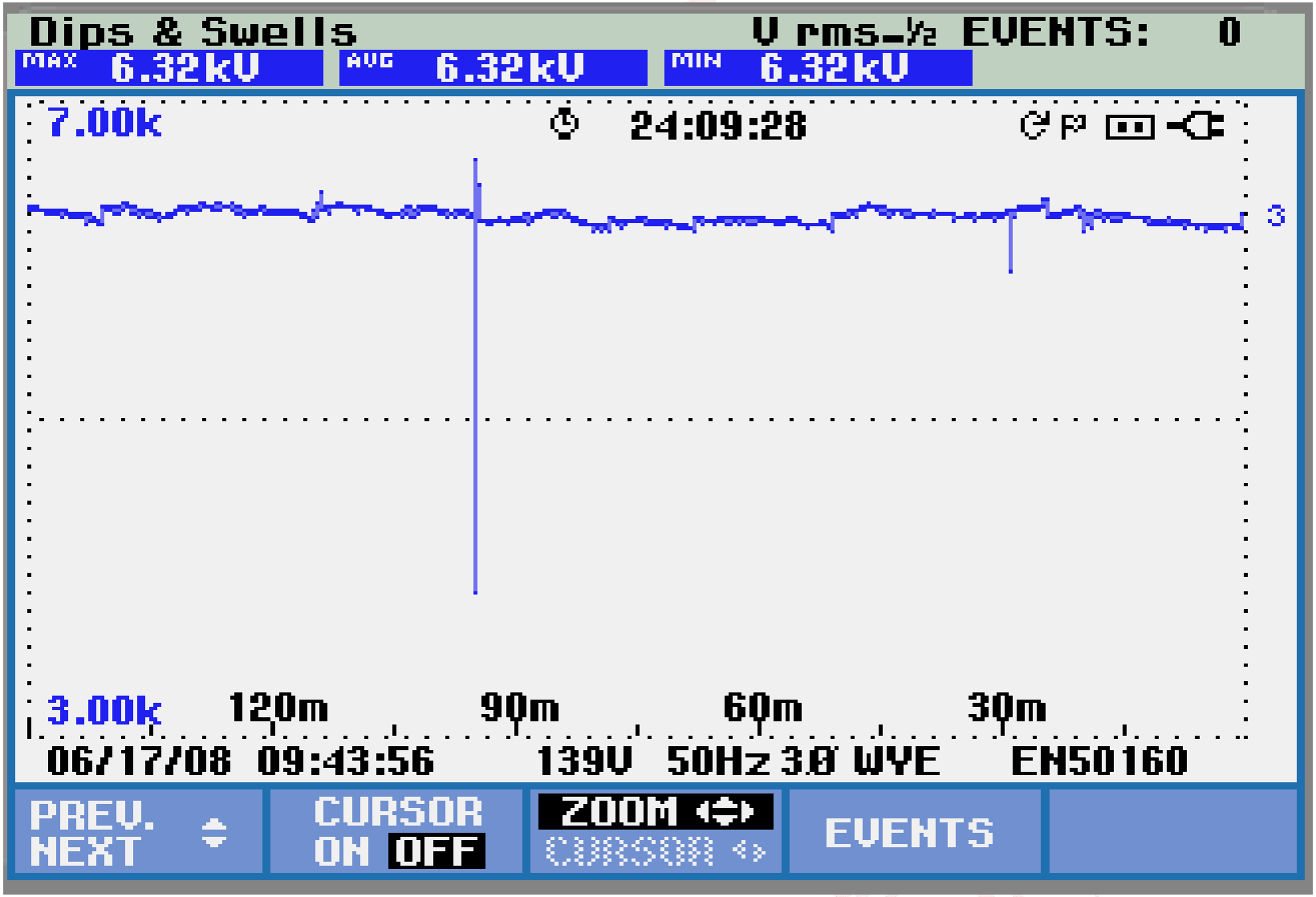
- This is a typical case of tripping of Variable Drives due to Voltage Sag experienced by a Textile Mill at Coimbatore
- Voltage Sag caused in the Feeder due to fault tripping of another feeder in the same Sub Station
- Voltage Sag magnitude is dependant on the strength of the Grid where the load is incident
- Duration of Voltage Sag is dependant on the duration of the equipment isolating the fault from the Grid

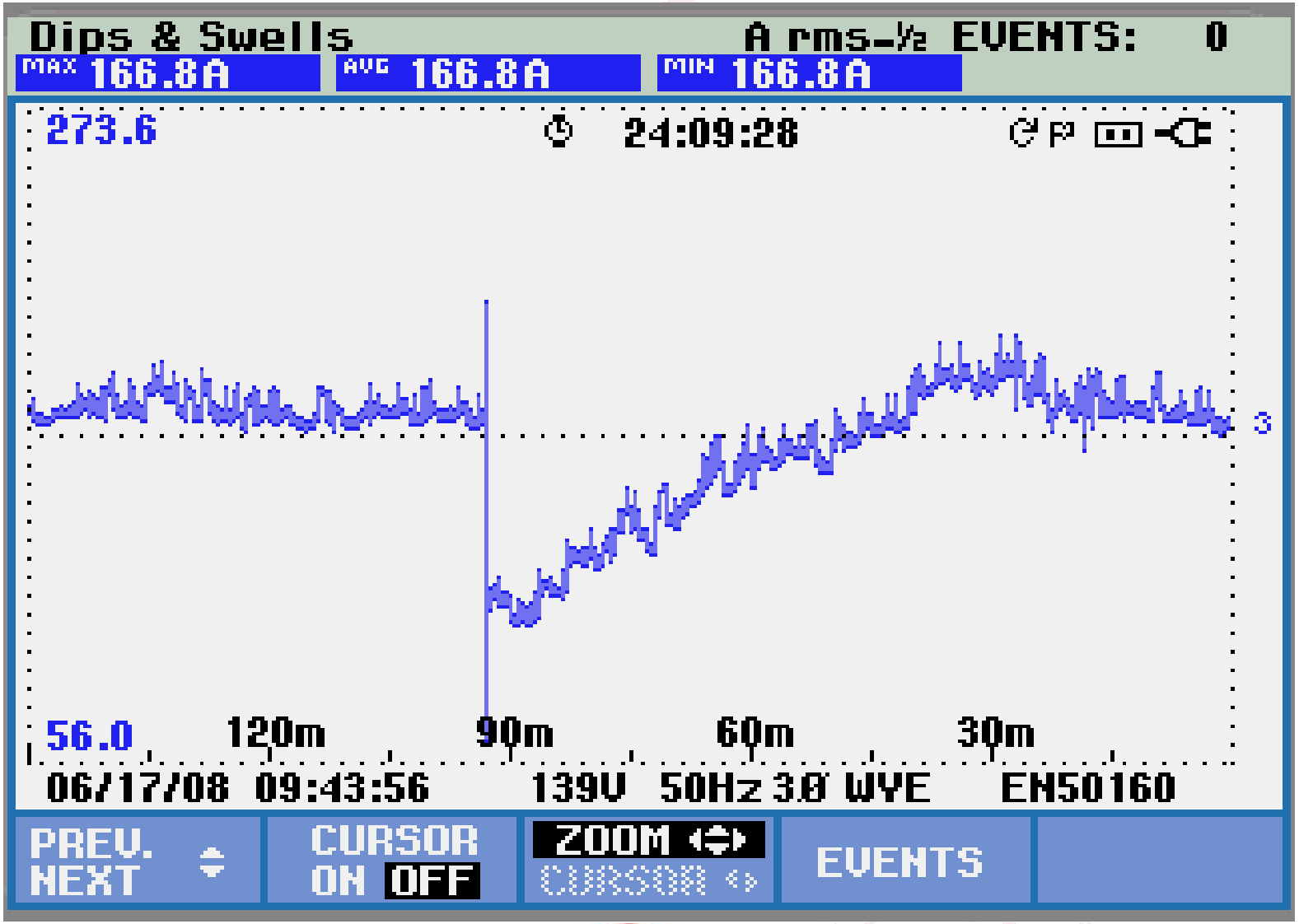
Voltage Sag


Dips & Swells
V rms-½ EVENTS: 0
MAX 6.35kV
AVG 6.35kV
MIN 6.35kV
7.00k
24:09:28
1
39%
3.00k
120m
90m
60m
30m
06/17/08 09:43:56
139V 50Hz 3Ø WYE
EN50160
PREV.
NEXT
CURSOR
ON OFF
ZOOM
EVENTS

