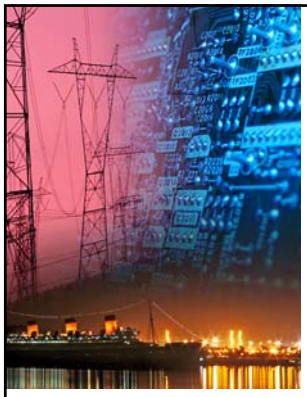

IEEE Transmission & Distribution Conference

Monitoring Electric Power Quality

Chicago, IL

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Scott Schindlbeck
Elspec North America
23 April 2008
Room s401d – 1:00pm

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Originally presented at EPRI PQA/ADA Conference 2007 – Long Beach, CA

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Objectives for Power Quality Monitoring

- Power Quality Statistics
- Power Quality Contracts
- Power Quality Troubleshooting
- Resolving Disputes
- Verifying Compliance With Standards

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Can Power Quality Really Be Measured?

- Power quality has many meanings depending on what the power is used for
- Measuring PQ is all about deviations from normal state
- USERS are interested in any deviation that is large enough to cause a problem
- SUPPLIERS are interested in ensuring that deviations are maintained below a level that might cause problems

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Quality Measurement Considerations

- PQ events are multi dimensional dips,voltage,current,time,harmonics,flicker,frequency
- PQ effects have thresholds (they become problematic above a certain level)

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Power Quality Parameters

- Supply voltage unbalance
- Voltage and current harmonics
- Interharmonics
- Rapid voltage changes
- Power frequency
- Magnitude of supply voltage
- Flicker
- Supply voltage dips and swells
- Voltage interruptions
- Transient voltages

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Existing Standards

- IEC 61000-4-30
  - Measurement methods
  - Measurement formulas
  - Accuracy levels
  - Aggregation period definition

- EN 50160
  - levels for power quality parameters
  - time-based percentage
    (e.g., limiting voltage flicker to 95% of the time per week)

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Supply Standard EN 50160

- Governs supply voltage parameters
- “95%”
- Excludes fault conditions, adverse weather
- Important standard but not a guarantee
- Written from suppliers point of view

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Measurement Standard IEC 61000-4-30

- Defines the method of measurement and interpretation of results for power quality parameters in single and three phase 50/60 Hz power systems

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

- Any instrument conforming to the IEC61000-4-30 Class A standard regardless of manufacturer will read the same when subjected to the same inputs(V,I)
- Creates a level playing field
- With today's technology we can measure beyond this standard providing power quality professionals the information they need to solve real issues

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

IEC 61000-4-30 Test Equipment specification

	Class A			Class B
	Measurement	**Interval**	**Accuracy**	
Power frequency	Hz	10 sec	± 10mHz	Manufacturer to indicate
Magnitude supply voltage	Vrms	10 cycles	**± 0.1%**	Manufacturer to indicate
Flicker (IEC 61000-4-15)	Plt	2 hr	± 5%	Manufacturer to indicate
Voltage dips, swells and interruptions, rapid voltage changes	½ cycle Vrms	10 ms	± 0.2%	½ cycle Vrms
Unbalance (method of symmetrical components)	Vrms fundamental	10 cycles	± 0.15% (uncert.)	Manufacturer to indicate
Harmonics (IEC 61000-4-7)	THD, Harm V, A, Inter harmonics	10 cycles	± 1-5%	Manufacturer to indicate
Transients (not specified)	V peak	50 µ sec (200kS/s)		
Mains signaling	Inter harmonic	10 cycles	± 1-5%	Manufacturer to indicate
Flagging	Dip, swells, interruptions might create unreliable readings of Hz, Vrms, Unbalance and Harm. Therefore must be re flagged (dirty) to avoid miss interpretation			Not specified
Time synchronization	**External clock; GPS**		1 period	Manufacturer to indicate

Leonardo ENERGY www.leonardo-energy.org

Copper Development Association www.cda.org.uk

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Current Trends in Power Quality Standards

