POWER QUALITY CHALLENGES IN INDUSTRY
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Outline

- Power Quality Issues
- Impact of Power Quality
- Voltage Sag
- Equipment Tolerances
- Field Measurements
- Mitigation Techniques
- Harmonics
- Conclusions & Suggestions for Future R&D Work

Power Quality Issues

- Voltage Sags & Swells
- Momentary & Extended Power Interruptions
- Harmonic Distortion
- Grounding
- Over Voltage Transients

This Presentation will Focus on
Voltage Sag & Harmonics

Power Quality Definition

- **Power Quality (Per IEEE Std 1100): It is the concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that Equipment.**
- **Power Quality problems are of increasing concerns in industry and commercial installations**
- **Modern Equipment is more sensitive to Voltage Sags**

Equipment Impacted by Power Quality

- **Industrial Power Electronic Equipment including Adjustable Speed Drives, UPS, Soft Starter, etc**
- **Data Control Centre**
- **Electronic Process Monitoring and Control, such as PLC**
- **Telecommunications**
- **Robotics**

What is the Primary Problem?

- *Voltage Sags* have been identified as being the Single Most Expensive Power Quality Event
- Both Industrial and Commercial Facilities are affected by this type of problem
- In many cases, the customer believes that the incoming supply has been interrupted i.e. a complete loss of power, when in fact it was a severe voltage sag
- Unfortunately, Voltage Sags are fact of life and can not readily be eliminated from regular Utility System

What is a Voltage Sag (Dip)?

- **A Voltage Sag, Per IEEE Std 1159, is:**
  " A reduction in rms Voltage in the range of 0.1 -0.9 PU for the duration greater than 0.5 cycle to 1 min". *Typical duration is ≤ 1 Sec*

- **Voltage Sag is a sudden Voltage drop while the Load remain connected to the Supply.**

What is a Voltage Sag (Cont.)?

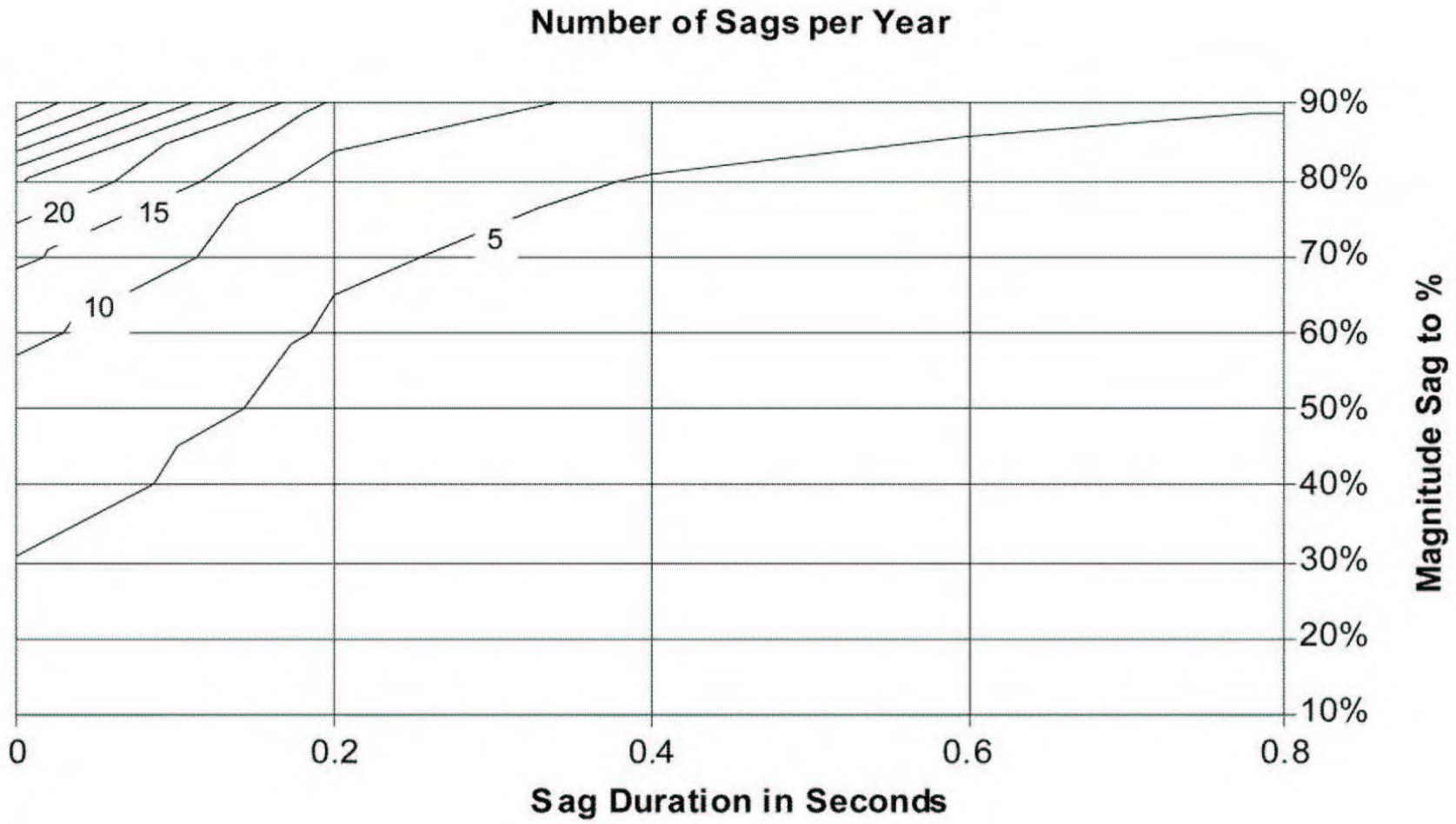
- **The measurement of Voltage Sag is stated as a percentage of the Nominal Voltage. It is a measurement of the remaining Voltage and is stated as a sag to a Percentage value. Thus a Voltage Sag to 70% is equivalent to 70% of Nominal Voltage, or 336 V for a 480 V system**