Tripping of Drives Due to Voltage Sag



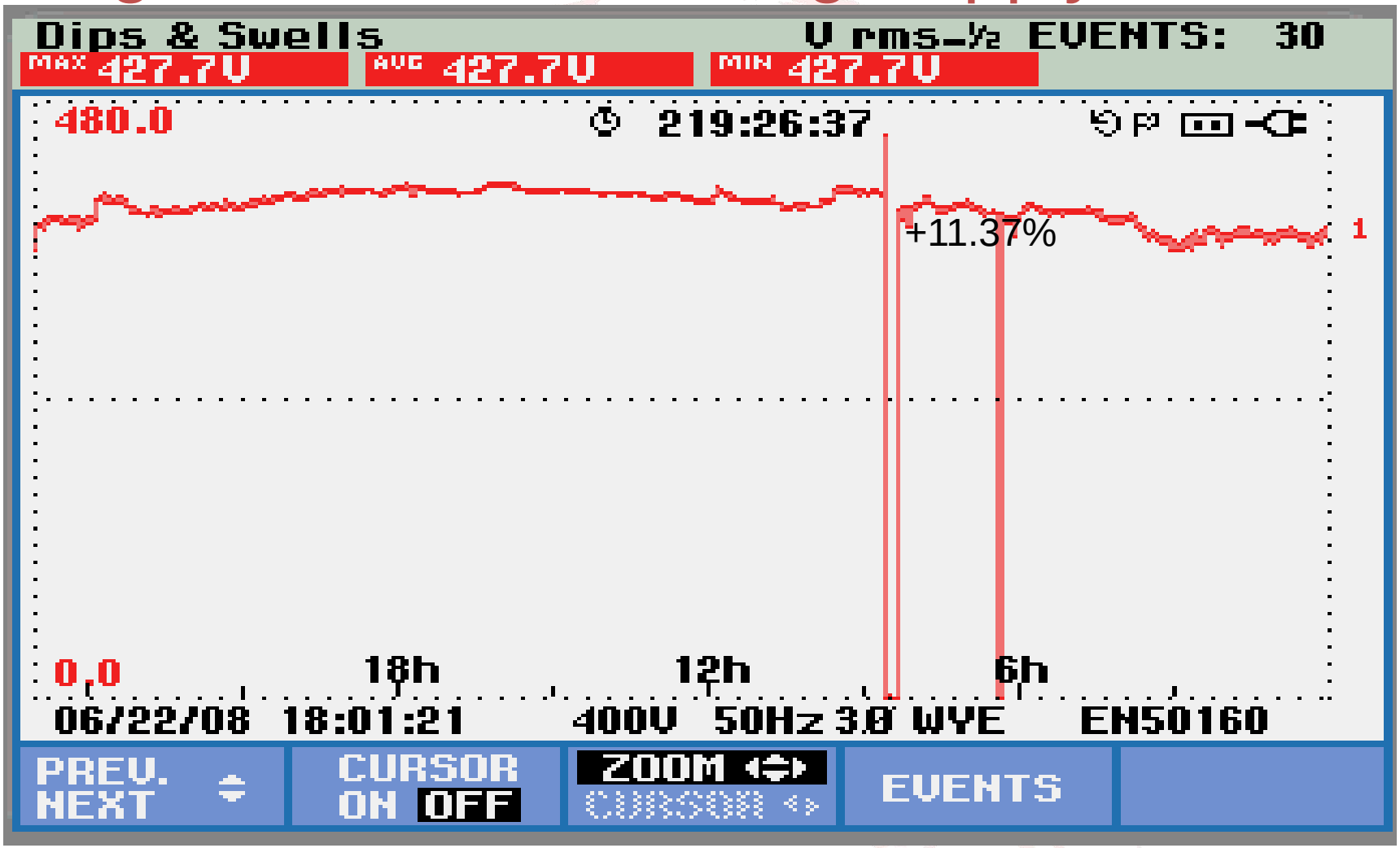

Dips & Swells
V rms-½ EVENTS: 0
MAX 6.32kV
AVG 6.32kV
MIN 6.32kV
7.00k
24:09:28
3
3.00k
120m
90m
60m
30m
06/17/08 09:43:56
139V 50Hz 3Ø WYE
EN50160
PREV.
NEXT
CURSOR
ON OFF
ZOOM
EVENTS


Dips & Swells
A rms-½ EVENTS: 0
MAX 166.8A
AVG 166.8A
MIN 166.8A
273.6
24:09:28
56.0
120m
90m
60m
30m
06/17/08 09:43:56
139V 50Hz 3Ø WYE
EN50160
PREV.
NEXT
CURSOR
ON OFF
ZOOM
EVENTS

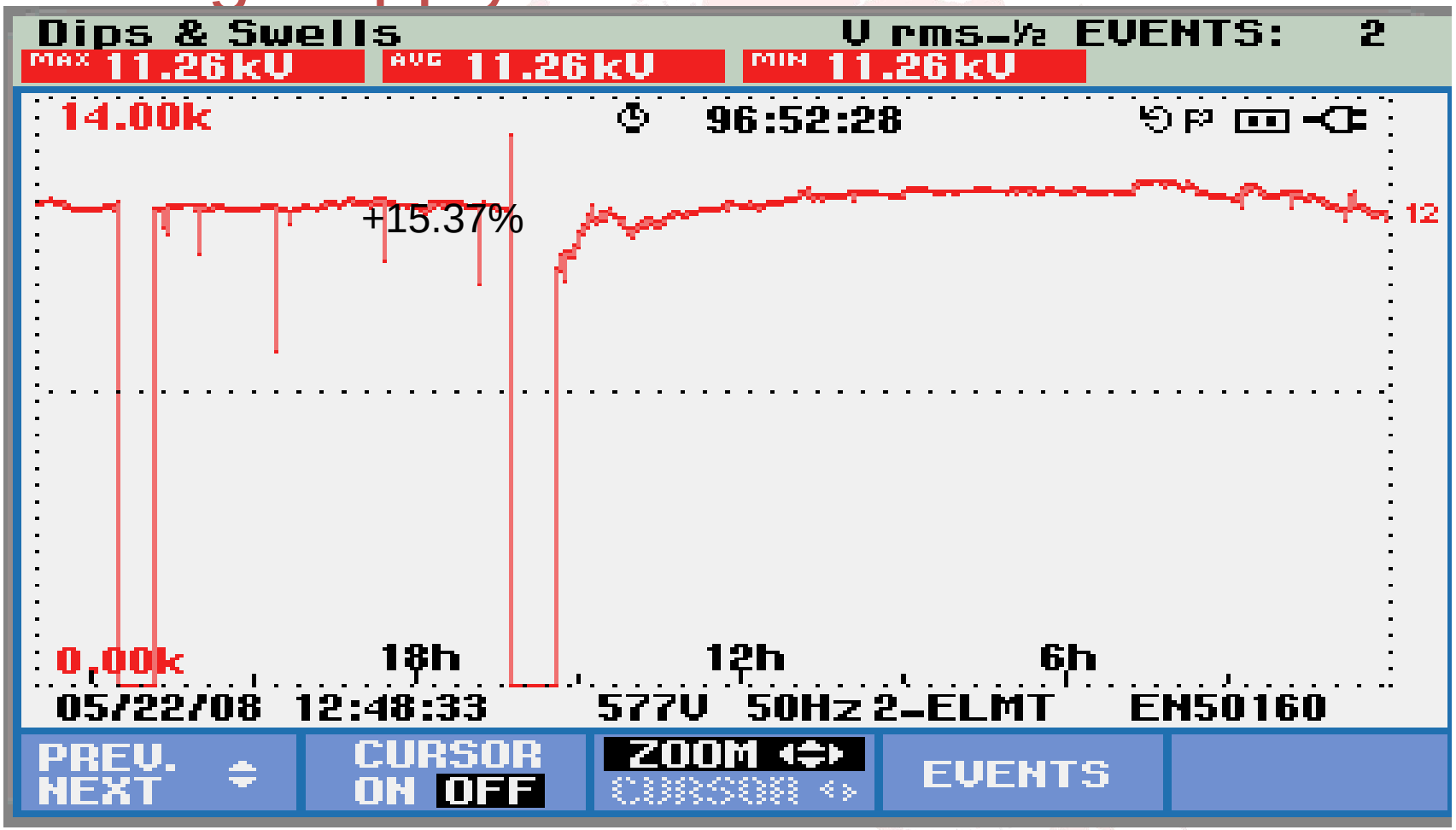
Case Study (Voltage Swell)

- This a case study of Voltage Swell
- Voltage swell caused in a Wind Mill connected feeder
- Voltage Swell seen when Wind Mill connected feeder is isolated manually
- Voltage swell due to discharge of Capacitors connected for PF correction

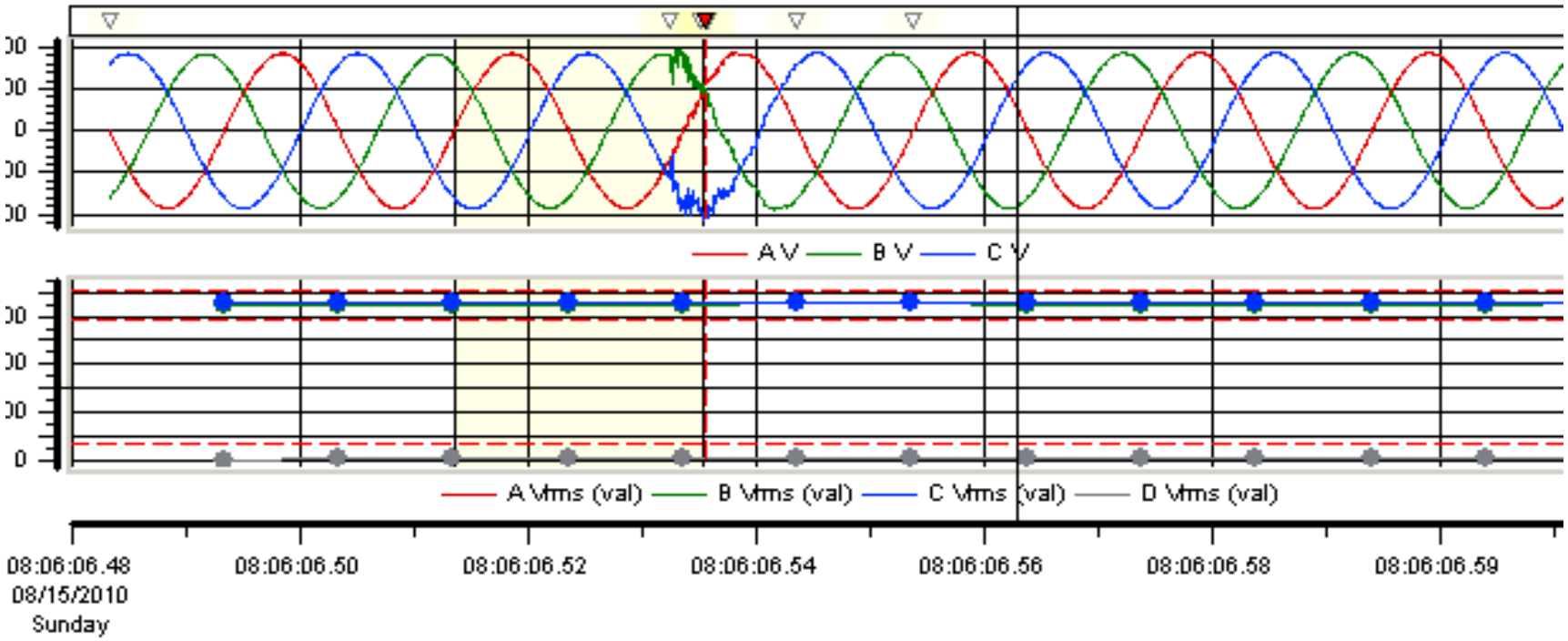
Voltage Rise in WM During Supply Failure