- Several countries are modifying Standards to improve network power quality. Examples:
  - Norway (Norwegian Water Resources and Energy Directorate):
    - Reduce averaging periods from 10 minutes to 1 minute
    - Force maximum 100% levels of compliance, (compared to 95% in EN 50160).
  - Hungarian Regulatory Agency:
    - Force averaging period every 3 seconds

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

The impact of existing standards on Power Quality Analysis and Solutions

- Time aggregation hides power quality issues
- Parameter values are limited and time-restricted
- Power quality variables are bound to only 3 voltages
- Source identification and propagation analysis becomes extremely difficult (or near impossible) due to limited information available from power anomalies

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

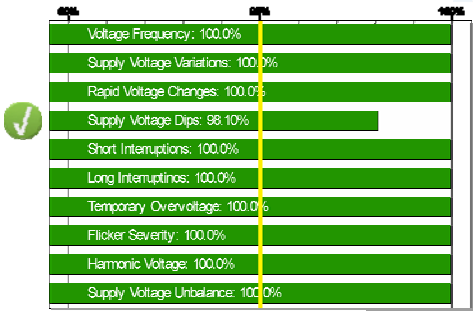
Requirements for Optimizing Power Quality Analysis

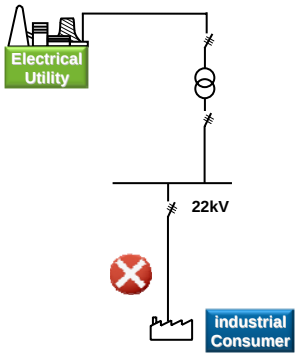
- Data compression technology
- Continuous measurement of available information all the time in 1024 sample/cycle
- 2 parallel computation engines: IEC 61000-4-30 Class A and cycle-by-cycle, up to the 511th harmony
- Full scale readings 6000V / 75A at high accuracy
- Real time flickering – 2, 10 and 60 second periods
- Periodic storage of 4 quadrant energy (active and reactive) for total 16 parameters
- Detailed Inter- and Sub-harmonics

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

EN 50160 Compliance

- Main service of an industrial customer
- Unexplained production interruptions and equipment failures
- According to EN50160 everything is OK although the site is experiencing significant damage



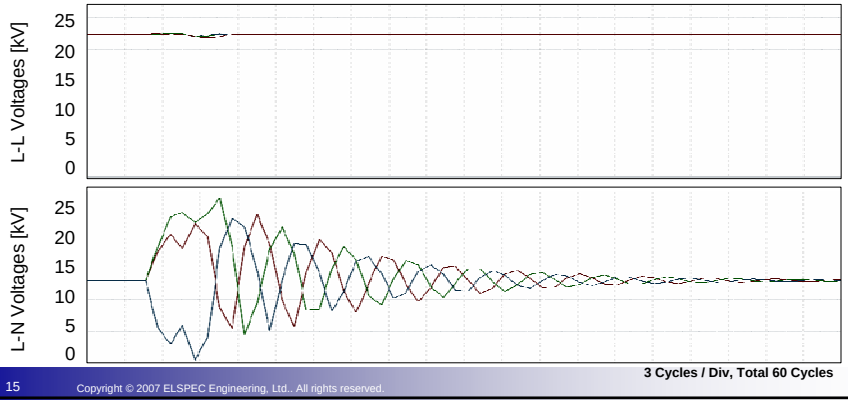


Compliance with EN 50160 at Industrial Customer's Main Service

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Not Recording All Parameters: Hidden Line-to-Ground Event

- EN50160 limits measurements on Delta connections to Line-to-Line voltages
- The following event causes accumulative damage to MV Delta connected
- Source: Short circuit between the blue phase and the ground
- Result: No Record of a potentially damaging Line-to-Ground event