- **An interruption, on the other hand, is the reduction of supply voltage to less than 10% of the Nominal rms magnitude. Example: Supply Voltage is reduced to less than 48 V on a 480 V System**

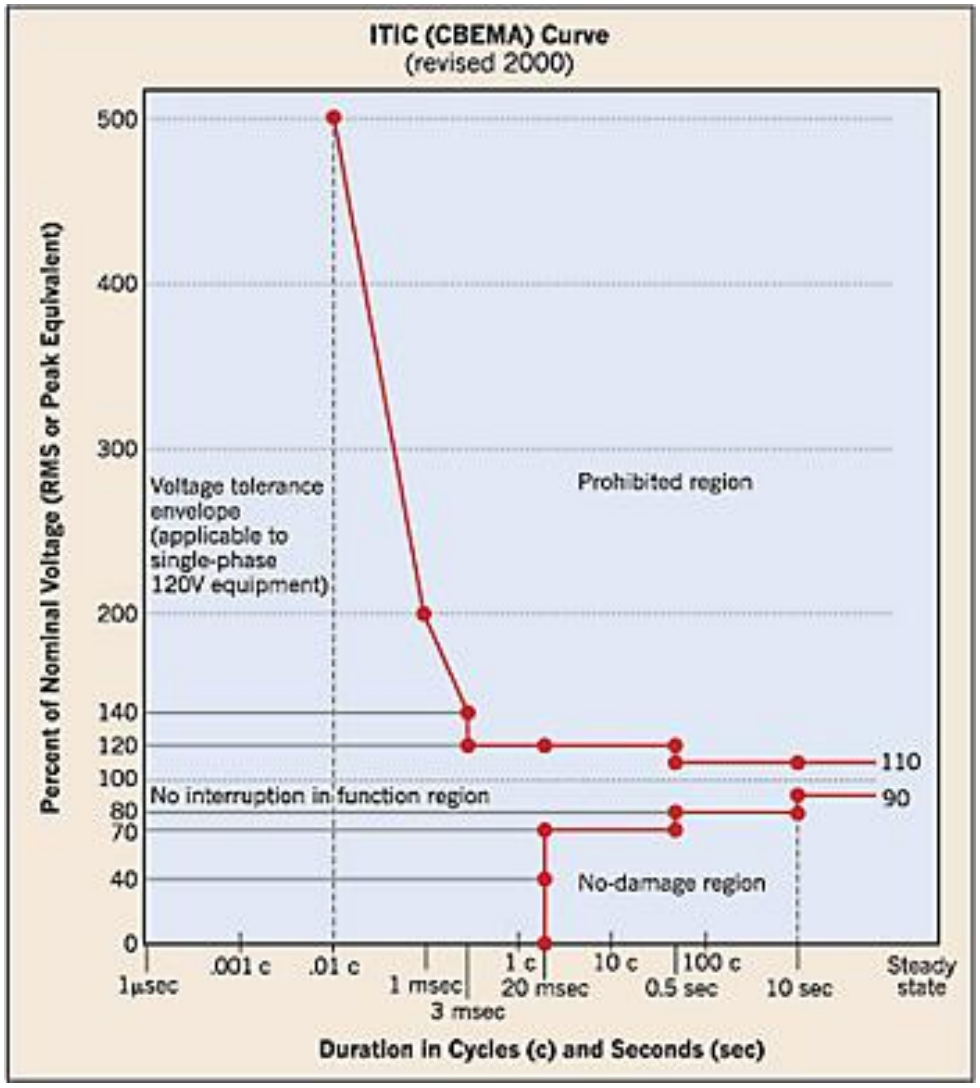
Cost of Power Quality

- **US Estimates of industrial cost is in the multi-billion $ per annum**
- **EPRI reported that 97% of cost related to Power Quality is due to voltage Sags.**
- **Lost Production, Wasted Product, Possible Equipment Damage, Restart Time and Associated Labour**