Voltage Rise in Wind Mill Feeder During Supply Failure



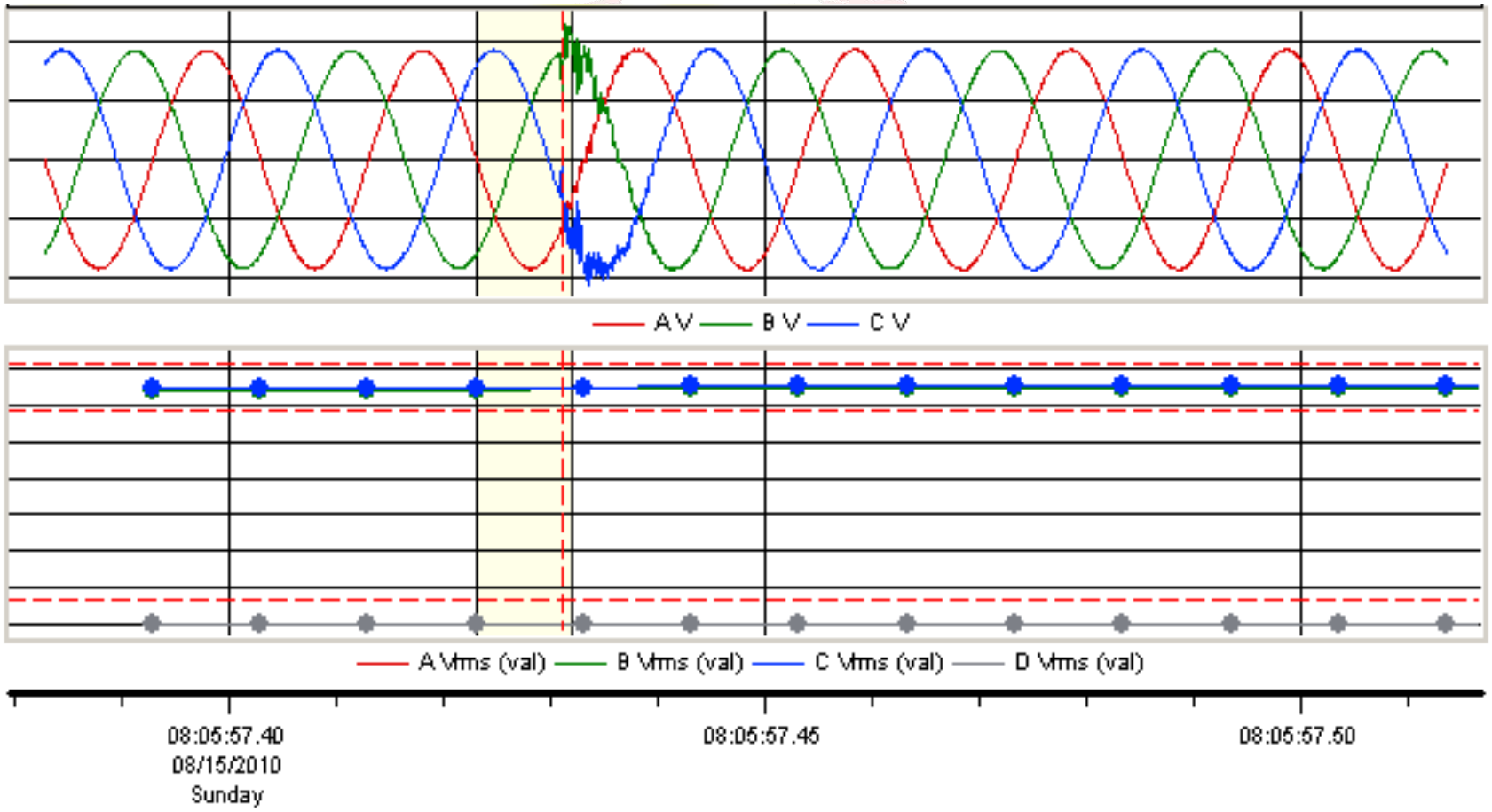
Bipolar Transient



Event #43383 at 08/15/2010 08:06:06.513
CV Mild Bipol Trans Pos 1/16 Cyc
CATEGORY: Impulsive Transient (microsec duration)

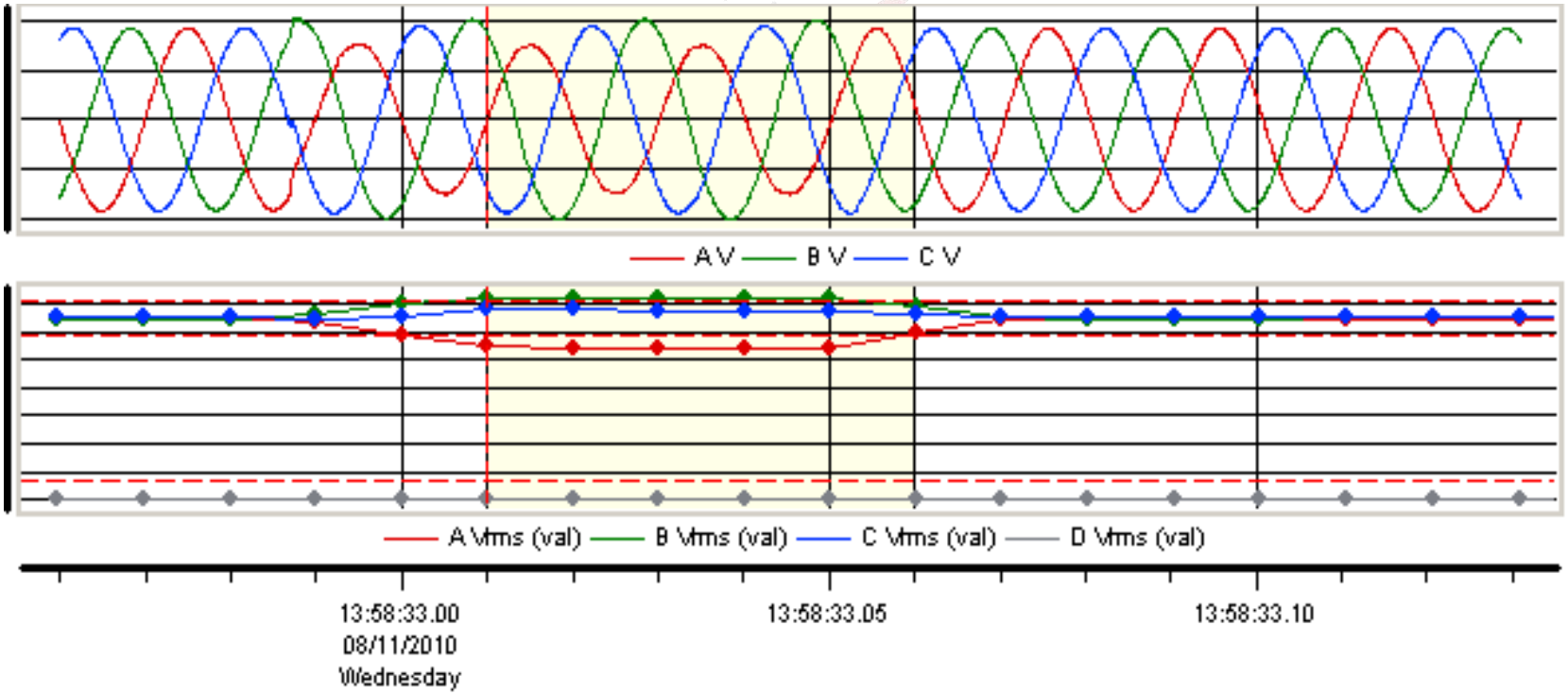
10% Ampl	-98310
50% Ampl	-101311
90% Ampl	-104346
10% Offset (usec)	22110
50% Offset (usec)	22141
Rise time 10-90% (usec)	62.0

