

# Common Power Quality Waveform Signatures using IEEE COMTRADE and PQDIF

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## Overview of Presentation

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- ◆ Introduction
- ◆ Power Quality Categories
- ◆ Data Interchange Formats – IEEE PQDIF & COMTRADE
- ◆ Representative Power Quality Waveforms Signatures
- ◆ Summary and Conclusions

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## Introduction

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- ◆ Power quality refers to a variety of different parameters that characterize the voltage and current on the power system.
- ◆ Power quality variations and disturbances:
  - Disturbances signify onetime, momentary events
  - Variations refer to the full range of conditions, including changes in steady-state characteristics (harmonic distortion)
- ◆ Data interchange formats PQDIF & COMTRADE.
- ◆ Representative waveforms for various events:
  - Voltage sags, momentary interruptions, voltage swells, harmonics, capacitor switching transients, transformer energizing transients, and ferroresonance

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## Power Quality Categories

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- ◆ Importance of power quality phenomena for a customer is dependent on the type of equipment used.
- ◆ The most important problem categories:
  - Have the highest negative impact on productivity
  - Are difficult to diagnose and characterize
  - Are more difficult and/or expensive to resolve
- ◆ The most important phenomena:
  - Transients, especially capacitor bank switching transients
  - Harmonic distortion, especially resonance conditions
  - Voltage variations, especially rms voltage sags and interruptions

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## Power Quality Categories - continued

Categories	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude
Short Duration Variations			
Instantaneous			
Sag (Dip)		0.5 - 30 cycles	0.1 - 0.9 per-unit
Swell		0.5 - 30 cycles	1.1 - 1.8 per-unit
Momentary			
Interruption		0.5 cycles - 3 sec	< 0.1 per-unit
Sag (Dip)		30 cycles - 3 sec	0.1 - 0.9 per-unit
Swell		30 cycles - 3 sec	1.1 - 1.4 per-unit
Temporary			
Interruption		3 sec - 1 min	< 0.1 per-unit
Sag (Dip)		3 sec - 1 min	0.1 - 0.9 per-unit
Swell		3 sec - 1 min	1.1 - 1.2 per-unit
Long Duration Variations			
Interruption, Sustained		> 1 minute	0.0 per-unit
Undervoltages		> 1 minute	0.8 - 0.9 per-unit
Overvoltages		> 1 minute	1.1 - 1.2 per-unit

Source: IEEE Std. 1159-1995 (partial listing)

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## Data Interchange Formats: PQDIF

- ◆ IEEE *Recommended Practice for the Transfer of Power Quality Data* is a standard (1159.3) that was published in 2003 by the Working Group on Monitoring Electric Power Quality.
- ◆ Defines a file format suitable for exchanging power quality related measurement and simulation data in a vendor-independent manner.
- ◆ Provides a set of requirements and attributes for a power quality data interchange format. Key among these is the ability to represent data from a variety of sources (e.g., measured), in the time, frequency, and probability domains.

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## Data Interchange Formats: COMTRADE

- ◆ IEEE *Standard Common Format for Transient Data Exchange for Power Systems* is a standard (C37.111) published by the Power System Relaying Committee in 1991. Updated in 1999, reaffirmed in 2005.
- ◆ Defines a common format for data files and an exchange medium used for the interchange of various types of fault, test, or simulation data for electrical power systems.
- ◆ Describes the sources of transient data such as digital protective relays, digital fault recorders, and transient simulation programs (e.g., PSCAD/EMTP/ATP) and discusses the sampling rates, filters, and sample rate conversions for the transient data being exchanged.

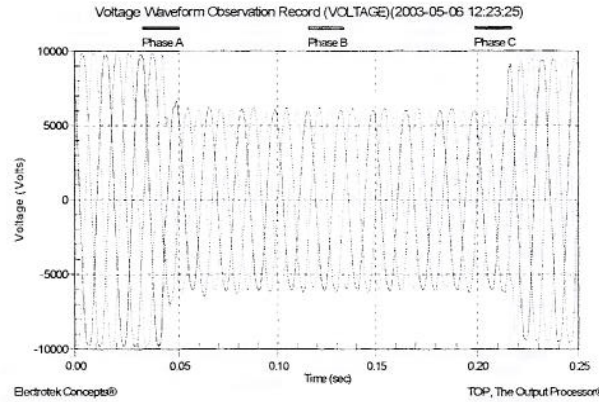
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## Representative PQ Waveforms

- ◆ Voltage Sags
- ◆ Momentary Interruptions
- ◆ Voltage Swells
- ◆ Harmonics
- ◆ Utility Capacitor Bank Switching Transients
- ◆ Transformer Energizing Transients
- ◆ Ferroresonance