Per IEEE Std. 1100-2005, Emerald Book & EPRI Study



New ITI (CBEMA) Curve



Causes of Voltage Sags

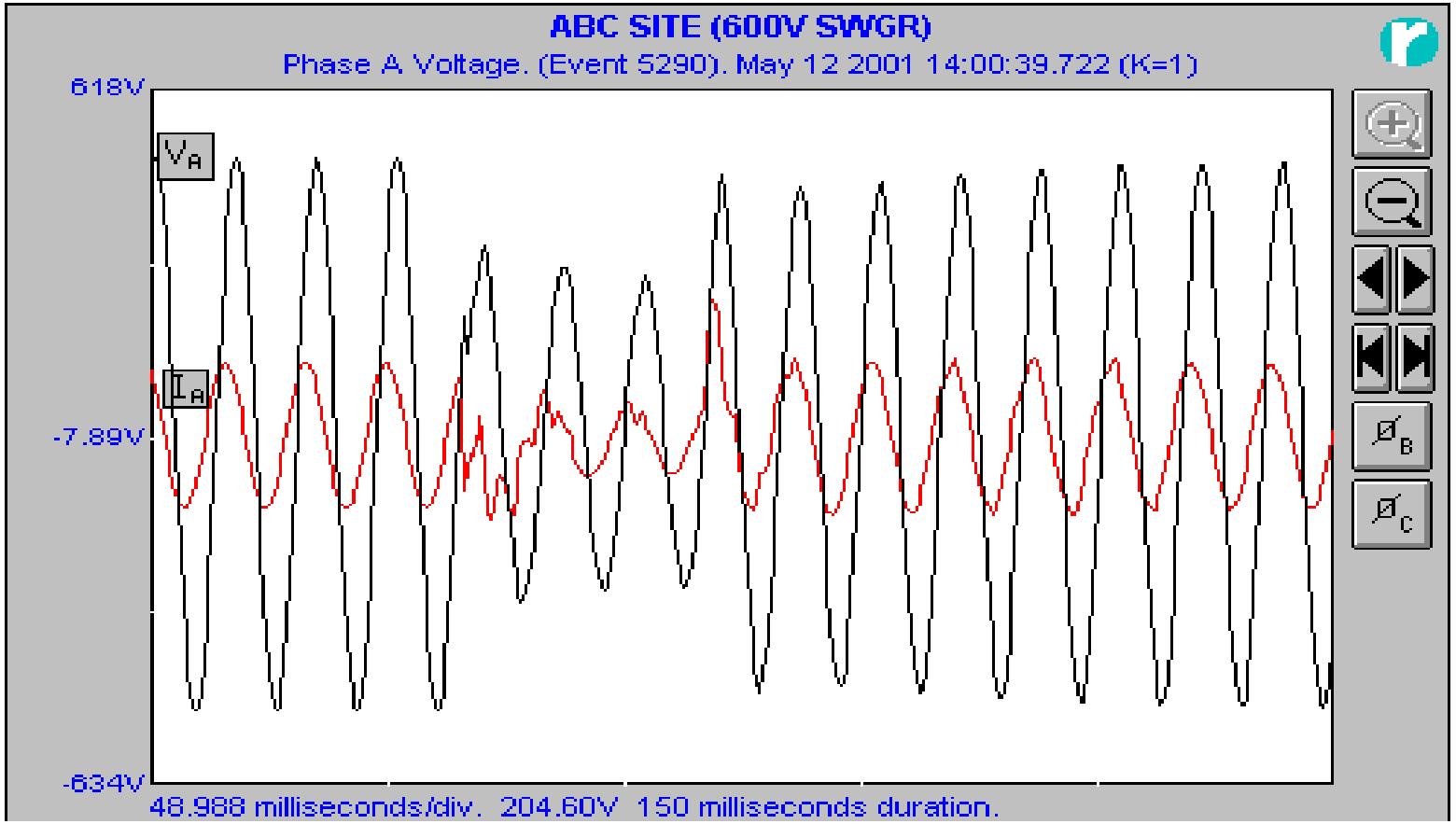
- **External (Utility System)**
  - Bad Weather
  - Equipment Failure
  - Human Error,
  - Animals & Birds,
  - Vehicle, etc.

- **Internal (Industrial Plant):**
  - Electrical fault,
  - Large Motor Starting,
  - Switching, etc.