B-Phase voltage Drop out



Event #43373 at 08/15/2010 08:05:57.423
CV Dropout 1/16 Cyc

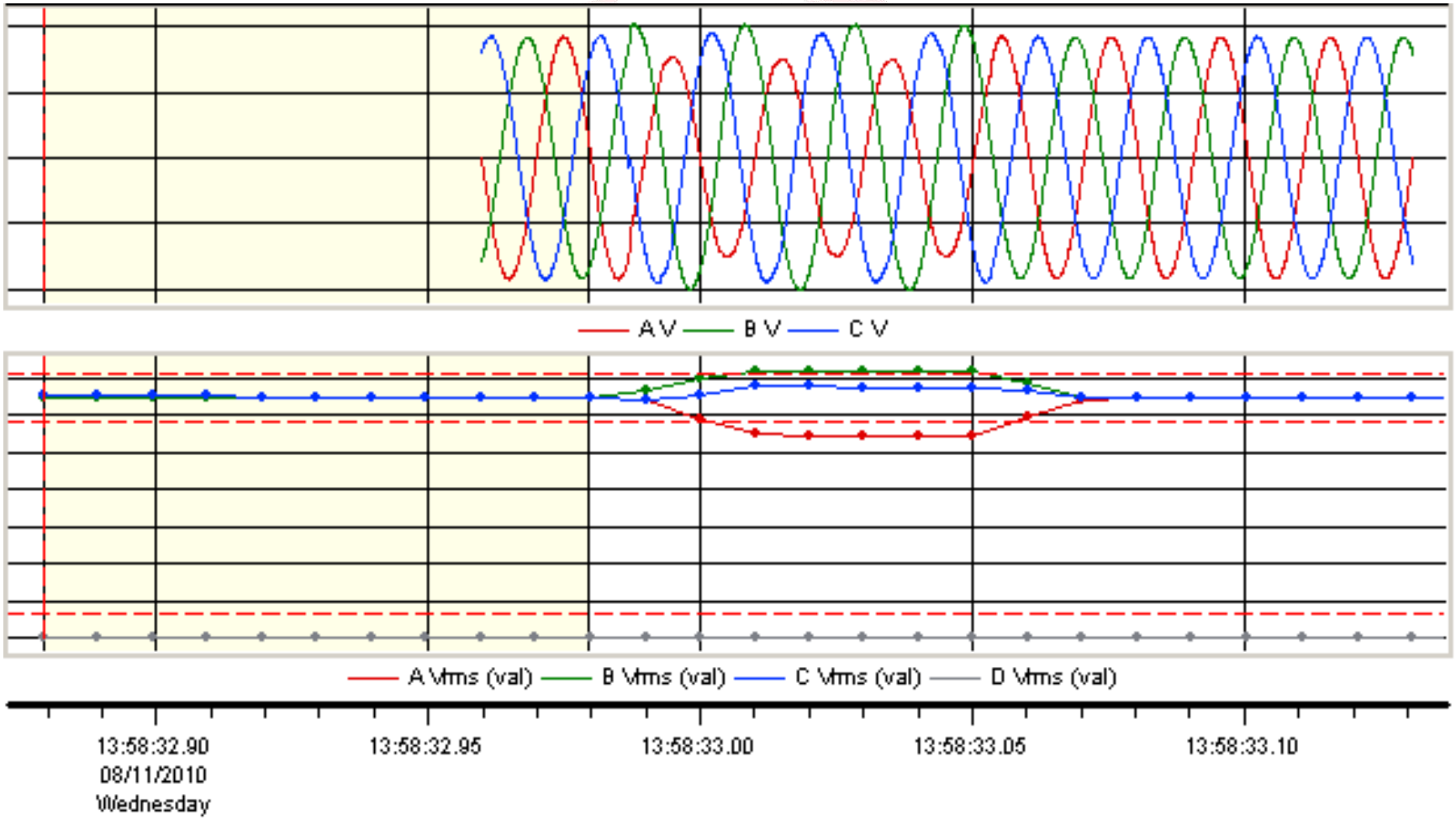
Voltage SAG



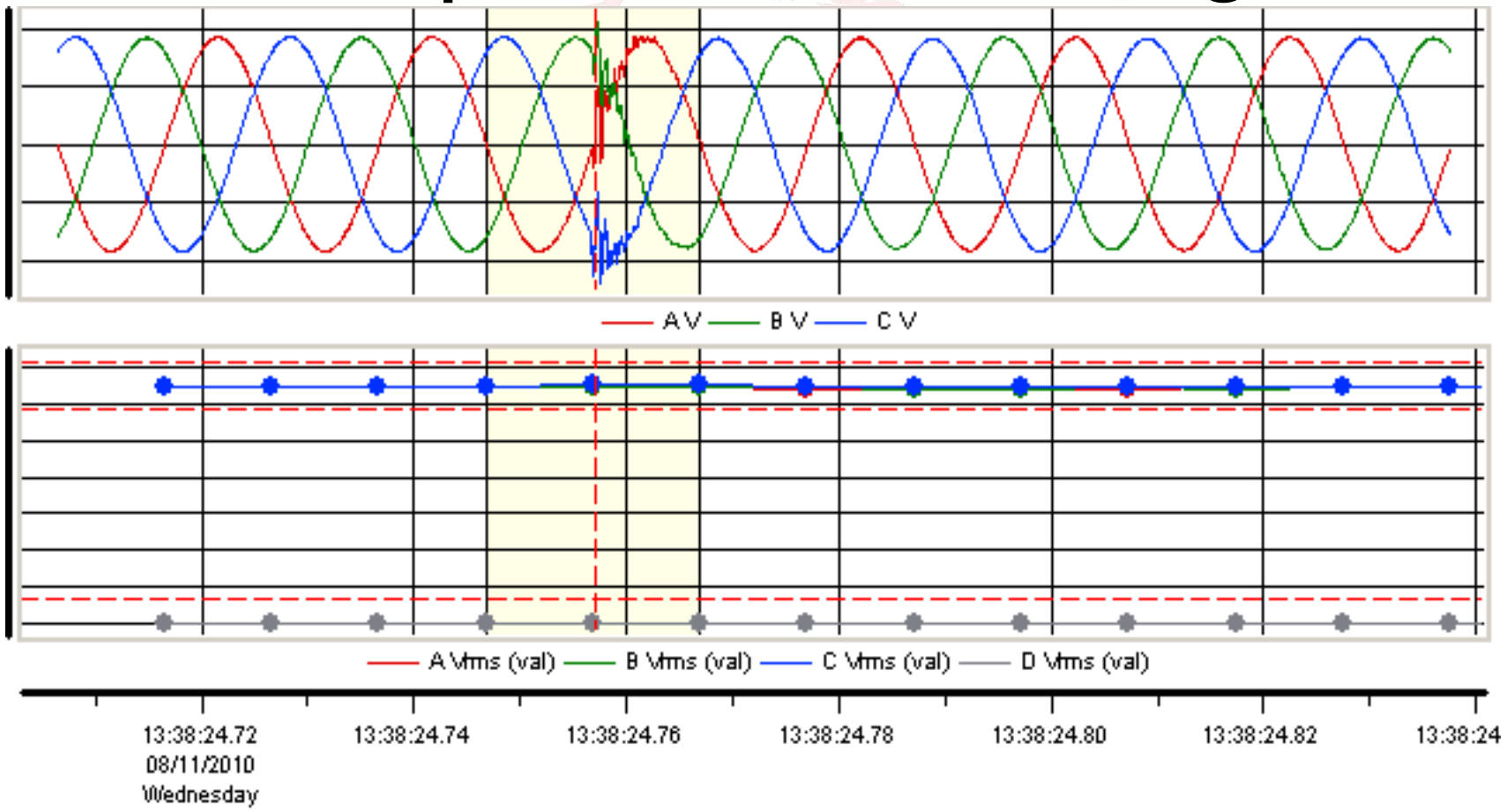
Event #19741 at 08/11/2010 13:58:33.010
AVrms, BVrms Instantaneous Sag
CATEGORY: Short Duration Instantaneous Sag

	AV	BV
Threshold crossed (V)	58365	58365
Magnitude (V)	54263	71540
MaxRMS (V)	54737	72041
Duration (sec.)	0.05012	0.05012

Voltage Sag

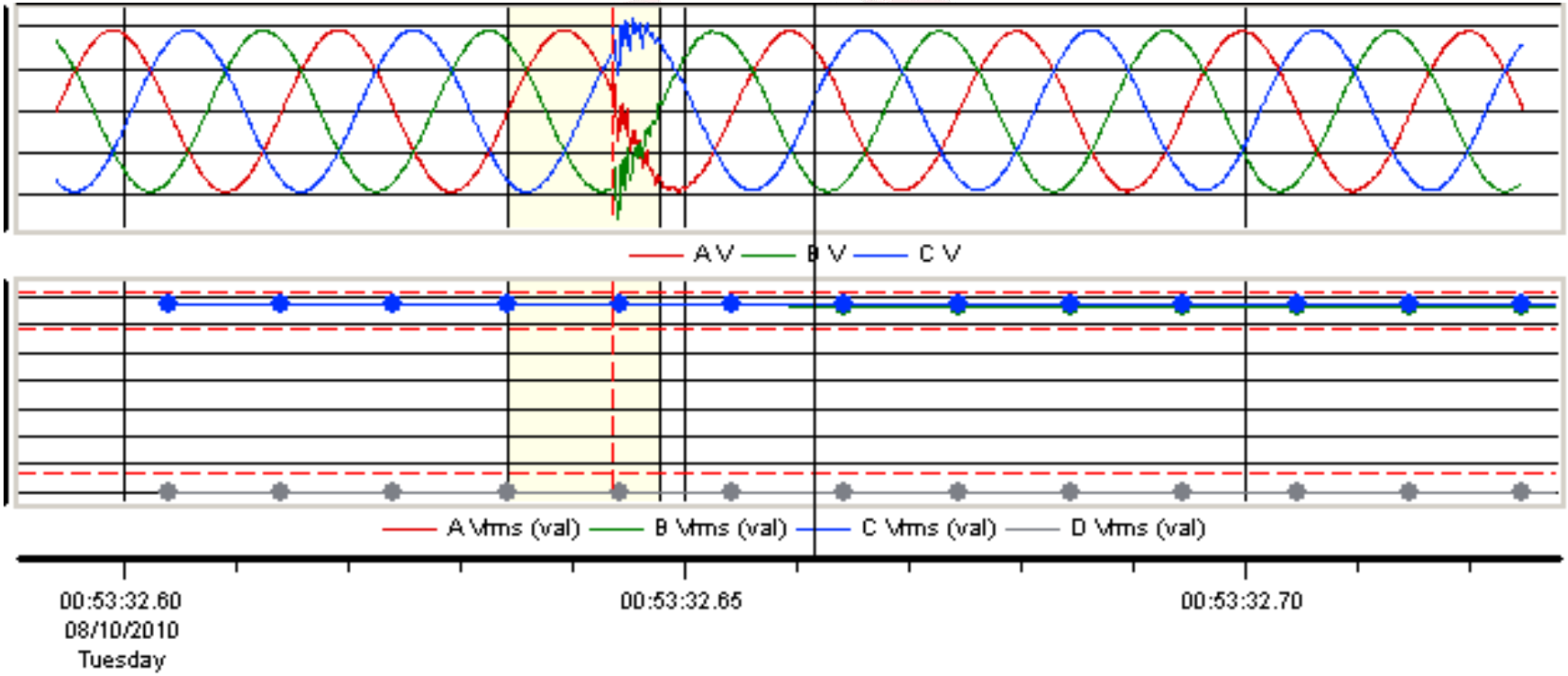

A V
B V
C V
A Vrms (val)
B Vrms (val)
C Vrms (val)
D Vrms (val)
13:58:32.90
08/11/2010
Wednesday
13:58:32.95
13:58:33.00
13:58:33.05
13:58:33.10