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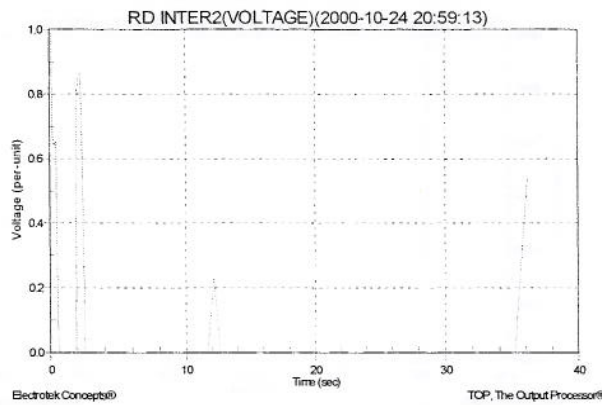
## Remote Three-Phase Voltage Waveform



Three-phase voltage sag measurement for a remote three-phase fault on a distribution feeder. The magnitude of the resulting sag was approximately 60% for 9 cycles. Measurement captured using a Dranetz-BMI 5530 DataNode. Stored using PQDIF format. Power conditioning options include UPSs and CVTs. Keywords: *sag* and *fault*. Slang terms: *glitch*, *blink*, *wink*, and *outage*.

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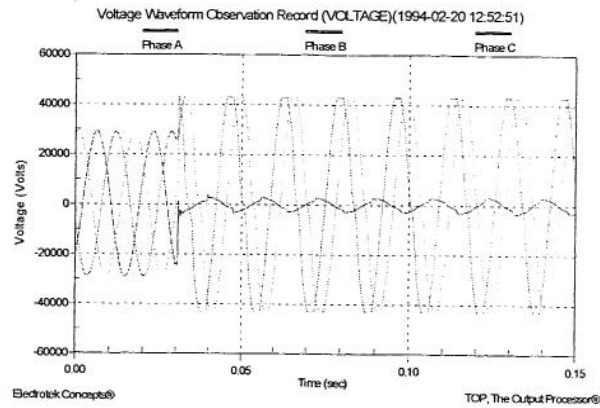
## Reclosing during a Feeder Fault



Voltage rms trend during a distribution feeder momentary interruption sequence. Interruptions lasted about 1.2, 9.0, and 22.5 seconds respectively. Measurement captured using a Dranetz-BMI 8010 PQNode. Stored using PQDIF format. Power conditioning options UPSs and CVTs. Keywords: *interruption* and *fault*. Slang terms: *glitch*, *wink*, and *outage*.

Common Power Quality Waveform Signatures using IEEE COMTRADE and PQDIF: 10

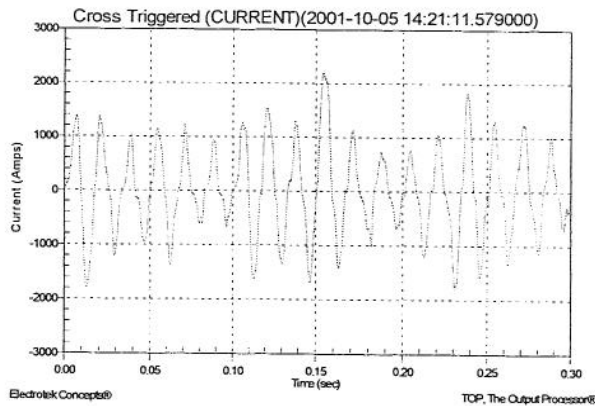
## Voltage Swell on a Distribution Feeder



Feeder voltage swell that occurred on the unfaulted phases near a single line-to-ground fault on a 34.5kV distribution feeder. The swell was approximately 150%. Measurement was captured using a Dranetz-BMI 8010 PQNode. Stored using COMTRADE format. Customer power conditioning options include UPSs and CVTs. Keywords: *swell* and *fault*. Slang terms: *glitch* and *surge*.

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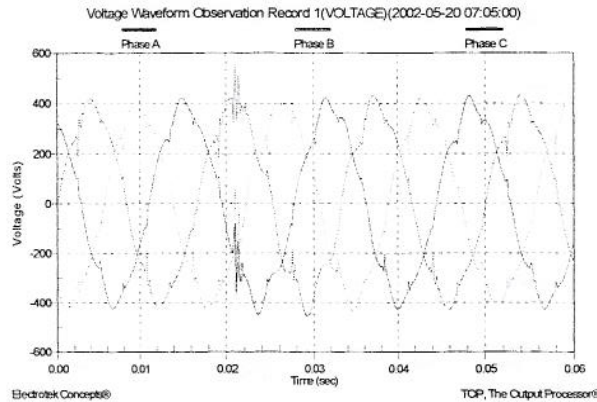
## Arc Furnace Current



Measured 13.8kV, 740 amp fundamental, 0.75 displacement power factor arc furnace load current. The waveform is an 18-cycle snapshot of one operating point for the furnace. Measurement captured using a Dranetz-BMI 5530 DataNode. Stored using PQDIF format. Power conditioning options include harmonic filters and SVCs. Keyword: *current distortion*. Slang term: *dirty power*.