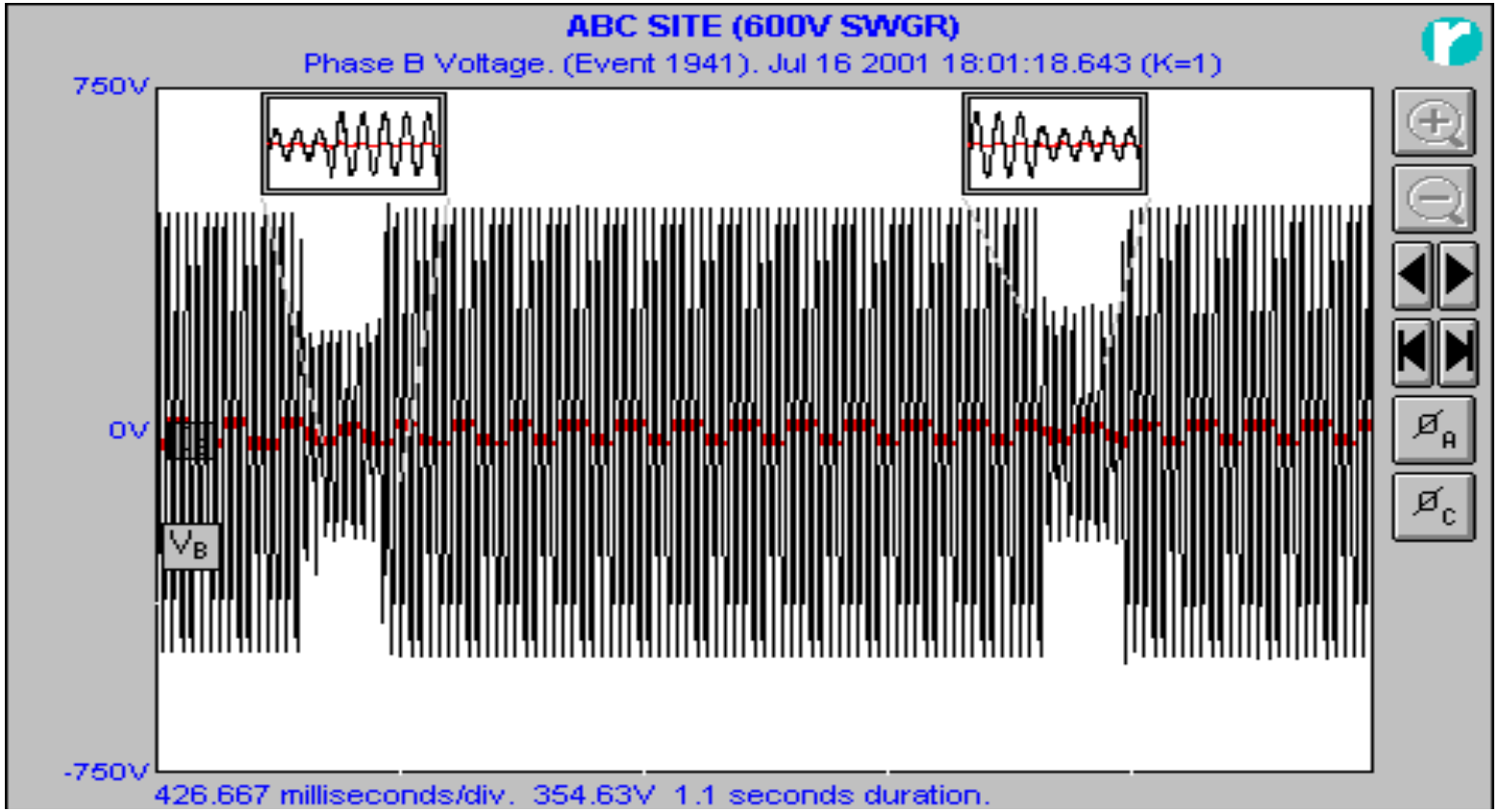
Field Measurements Cases

- Severe Voltage Sags
- Two Consecutive Voltage sags
- Summary of Voltage Sags History for One Year
- Momentary Power Outage, Auto re-closure
- Total Power Interruption & Emergency Generator Auto re-Start
- Province-Wide Outage on August 14, 2003

Voltage Sag to 50% for 4 Cycles, UPS System Crashed due to Bad Battery Cells in all four strings. Disturbance was caused by a fault on 230 kV line



Two Voltage Sags to 50% within 1 Sec.