Multiple Zero Crossing



Event #19096 at 08/11/2010 13:38:24.746
AV Mult Z Cr

Phase Shift Event



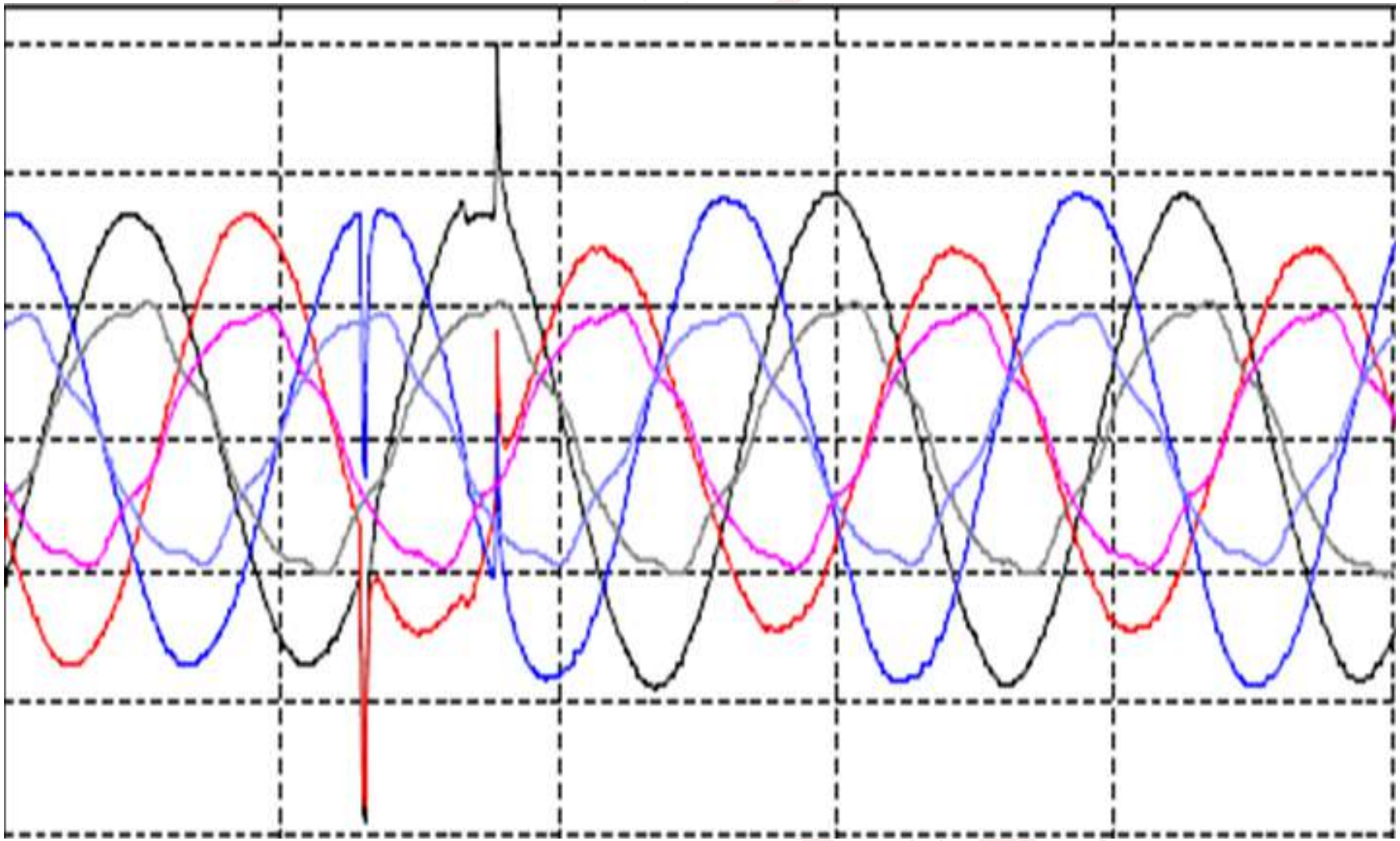
Event #9241 at 08/10/2010 00:53:32.634
BV Mild Phase Shift Neg 1/8 Cyc

	A	B	C	D	A-B	B-C	C-A
Vrms	67363	67398	67360	21.07	116145	116785	116633
VPeak	95629	127450	106794	30.73			
Irms	97.00	102.5	89.45	0.09468			
IPeak	251.8	195.6	167.6	0.1865			

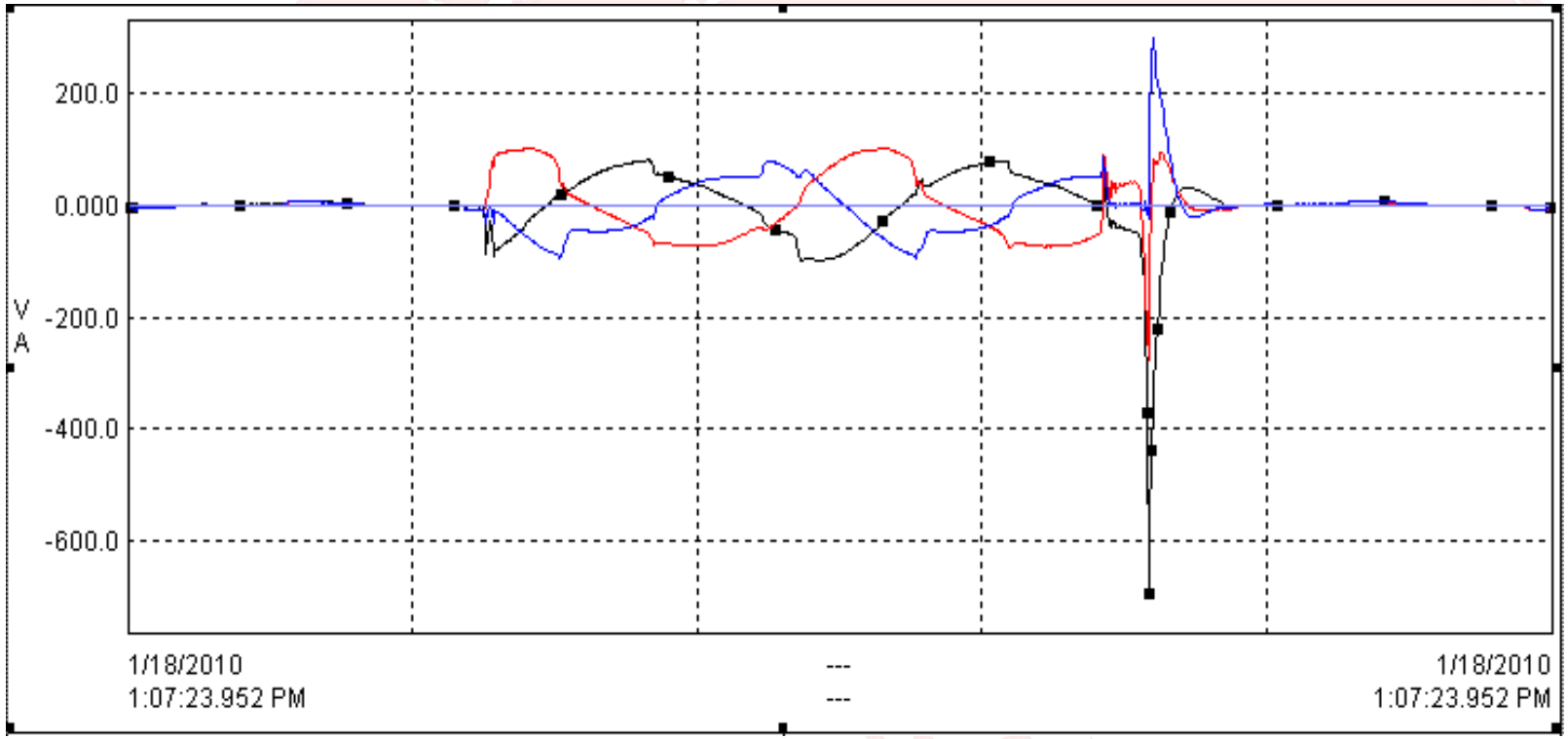
Case Study (Transient)

- This is a typical case of Transient caused by switching of a capacitor bank in the Sub Station
- Voltage transient is seen in all the feeders connected to the Sub Station
- Voltage transient is also dependent on the strength of the Grid