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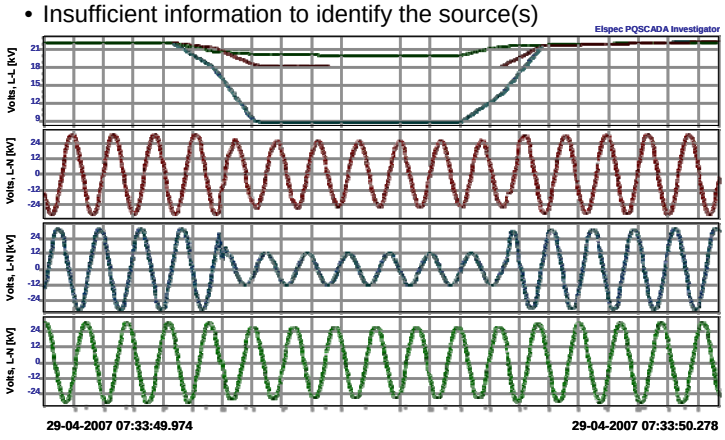
Not Recording All Parameters: Event Analysis

- Conclusion from 16 cycles: Line-to-Line Voltage Sag
- Insufficient information to identify the source(s)



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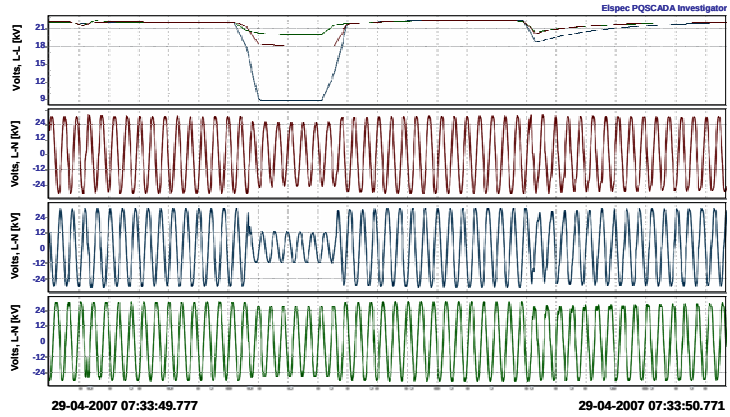
Not Recording All Parameters: Sequence of Events (Zoom-Out)

- 1 second of information reveals two sequential events



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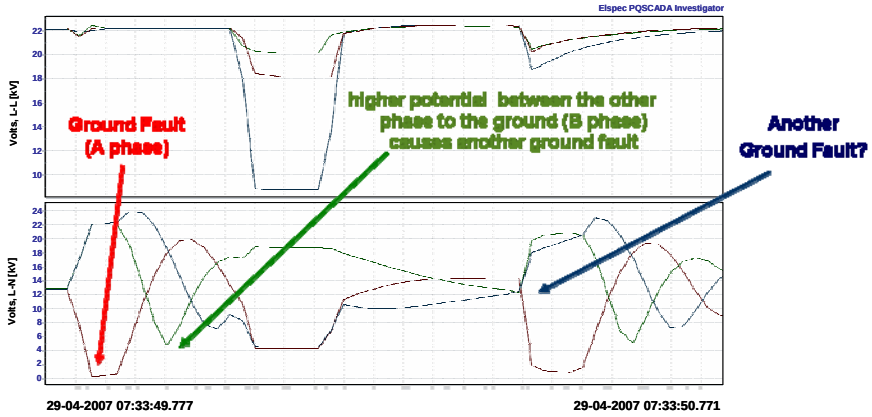
Not Recording All Parameters: Sequence of Events (L-N Added)

- Adding Line-to-Neutral voltages reveals the cause



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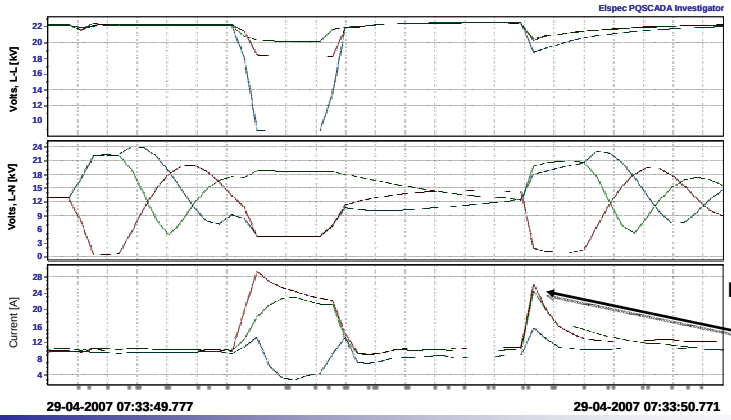
Not Recording All Parameters: Sequence of Events (Aftershock)