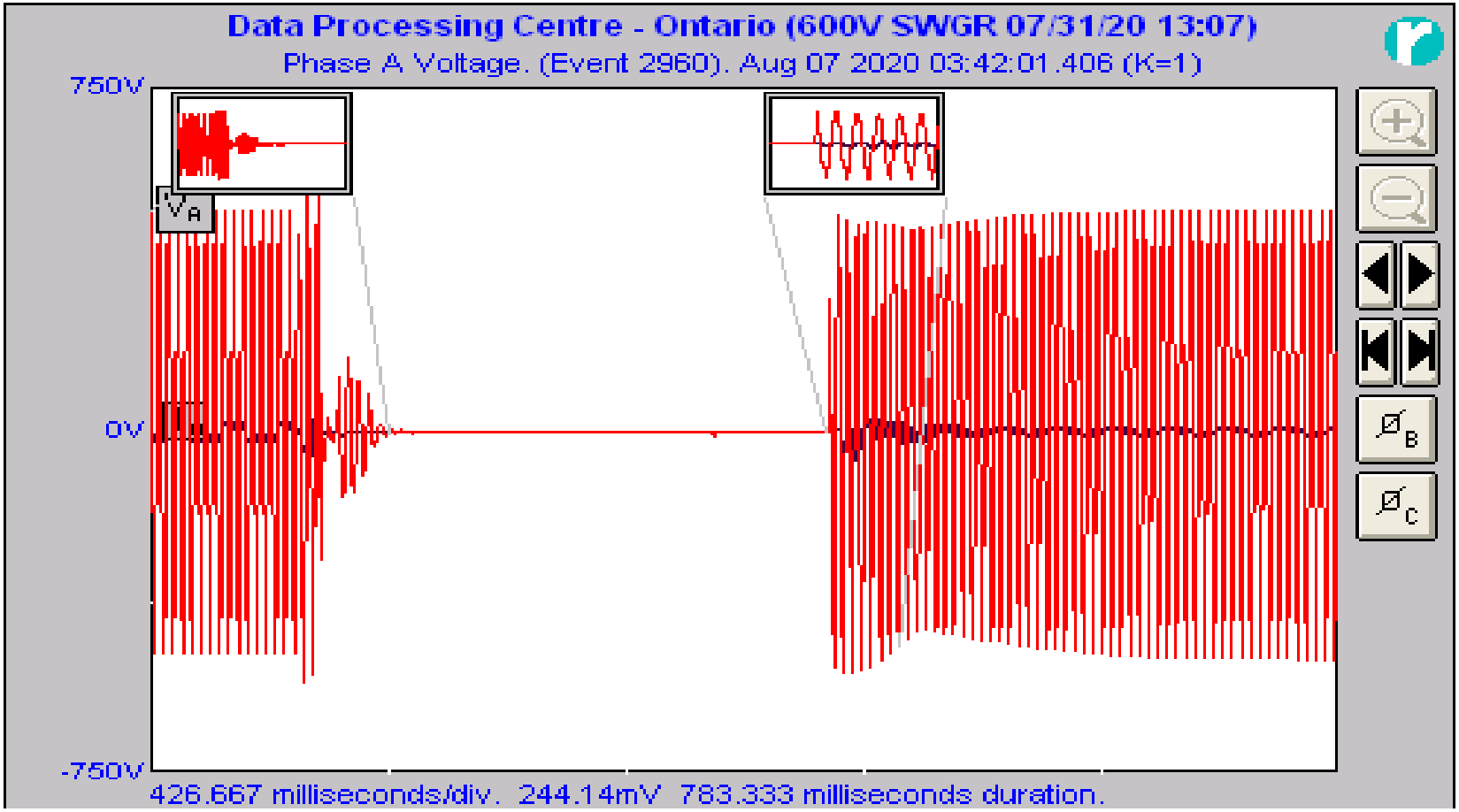
Summary of Voltage Sags for a Data Processing Centre for the period Jan – Dec, 2007. The Incoming Supply is at 27.6 KV. Twenty Three Disturbances Captured

Date	Time	Sag Magnitude To % Nominal	Duration	Comment
January 05	14:31	65%	101 ms	Severe Disturbance
January 24	11:50	75%	168 ms	Severe Disturbance
January 24	11:50	75%	168 ms	Severe Disturbance
January 30	06:24	45%	265 ms	Severe Disturbance
January 30	13:34	63%	168 ms	Severe Disturbance
January 30	13:34	63%	168 ms	Severe Disturbance
February 27	11:55	80%	83 ms	Severe Disturbance
March 07	03:01	60%	100 ms	Severe Disturbance
March 11	12:08	65%	116 ms	Severe Disturbance
March 17	10:42	40%	150 ms	Severe Disturbance
March 17	10:42	40%	150 ms	Severe Disturbance