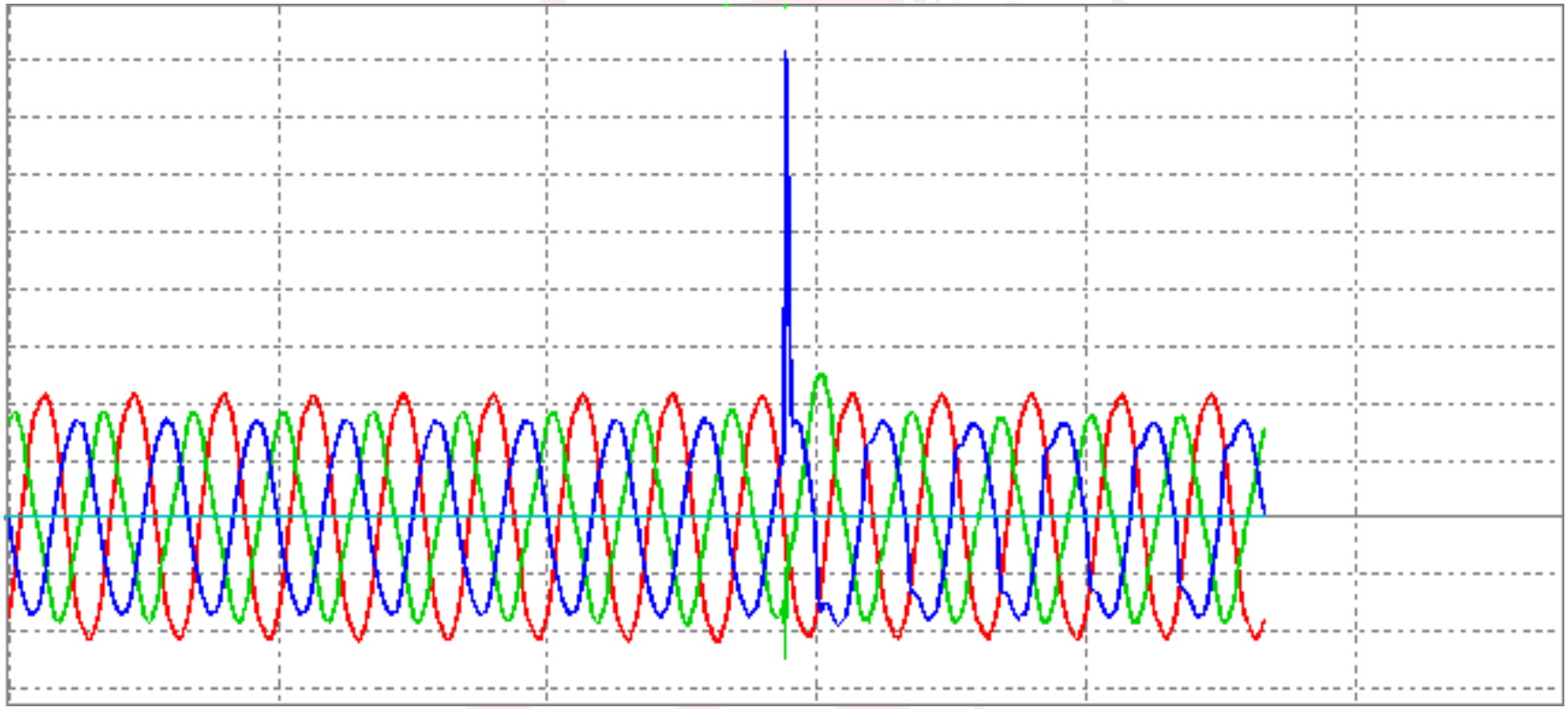
Transient



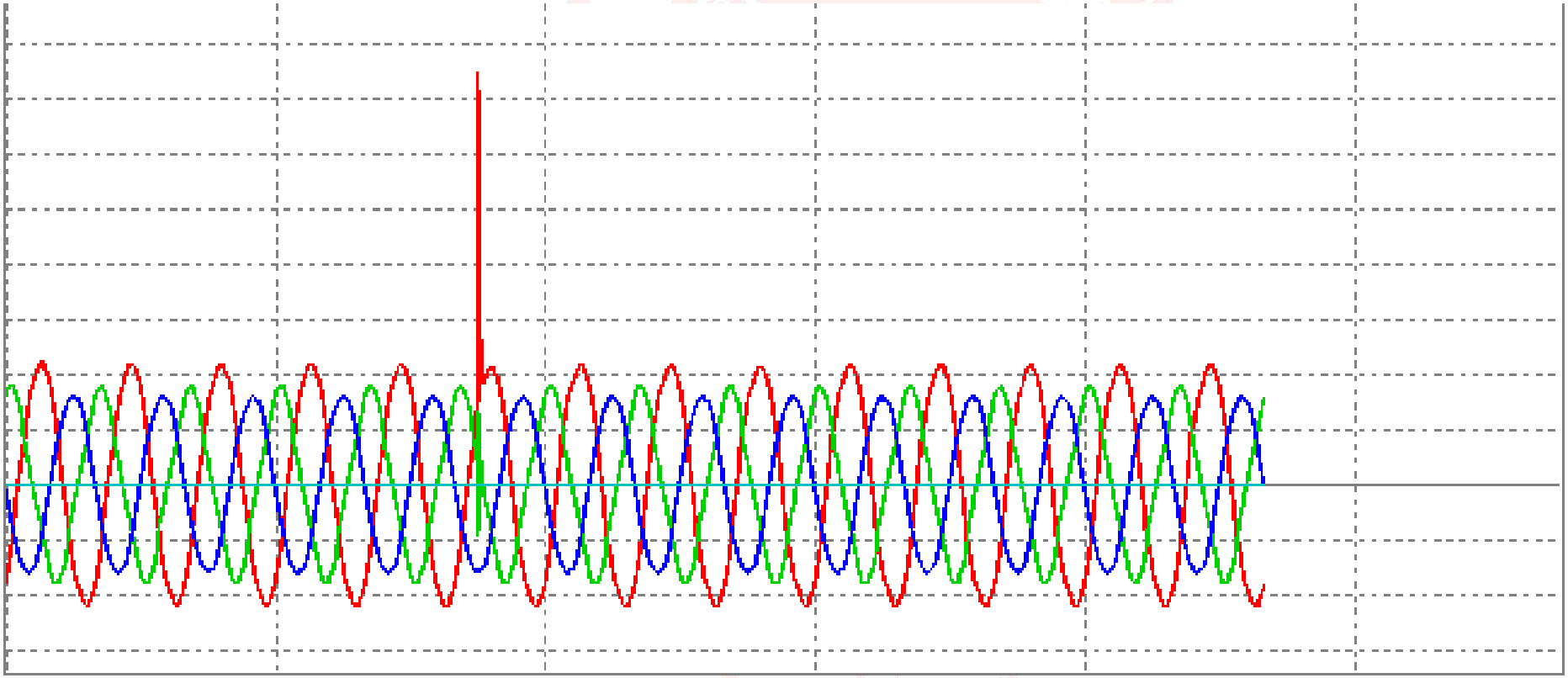
Transient due Tripping of Breaker due to inrush current



