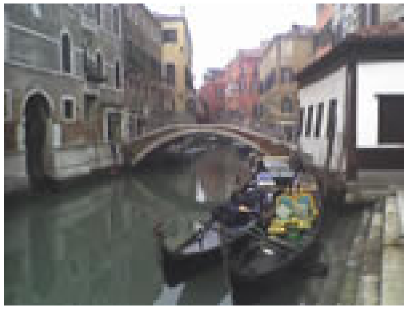
UIE Working Group 2
Power Quality

Voltage Dip Immunity of Equipment and Installations



TUTORIAL

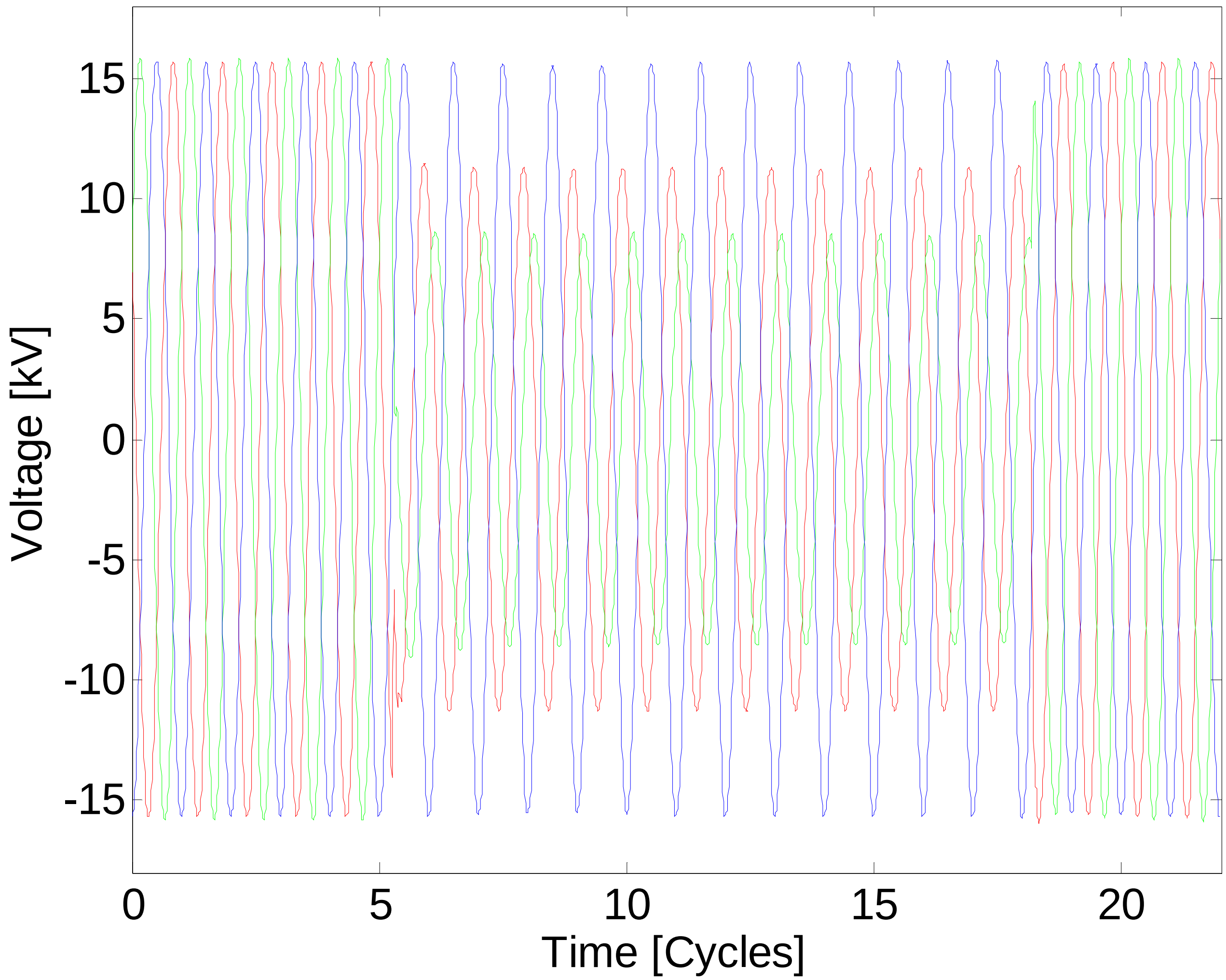
Voltage Dip Characteristics
(Part 2)