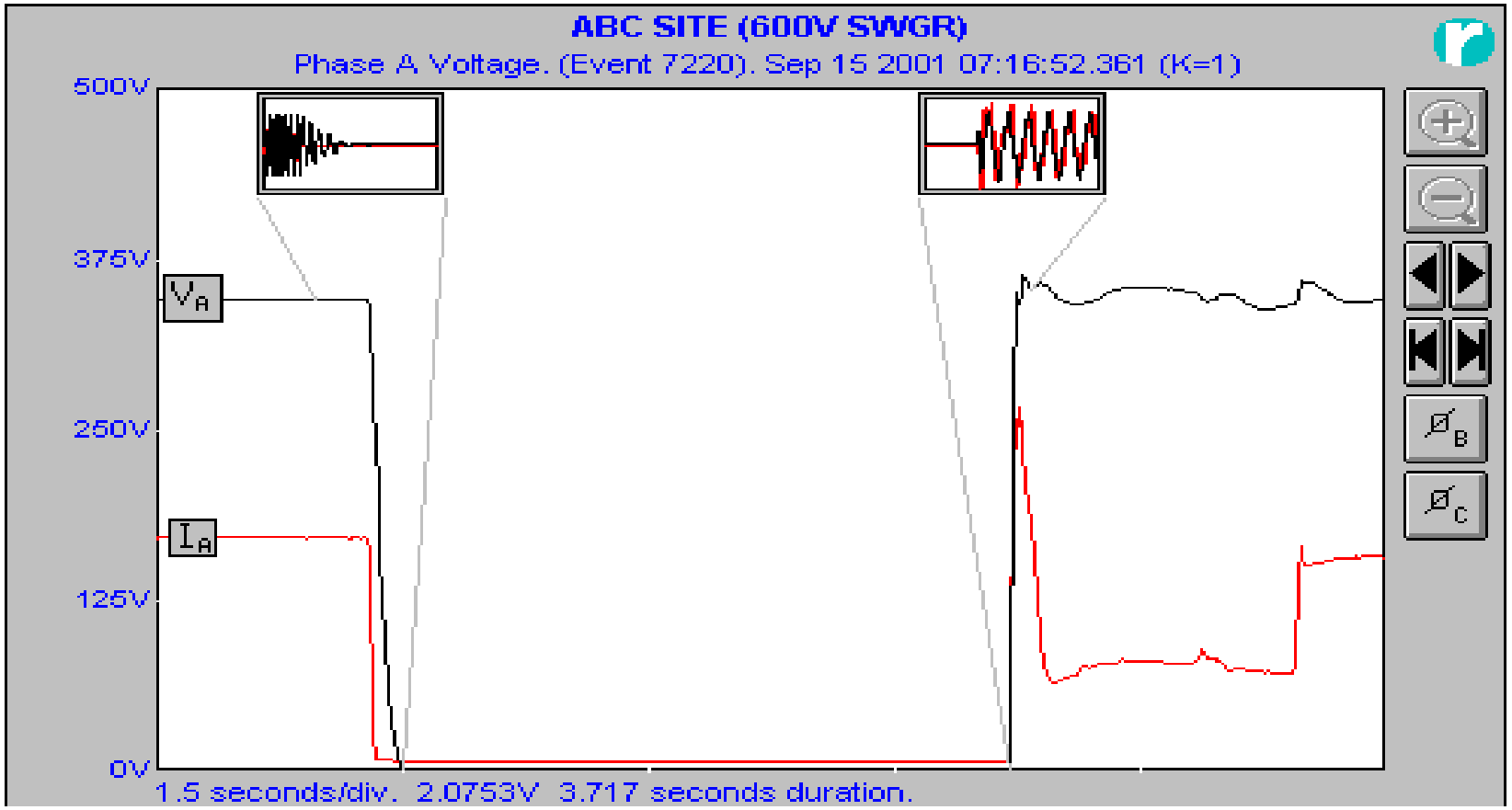
Summary of Voltage Sags for a Data Processing Centre for the period Jan – Dec, 2007.

Date	Time	Sag Magnitude To % Nominal	Duration	Comment
May 18	09:03	45%	50 ms	Severe Disturbance
May 24	13:16	35%	50 ms	Severe Disturbance
May 31	16:29	35%	132 ms	Severe Disturbance
June 11	16:16	0%	832 ms	Momentary Outage (Auto Re-closure)
June 19	15:16	0%	1 minutes	Prolonged Outage Emergency Gen. Started
July 04	07:28	70%	168 ms	Severe Disturbance
August 20	01:19	60%	116 ms	Severe Disturbance
September 26	01:42	58%	51 ms	Severe Disturbance
November 25	07:06	0%	823 ms	Momentary Power Outage (Auto Re-closure)
November 25	13:17	10%	68 ms	Very Severe Disturbance
December 16	02:22	71%	150 ms	Severe Disturbance
December 16	02:25	71%	150 ms	Severe Disturbance

