Characterization of Power Quality Events

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PQ Monitoring Standards

- IEEE Standards: 1159
  - P1159: Recommended Practice for Electric Power Quality Monitoring (1159-1995/R2001)
  - P1159.1 Recommended Practice for Power Quality Measurements in A.C. Power Supply Systems (withdrawn)
  - 1159.3 Data File Format for Power Quality Data Interchange (PQDIF)
    - Additional related tasks being initiated.

Present IEEE P1159 Categories -- Table 4-2

- These phenomenon have been defined by 1159.
- 1159 does not provide guidance on how to characterize them.

Categories	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude
1.0 Transients			
1.1 Impulsive			
1.1.1 Nanosecond	5 ns rise	< 50 ns	
1.1.2 Microsecond	1 µs rise	50 ns -1 ms	
1.1.3 Millisecond	0.1 ms rise	> 1 ms	
1.2 Oscillatory			
1.2.1 Low Frequency	< 5 kHz	.3 - 50 ms	0 - 4 pu
1.2.2 Medium Frequency	5 - 500 kHz	20 µs	0 - 8 pu
1.2.3 High Frequency	0.5 - 5 MHz	5 µs	0 - 4 pu
2.0 Short Duration Variations			
2.1 Instantaneous			
2.1.1 Sag		0.5 - 30 cycles	0.1 - 0.9 pu
2.1.2 Swell		0.5 - 30 cycles	1.1 - 1.8 pu
2.2 Momentary			
2.2.1 Interruption		0.5 cycles - 3 s	< 0.1 pu
2.2.2 Sag		30 cycles - 3 s	0.1 - 0.9 pu
2.2.3 Swell		30 cycles - 3 s	1.1 - 1.4 pu
2.3 Temporary			
2.3.1 Interruption		3 s - 1 min	< 0.1 pu
2.3.2 Sag		3 s - 1 min	0.1 - 0.9 pu
2.3.3 Swell		3 s - 1 min	1.1 - 1.2 pu
3.0 Long Duration Variations			
3.1 Interruption, Sustained		> 1 minute	0.0 pu
3.2 Undervoltages		> 1 minute	0.8 - 0.9 pu
3.3 Overvoltages		> 1 minute	1.1 - 1.2 pu
4.0 Voltage Imbalance		steady state	0.5 - 2%
5.0 Waveform Distortion			
5.1 DC Offset		steady state	0 - 0.1%
5.2 Harmonics	0 - 100th H	steady state	0 - 20%
5.3 Inter-harmonics	0 - 6 kHz	steady state	0 - 2%
5.4 Notching		steady state	
5.5 Noise	broad-band	steady state	0 - 1%
6.0 Voltage Fluctuations	< 25 Hz	intermittent	0.1 - 7%
7.0 Power Frequency Variations		< 10 s	

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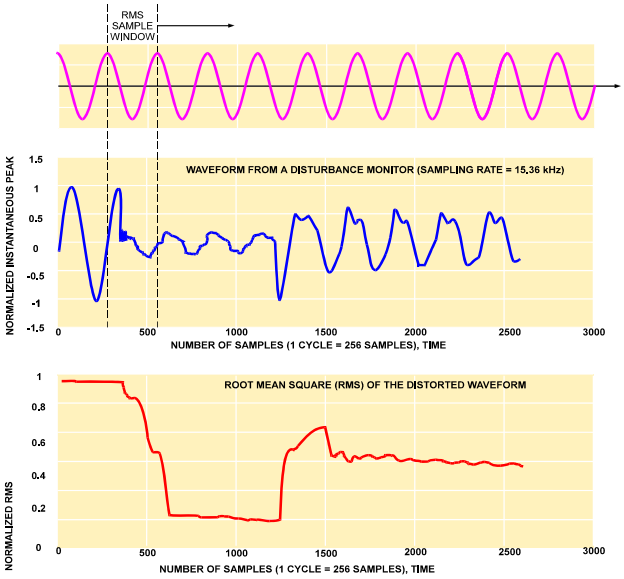
How do we characterize a complex sag?



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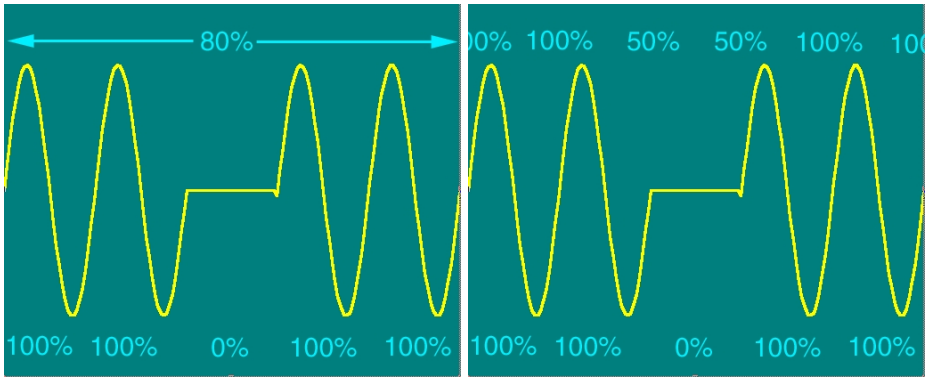
Two instruments measuring the same event: Which one is right?