- Aftershock event caused by simultaneous re-connection of many loads after the event



Monitoring the Current adds information

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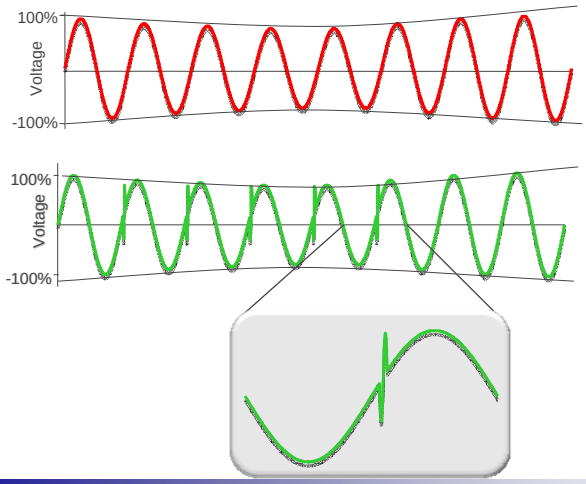
High Sampling Rate



Event at 64 samples per cycle – a Voltage Sag?

Same event at 1,024 samples per cycle – Transients!

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Averaging vs. Rapid Parameter Monitoring

- Standards recommend averaging periods for parameters
- What averaging achieves:
  - Fewer resources required, such as less storage space and bandwidth
  - More stable readings
  - Similar information on every analyzer

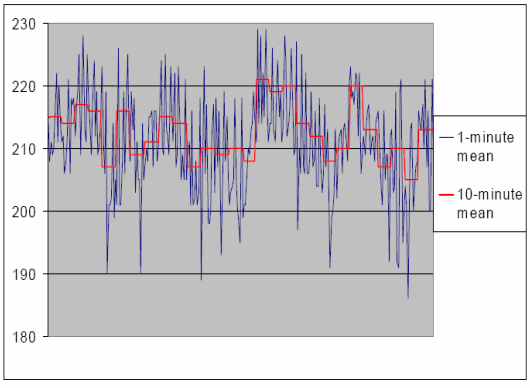
- What averaging causes:
  - A large amount of vital power quality information remains hidden
  - No ability to understand the network and the propagation of events

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Averaging vs. Rapid Parameter Monitoring

- Source: SINTEF Energy Research, Norway

Different Results:

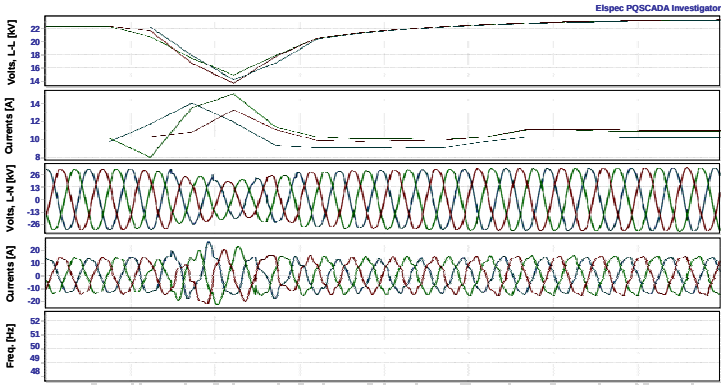


- 10 minute averaging = Voltage is below 207V 3.5% of the time (nominal 230V minus 10%)
- 1 minute averaging = Voltage is below 207V 28% of the time.
- Cycle-by-cycle RMS Voltage Monitoring is essential in order to understand the cause and provide a solution

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Continuous Logging - 16 Cycles

- Voltage drop at a large industrial area.
- Rule of thumb: Voltage drop plus current rise => downstream event