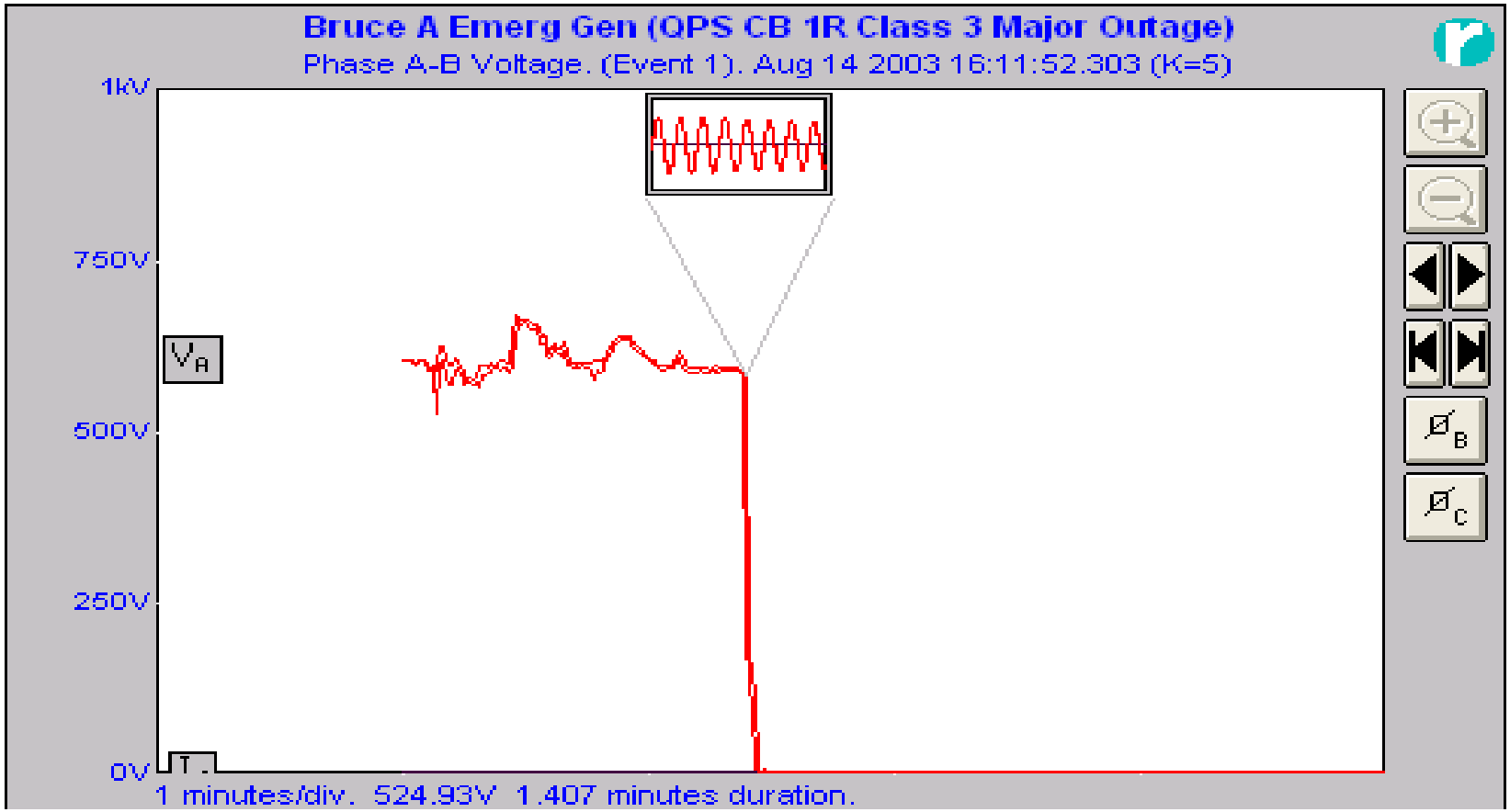
Momentary Loss of Power - 930 ms.
Aug 07, 2020 (Auto Re-closure)



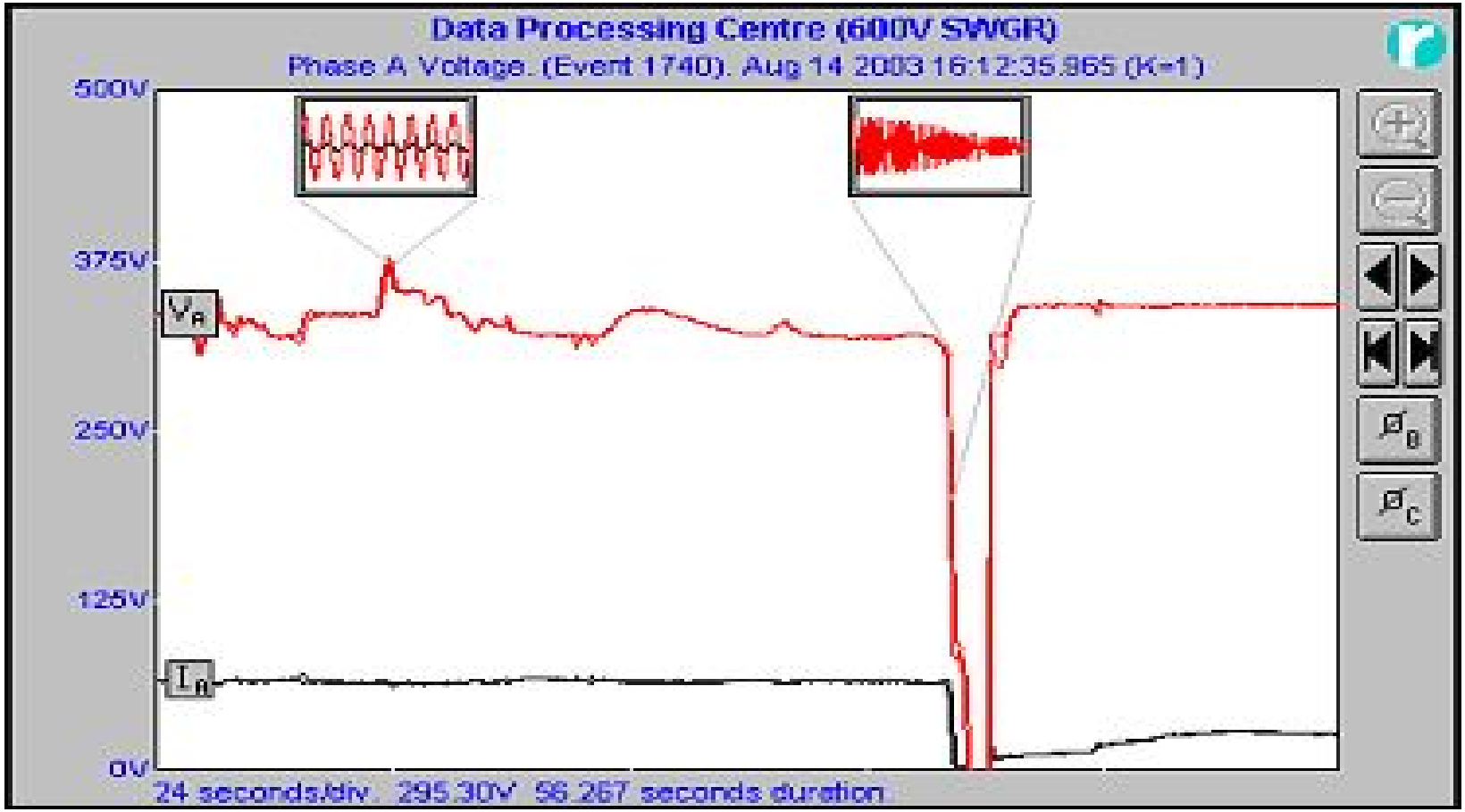
Total Interruption Generator on line in 4 sec.