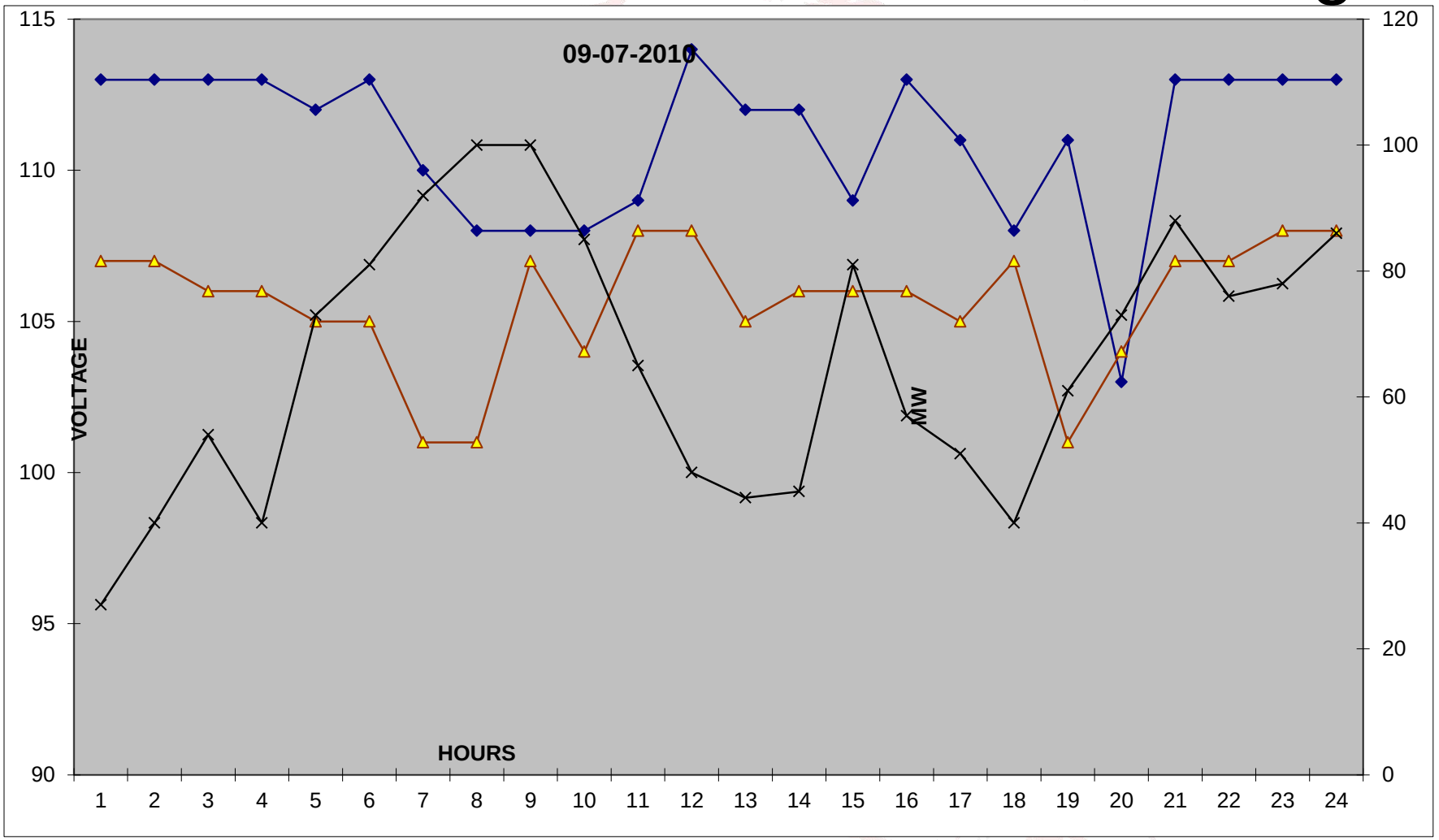
Severe Transient



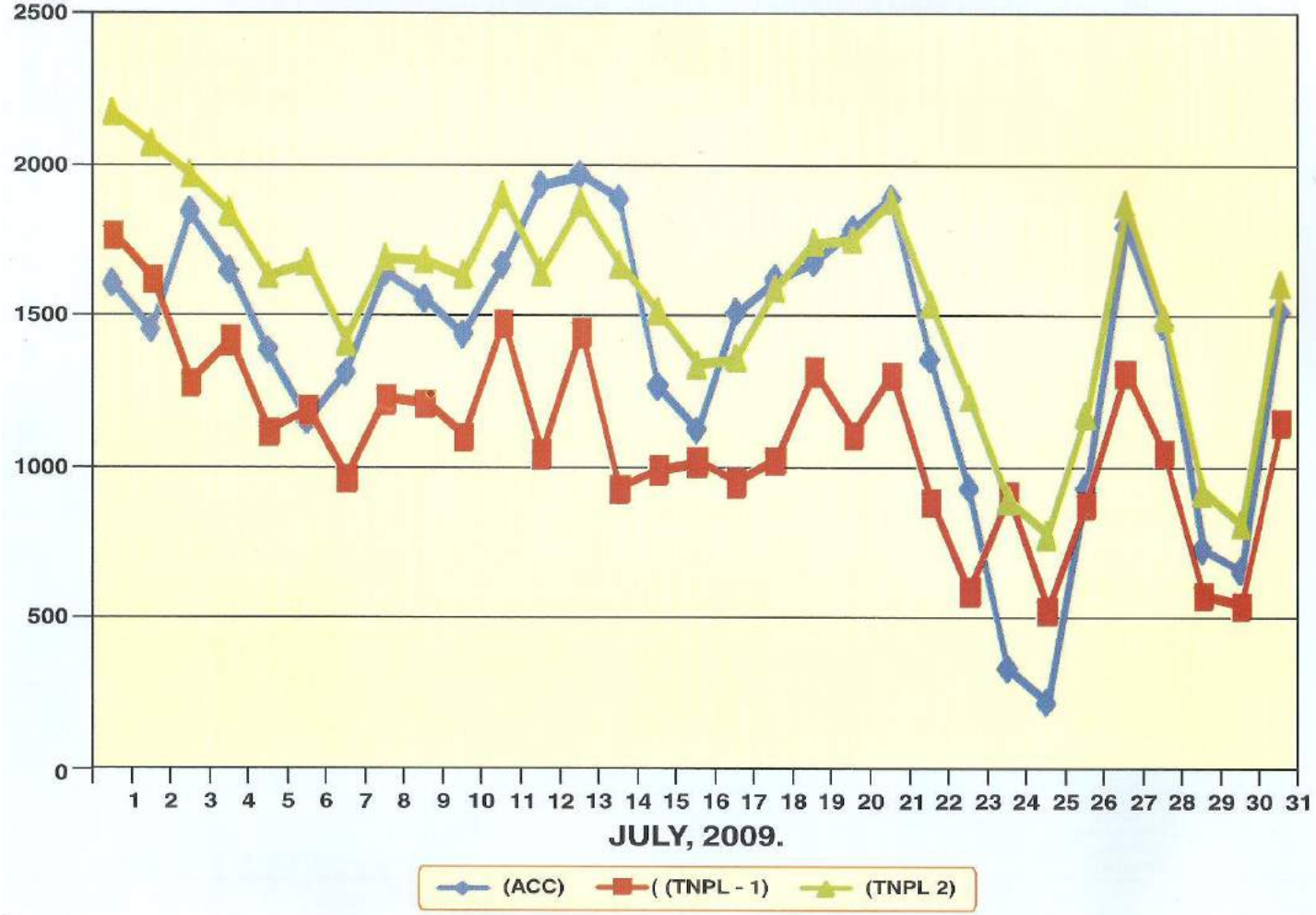
Severe Transient



WM Generation Vs 110 kV Bus Voltage



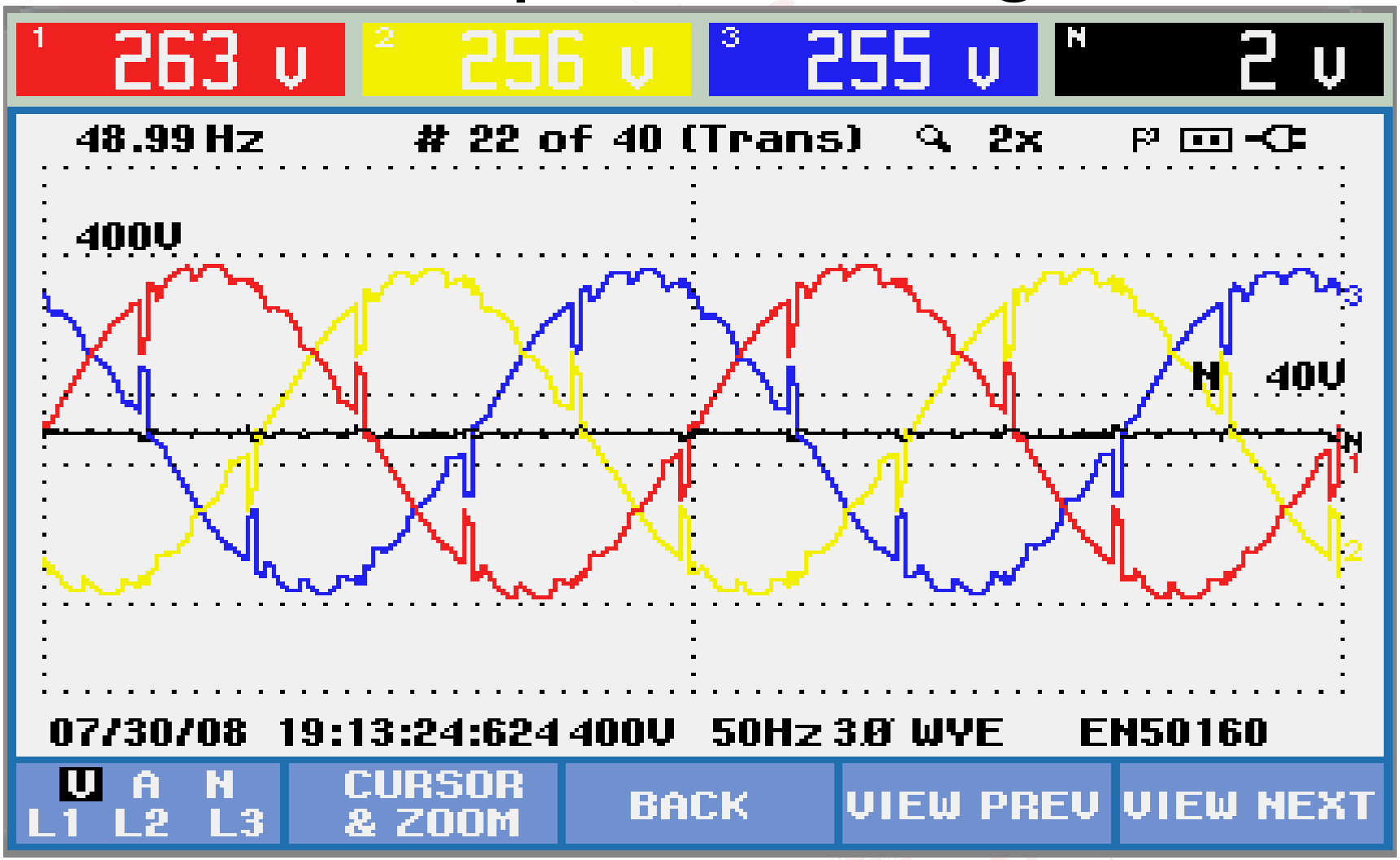
WIND MONITOR GRAPH



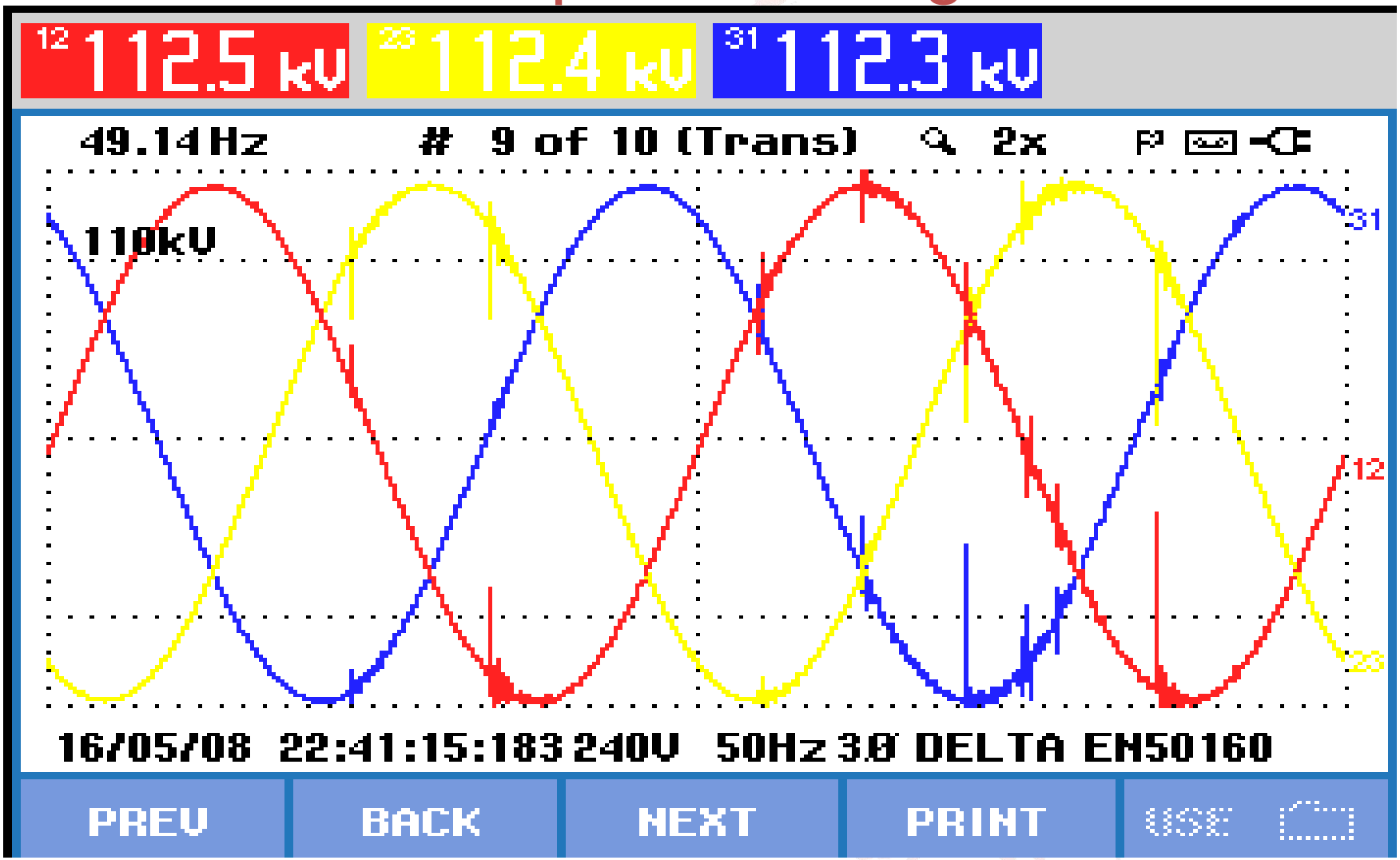
Case Study (Notching)

- This a typical case study of Notching of Voltage
- Notching is due operation of Power Electronic devices
- Notching depth is also dependant on the Strength of Grid
- Width of the Notching is dependant on the firing angle of the device