16 waveforms sampling

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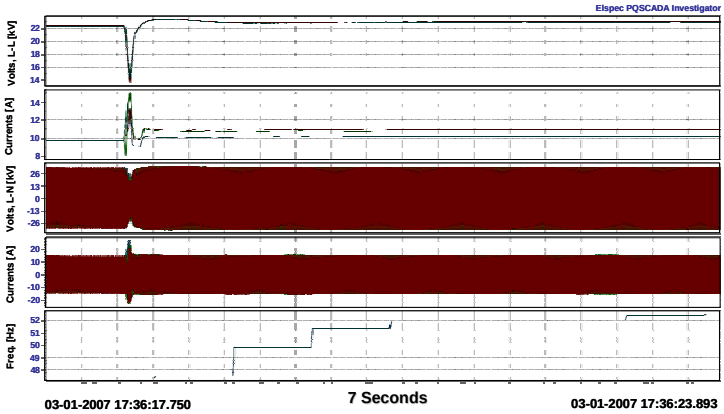
Continuous Logging - ~300 Continuous Cycles (Zoom-Out)

- The change in frequency points to an external source



03-01-2007 17:36:17.750 7 Seconds 03-01-2007 17:36:23.893

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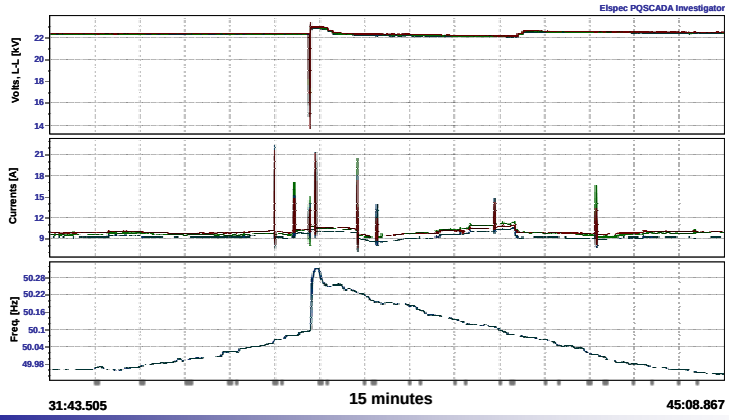
Continuous Logging – 45,000 Continuous Cycles (2nd Zoom-Out)

- The current changes before the event again points to a downstream problem



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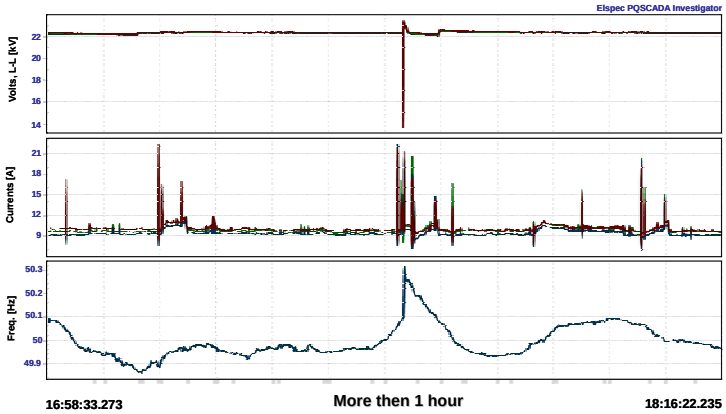
Continuous Logging – 250,000 Continuous Cycles (3rd Zoom-Out)

- Now we see that the current rises are typical to this site



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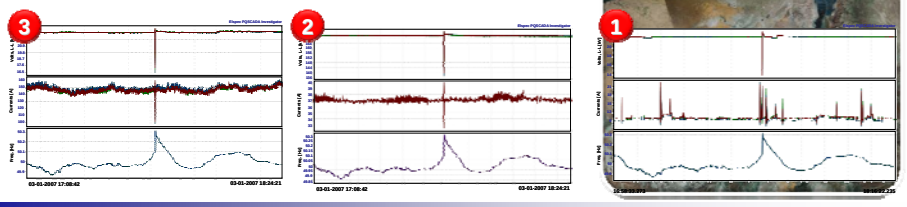
Large Scale Event