Province Wide Utility Blackout on Aug 14, 2003



Voltage Profile at Data Processing Centre during Utility Blackout on Aug 14, 2003



Mitigation Techniques

- Uninterruptible Power Supply (UPS)
- Active Voltage Conditioners (AVC)
- Sag Ride-Through Capability
- Plant-Wide Automatic Re-Acceleration

Harmonics

- Harmonic is a Voltage or current at multiple of the fundamental frequency of the system
- Harmonics are produced when non-linear load is used such as rectifier or inverters
- A 3-phase static power converter generates harmonic currents (h) the order of which is given by

  $h = kp \pm 1$

  k: is any integer, 1, 2, 3…

  p: number of pulses of the converter system

Harmonics

- A balanced, 3-phase, 6-pulse converter produces odd harmonics 5^{th}, 7^{th}, 11^{th}, 13^{th}, etc. The theoretical maximum amplitude of each harmonic current is equal to fundamental component divided by harmonic order.
- Harmonics are reduced by Multi-pulsing. The dominant harmonics for 12 pulse are 11^{th}, 13^{th}, 23^{rd}, 25^{th}, etc. This is achieved by using Multi-winding isolating transformer.
- For large adjustable speed drives rated say 10,000 HP a 36 pulse converter might be used having an isolating transformer with six secondary windings.

IEEE 519 Standard

- **This standard specifies guidelines with regard to limiting the harmonic voltage distortion that a utility is required to meet at the point of common coupling (PCC).**
- **It also specifies the amount of current distortion that an end-user is allowed to inject back into the network at PCC.**
- **The voltage and current distortion limits are specified in 519 standard. For example, an end user is allowed higher current distortion limits if it is connected to a stiff system, higher MVA fault.**

Typical Harmonic Issues

- **Increased losses in Electrical Equipment, possibly resulting in over-heating in transformers and motors.**
- **Possible of Electrical resonance with existing power factor correction capacitors.**
- **Interference with communication network.**

Reference Material

- **1159 -2019: IEEE Recommended Practice for Monitoring Electrical Power Quality.**
- **IEEE P3002.8-2018: Recommended Practice for Conducting Harmonic Studies and Analysis of Industrial and Commercial Power System.**
- **1566-2015: IEEE Standard for Performance of Adjustable-Speed AC Drives rated 375 kW and Larger.**
- **C57.18.10 – 1998: IEEE Standard Practices and Requirements for Semiconductor Power Rectifier Transformers. A Draft is now in Circulation.**

Conclusions

- **Voltage Sag is Considered the Most Costly Power Quality Problem in our Industry**
- **Conduct Power Quality Study to Determine any Existing System Abnormalities and when Installing new Equipment**
- **On-Line Power Quality Monitoring Equipment are Available for Measurements. Also, commercial software for harmonic analysis and Filter Design**
- **Harmonics are Produced whenever non-linear loads are presents**

Suggested Future R&D Work

- **Active Voltage corrections equipment having fast waveform analysis and sag correction for longer durations.**
- **Advanced Portable and on-line Power quality monitoring devices with very high resolutions covering pre-fault, fault and post-fault events.**
- **Active harmonic Filters.**

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Any Questions, Please ???

Bob Hanna