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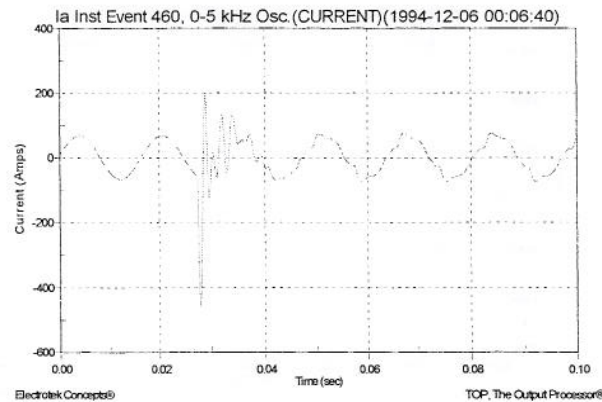
## Customer Voltage Notching



Customer secondary bus voltage with moderate notching and distortion ( $V_{THD} \approx 9\%$ ). Also shows a transient that was due to utility capacitor bank switching. Measurement captured using a Dranetz-BMI 5530 DataNode. Stored using COMTRADE format. Customer power conditioning options include inductive chokes, and harmonic filters. **Keywords:** *notching and resonance*. **Slang term:** *dirty power*.

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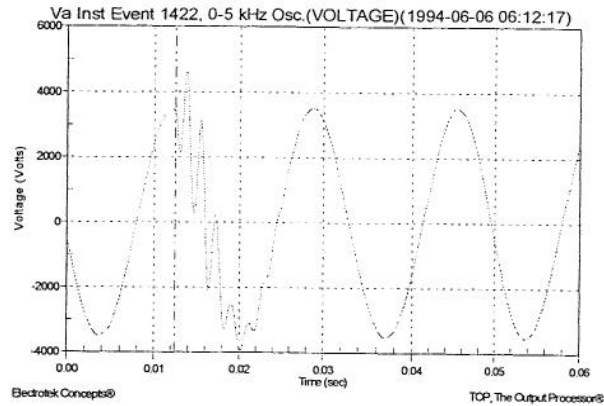
## Capacitor Switching and Resonance



A 13.8kV feeder current before-and-after energization of a 900-kVAr pole-mounted capacitor bank that creates a resonance (current distortion about 13%). Current measurement captured using a Dranetz-BMI 8010 PQNode. Stored using PQDIF format. Power conditioning options include arresters and harmonic filters. **Keywords:** *capacitor and resonance*. **Slang terms:** *surge, glitch, and spike*.

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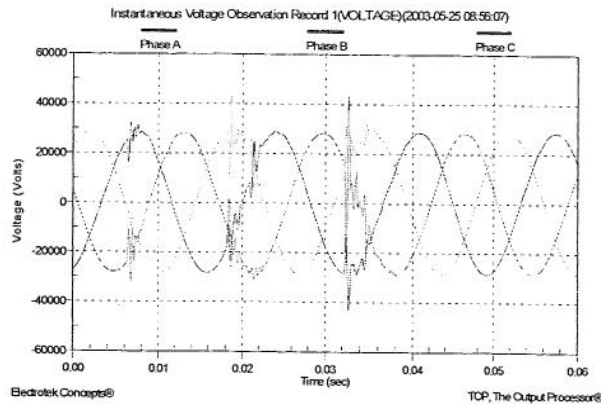
## Substation Capacitor Bank Switching



A 4.16kV bus voltage during utility capacitor bank switching. The resulting transient voltage was 1.35 per-unit, while the steady-state voltage rise was 1.2%. Measurement was captured using a Dranetz-BMI 8010 PQNode. Stored using PQDIF format. Power conditioning options include overvoltage control and arresters. Keywords: *oscillatory transient* and *overvoltage*. Slang terms: *surge* and *spike*.