Meter A: Measures the rms value with a 5-cycle window

Meter B: Measures the rms value with a 1-cycle window

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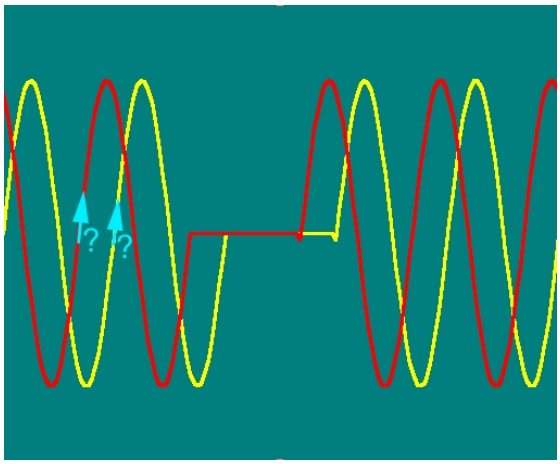
How do you define the window for a three-phase instrument?



What is the reference phase? Positive or negative zero crossing? Each channel independently? ...

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1159 states that there are additional waveform attributes

Steady state phenomena:

- Amplitude
- Frequency
- Spectrum
- Modulation
- Source impedance
- Notch depth
- Notch area

Non-steady state phenomena:

- Rate of rise
- Amplitude
- Duration
- Spectrum
- Frequency
- Rate of occurrence
- Energy potential
- Source impedance

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Additional Waveform Characteristics not identified in 1159

- Ideal (Nominal) Waveform
- RMS Magnitude
- Fundamental RMS Magnitude
- Phase Angle Shift (jump) using zero crossings
- Phase Angle Shift using the DFT fundamental
- Missing voltage
- Residual voltage
- RMS of residual voltage

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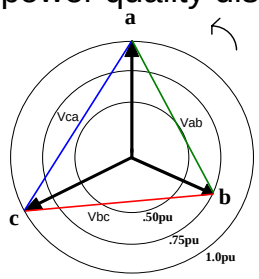
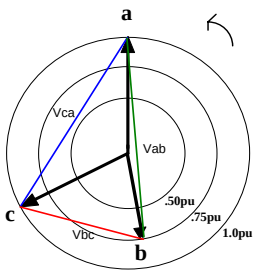
Phase Angle Shift

- Phase angle shift describes how the phase angle of a measured voltage or current shift during a power quality disturbance



A single-phase 75% sag on Phase B without phase shift resulting in a phase shift and sag for voltages Vab and Vbc but no change for Vca



A 75%, 50 degree phase-shifted voltage sag on phase B resulting in a swell and phase shift on voltage Vab and a sag and phase shift on voltage Vbc

Who cares? Electromagnetic devices, motor protectors, phase-controlled rectifiers (SCRs), line-commutated inverters, etc.

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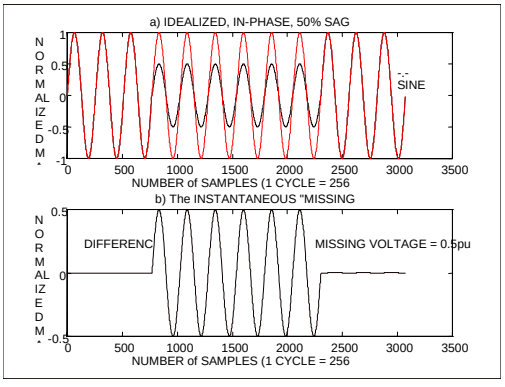
Missing Voltage

- The voltage required to be injected to fully compensate for the deviation from nominal.
- Can be greater than 1.0 pu even for a sag of greater than 1.0 pu retained.



Who cares? Series compensation devices – DVRs, rectifiers, etc.

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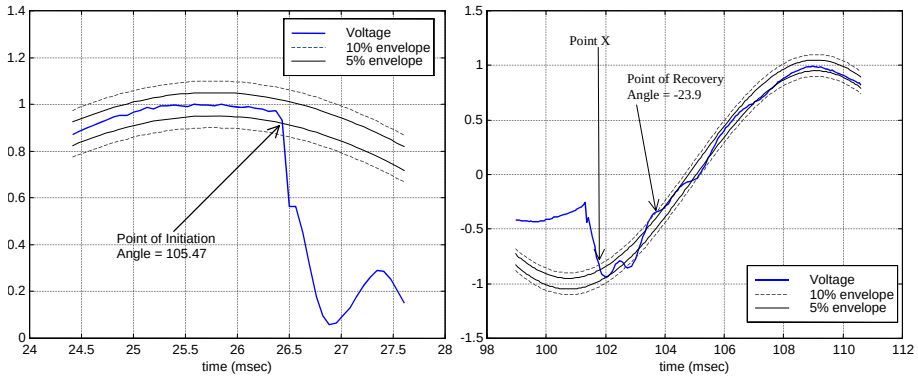
Point-on-wave