- These sites are located 106km (66miles) from each other and 62km/54km from the original one
- Voltage & Frequency look exactly the same
- Current drops during the event



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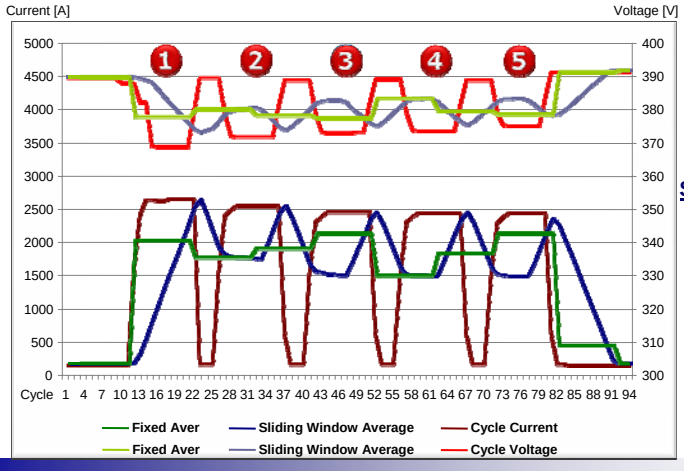
Rapid Parameter Monitoring – RMS in a Welding factory (Germany)

- IEC 61000-4-30 instructs: 10/12 Cycle averaging



IEC 61000-4-30
one voltage drop

Sliding Window Average
one voltage drop

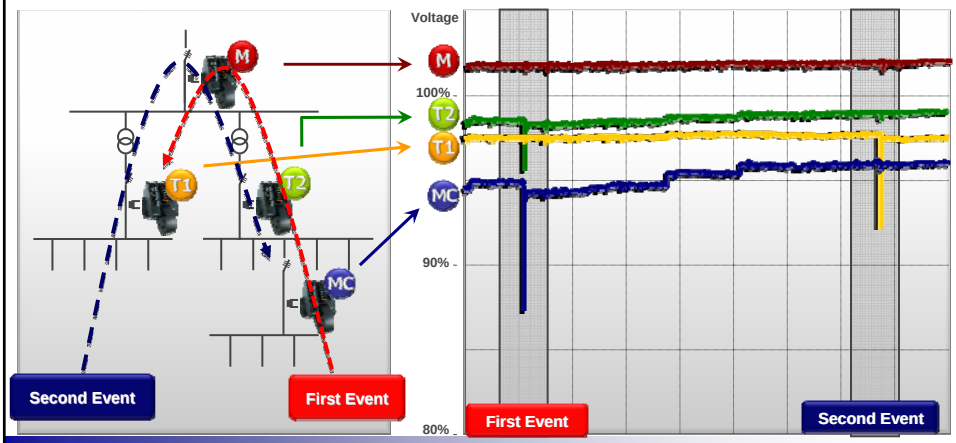
Cycle-by Cycle

5 different voltage drops

Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30

Multipoint Analysis – Multiple Sources

- **Two different events sources may be wrongly identified as same type**
- **Solving at one transformer will not prevent the event(s) from reoccurring and is likely the wrong analysis**



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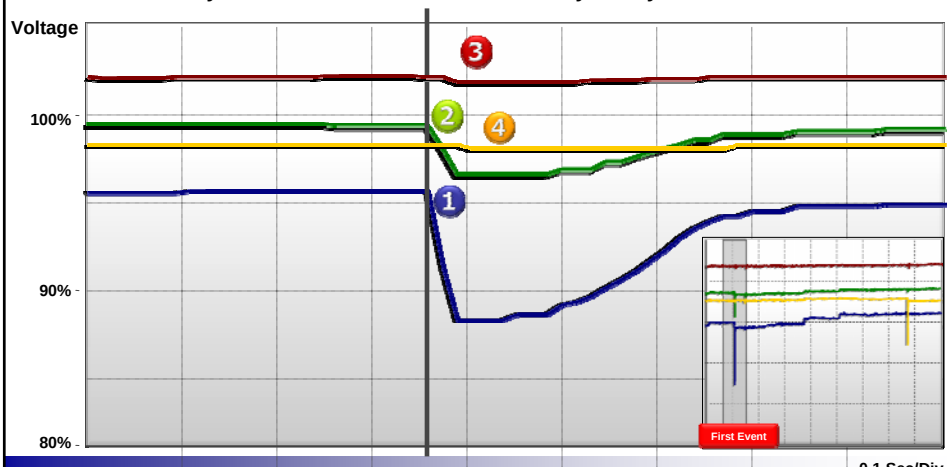
Multipoint Analysis - Time Delay and propagation Analysis