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## Capacitor Bank Switch Multiple Restrike

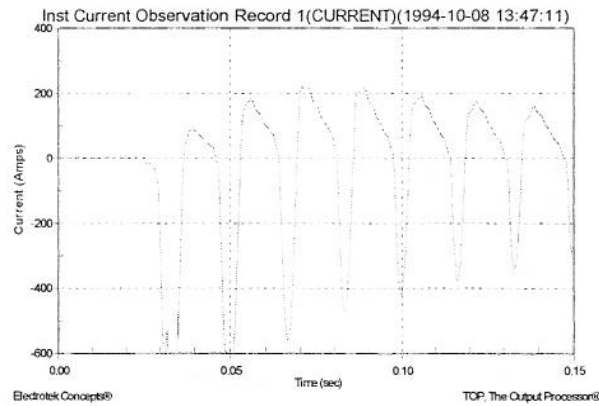


A measured bus voltage waveform during a multiple restrike event on a 34.5kV capacitor bank. The worst-case transient voltage was approximately 1.55 per-unit. Measurement was captured using a Dranetz-BMI 8010 PQNode. Stored using COMTRADE format. Power conditioning options include arresters. Keywords: *restrike* and *overvoltage*. Slang terms: *surge* and *spike*.

Common Power Quality Waveform Signatures using IEEE COMTRADE and PQDIF- 16



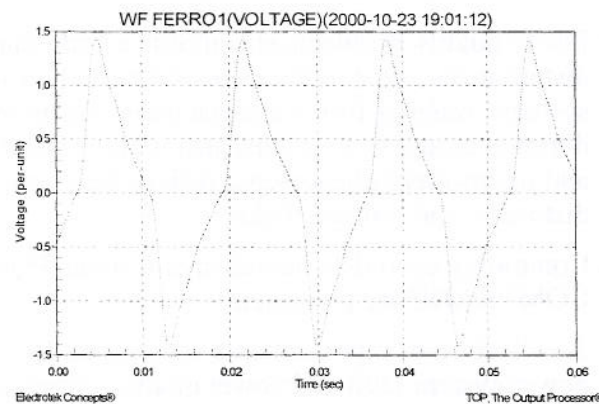
## Feeder Transformer Energizing



Inrush current for a distribution transformer energizing. Transformer inrush current typically decays over a period of about one second. The measurement was captured using a Dranetz-BMI 5530 DataNode. Stored using COMTRADE format. Power conditioning options include overcurrent protection, fuses, and reclosers. Keywords: *transient* and *overcurrent*. Slang terms: *surge*, and *spike*.

Common Power Quality Waveform Signatures using IEEE COMTRADE and PQDIF- 17

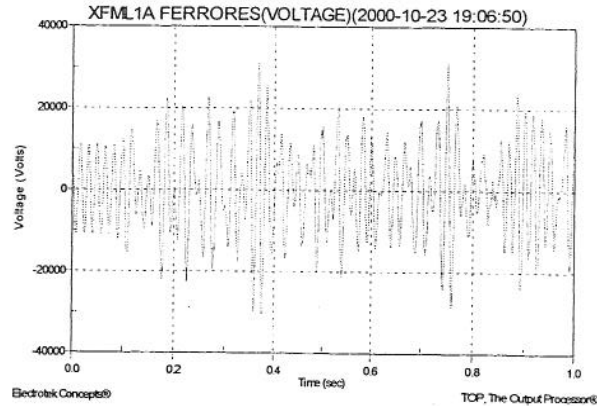
## Distribution Feeder Ferroresonance



Phase-to-phase voltage during ferroresonance that was caused by an unbalanced switching operation. The peak voltage was approximately 1.42 per-unit. The measurement was captured using a Dranetz-BMI 8010 PQNode. Stored using COMTRADE format. Power conditioning options include three-phase switches and secondary loads. Keywords: *ferroresonance* and *overvoltage*. Slang term: *surge*.

Common Power Quality Waveform Signatures using IEEE COMTRADE and PQDIF- 18

## Cable/Transformer Ferroresonance



Simulated voltage during ferroresonance on a 13.8kV feeder. The peak voltage is approximately 2.89 per-unit. There were no arresters included in the model. The waveform was created using an EMTF program and stored using the COMTRADE format. Power conditioning options include three-phase switches and secondary loads. Keywords: ferroresonance and overvoltage. Slang term: surge.

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## Summary and Conclusions

- ◆ Power quality problems encompass a wide range of disturbances and conditions on utility and customer systems, ranging from very fast transients to long duration outages. Problems also include steady state and intermittent phenomena, such as harmonic distortion and voltage flicker.
- ◆ Commonly used data interchange formats PQDIF and COMTRADE are presented.
- ◆ A collection of representative waveforms for various power system fault and power quality events is presented.

Common Power Quality Waveform Signatures using IEEE COMTRADE and PQDIF- 20