Sample Notching

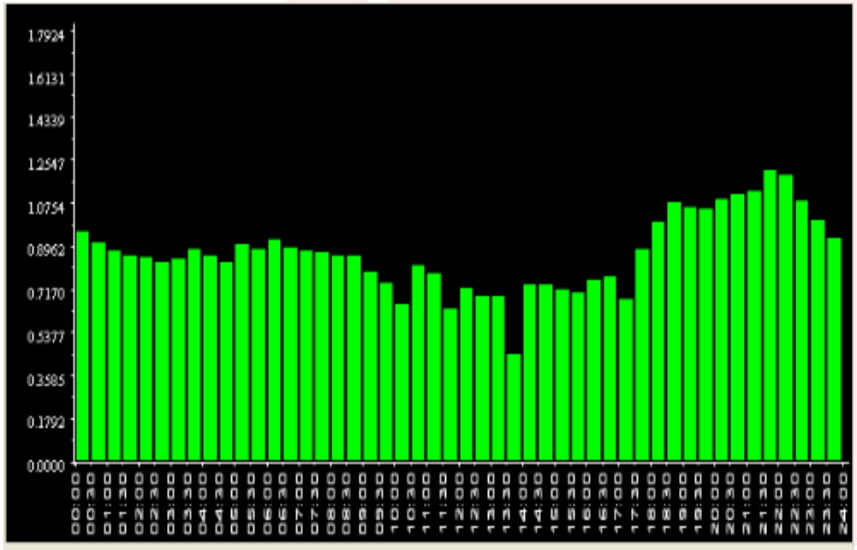


Sample Notching

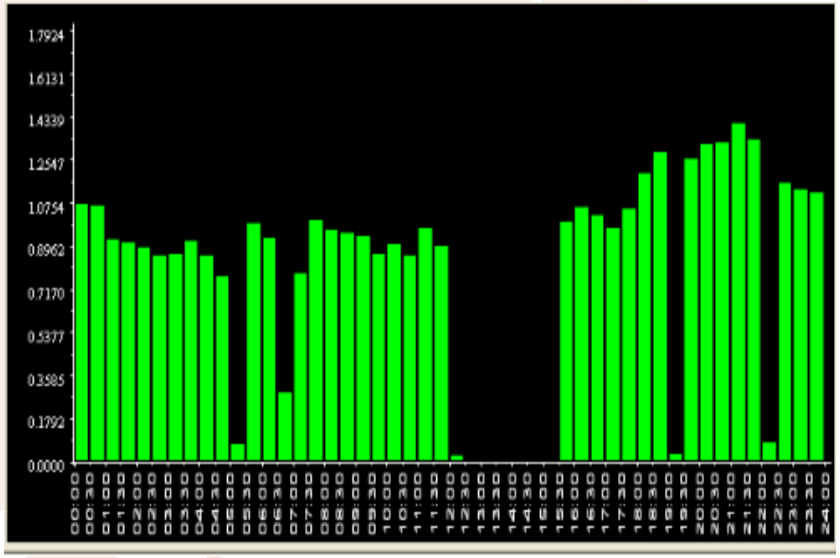


Comparison of LS Graph

Without Interruption

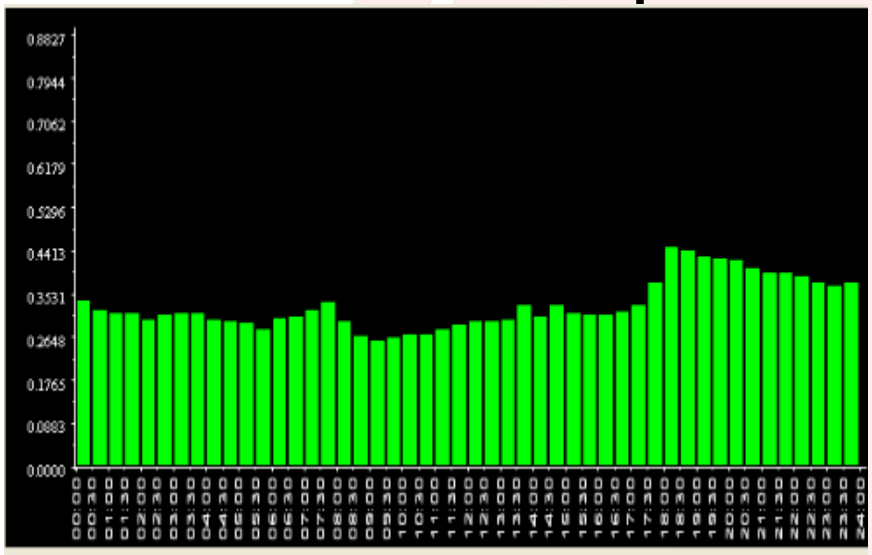


With Interruption

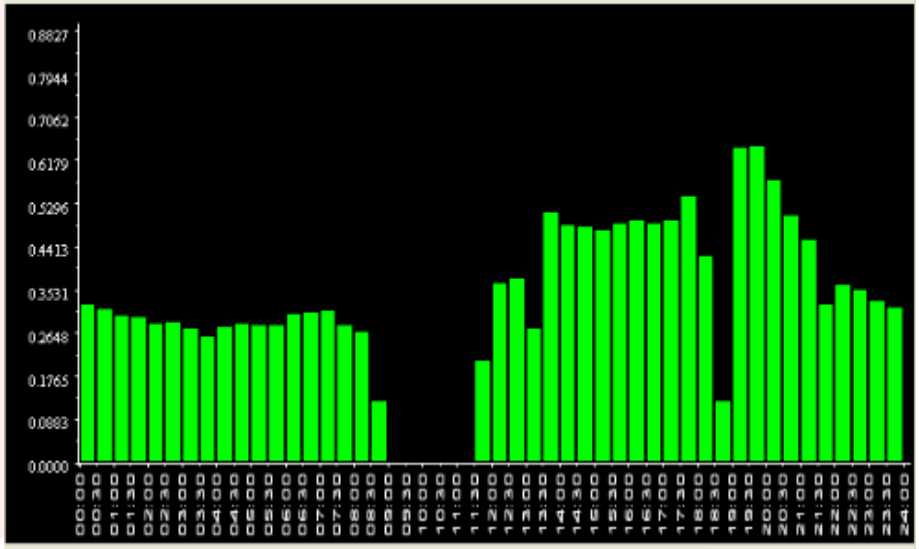


Comparison of LS Graph

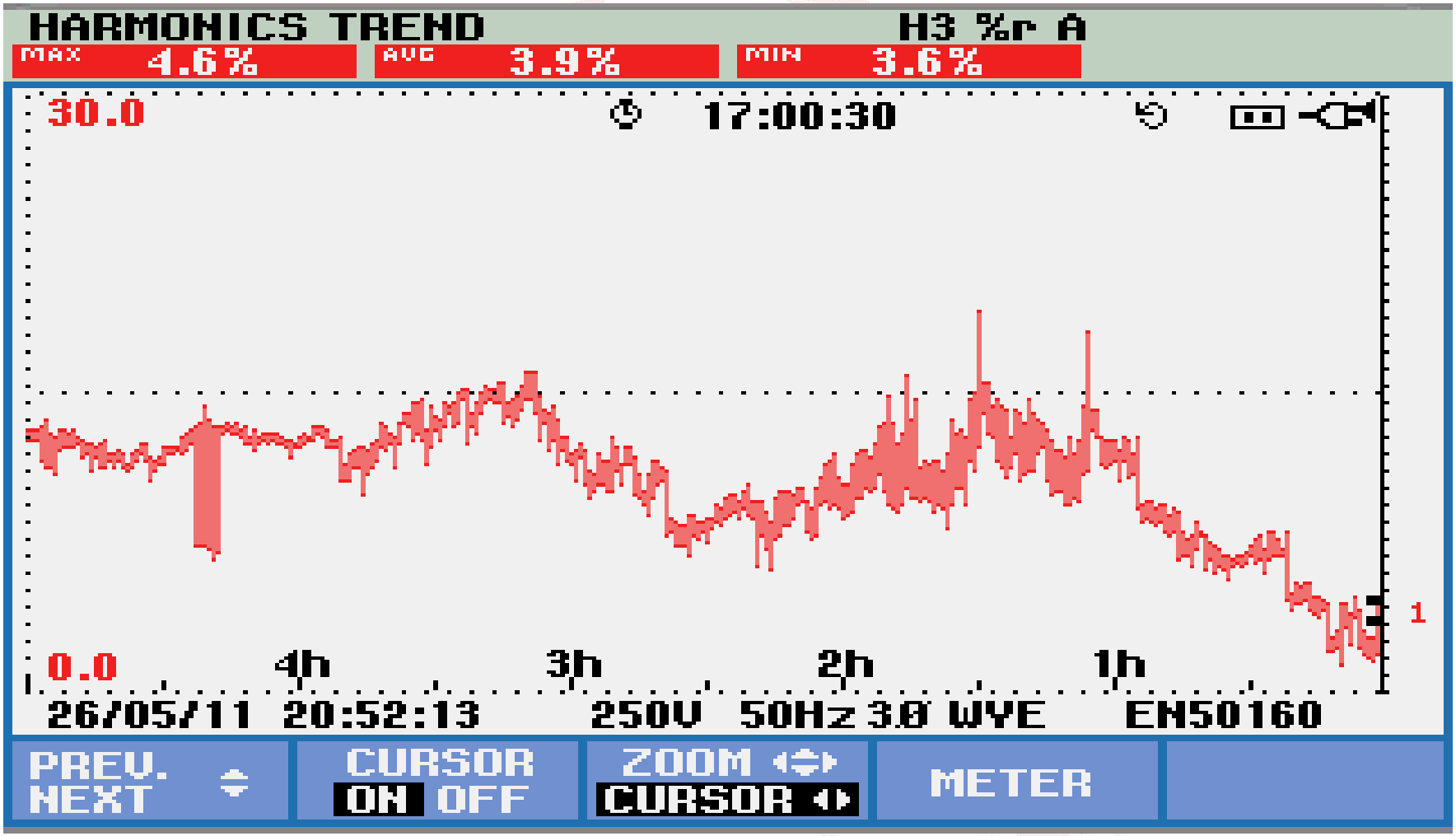
Without Interruption



With Interruption



Harmonic Trend in Domestic Complex



Questions Please?

Thank You