- Time synchronization allows time delay analysis



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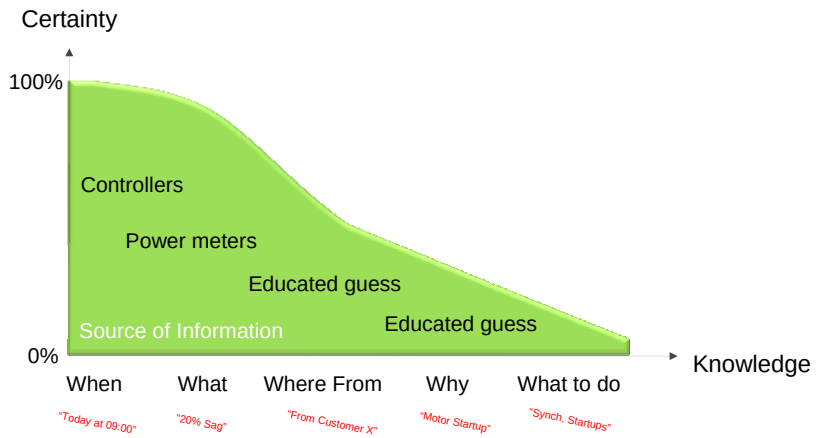
Knowledge Availability



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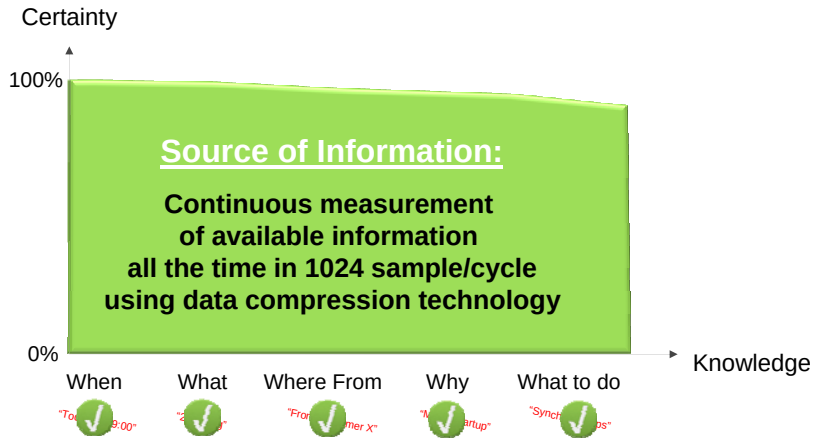
Ideal Knowledge Availability



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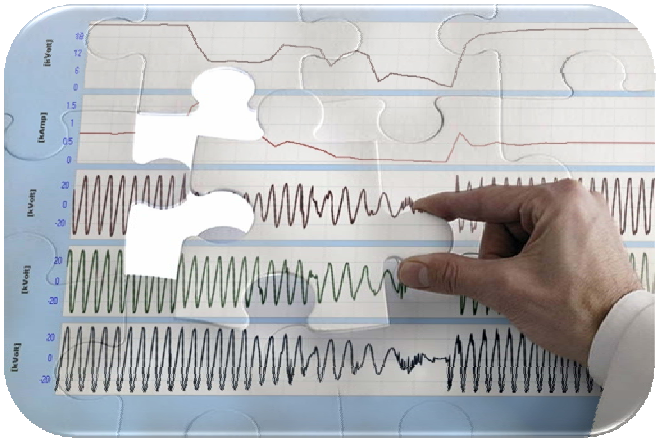
Thank You



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