Who cares? Relays/Contactors/Solenoids and Power Electronic Circuits

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IEC PQ Standards

- 61000-1-X - Definitions and methodology
- 61000-2-X - Environment (e.g. 61000-2-4 is compatibility levels in industrial plants)
- 61000-3-X - Limits (e.g. 61000-3-4 is limits on harmonics emissions)
- 61000-4-X - Tests and measurements (e.g. 61000-4-30 is power quality measurements)
- 61000-5-X - Installation and mitigation
- 61000-6-X - Generic immunity & emmissions standards

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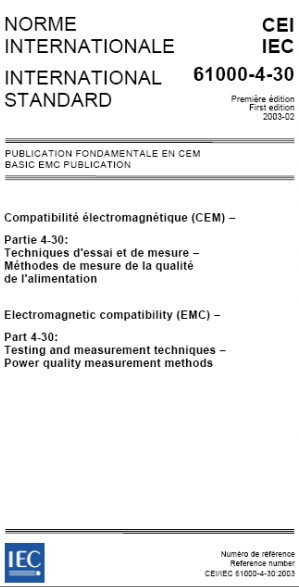
IEC 61000-4-30

- “Testing and measurement techniques- Power Quality measurement methods”



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Compatibilité électromagnétique (CEM) –

Partie 4-30:
Techniques d'essai et de mesure –
Méthodes de mesure de la qualité
de l'alimentation

Electromagnetic compatibility (EMC) –

Part 4-30:
Testing and measurement techniques –
Power quality measurement methods

IEC

Numéro de référence
Reference number
CEI/IEC 61000-4-30:2003

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IEC 61000-4-30 (2003)

- Provides Power Quality Measurement Methods
- Class A Instrument: Two instruments, connected to the same signals, will produce the same results.
- Class B Instrument: These will produce meaningful, but not necessarily accurate, results.

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Scope of IEC 61000-4-30

- 61000-4-30 covers instruments measuring
  - Magnitude of the supply voltage
  - Frequency
  - Voltage dips and swells
  - Harmonics and interharmonics (reference IEC 61000-4-7)
  - Flicker (reference IEC 61000-4-15)
  - Mains signalling
  - Under-deviation and over-deviation
- 61000-4-30 does not cover
  - High-frequency impulses
  - Noise
  - Current measurements

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IEC Standard 61000-4-30

- Provides a detailed methodology for measuring rms attributes of voltage sags and swells.
- Does not provide any guidance for measuring other PQ waveshape attributes
- New revision:
  - Don’t have to measure frequency at zero volts, etc.
  - Adds a “survey” class instrument
  - Will probably take a couple of years to complete.

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Previous IEEE PQ Standard Work

- Task Force for Characterization
  - Operated in the late 1990's through 2005
  - P1159.1 Working document title:
    - "Methods for Measurement and Interpretation of Results for Power Quality Parameters in a.c. Power Supply Systems"
  - Work ceased due to lack of progress and copyright issues

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Scope

"Methods for measurement and interpretation of results for power quality parameters in a.c. power supply systems."

This recommended practice will establish the data acquisition attributes necessary to characterize the electromagnetic phenomena listed in Table 2 of IEEE Std.1159-1995 (R2001). This recommended will include definitions, instrumentation categories and technical requirements that are related to the type of disturbance to be recorded. The disturbances will be characterized by converting suitably sampled voltage and current data set into specific power quality categories and with specific attributes within each category.

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Purpose

The purpose of this project is to provide a single recommended practice for acquiring and interpreting the attributes of power quality disturbances. There are two components to this work. One objective of this recommended is to describe the technical measurement requirements for each type of disturbance in Std 1159-1995 (R2001) to avoid confusion and interpretation of levels or limits specified in other IEEE standards. The second objective is to provide methods for interpreting these measurements into a quantifiable set of descriptors. The draft international power quality measurement standard IEC 61000-4-30 covers some of these issues, but is limited in scope. This project will use the IEC 61000-4-30 draft standard as a core, and expand upon it by adding the work already done by the P1159.1 Task Force and the P1159.2 Task Force. IEEE Std 1159-1995 (R2001) defines disturbances in 24 categories of typical characteristics of power system electromagnetic phenomena. Each category is discussed in several other standards in terms of emission limits, severity levels, planning levels or immunity levels.

Measurement requirements are not currently covered by standards. Therefore, levels or limits may be subjected to interpretation. This adds confusion in the rationale for which standards were drafted. Furthermore, equipment which operates on the ac power system does not respond solely to the phenomena listed in 1159-1995 (R2001). Studies have shown that attributes not commonly quantified by measuring equipment may have a significant impact on the equipment's ability to operate during power quality variations. This standard will provide a set of attributes that are important to equipment connected to the ac power system and provide recommended methods of arriving at these attributes from the measurement devices.

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Why coordinate?

- PQ Monitors should always give meaningful answers.
- PQ Monitors using IEEE Standard definitions should not give different results from those using IEC Standard definitions.
- Where are we now?

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