The First International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies

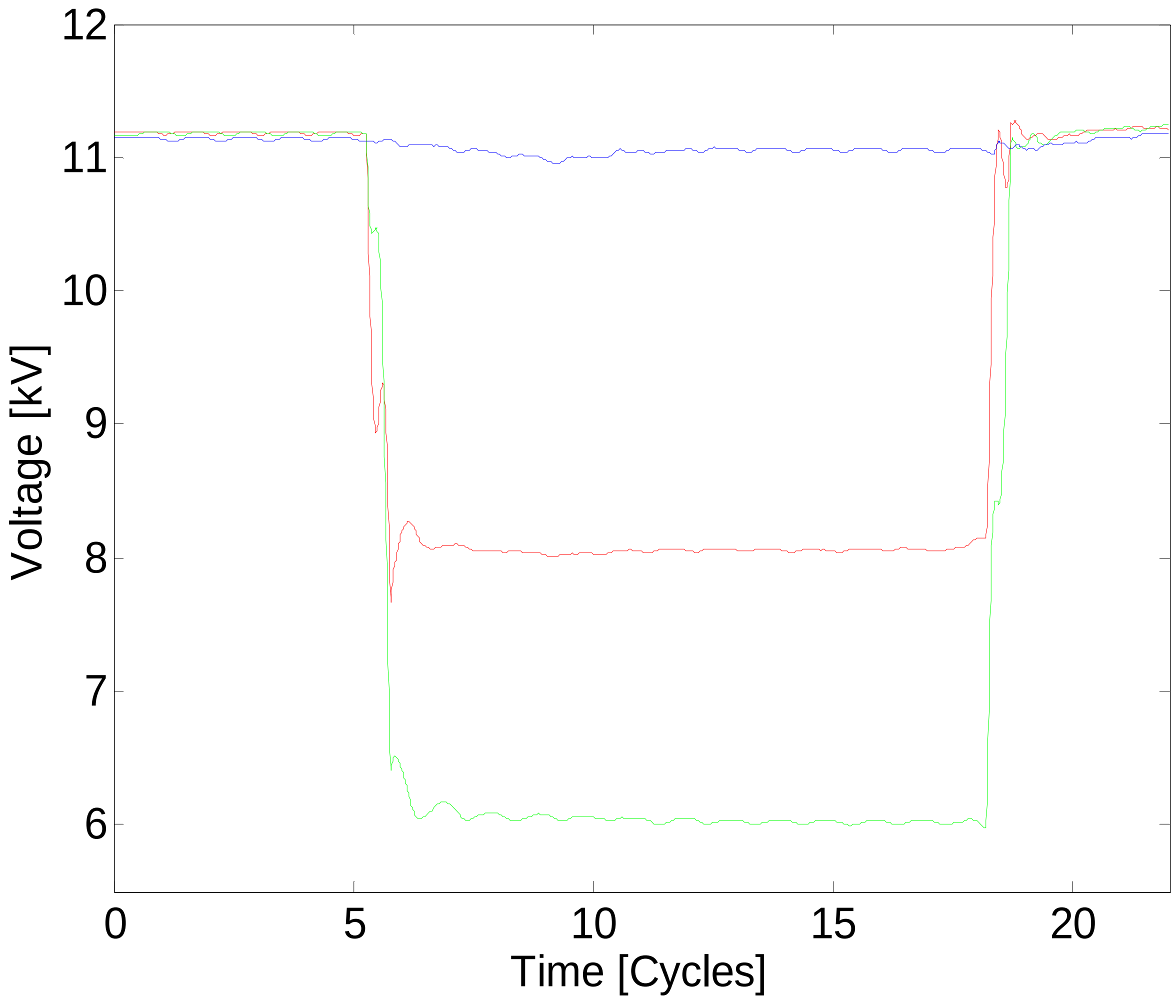
ENERGY 2011

May 22-27, 2011 - Venice/Mestre, Italy

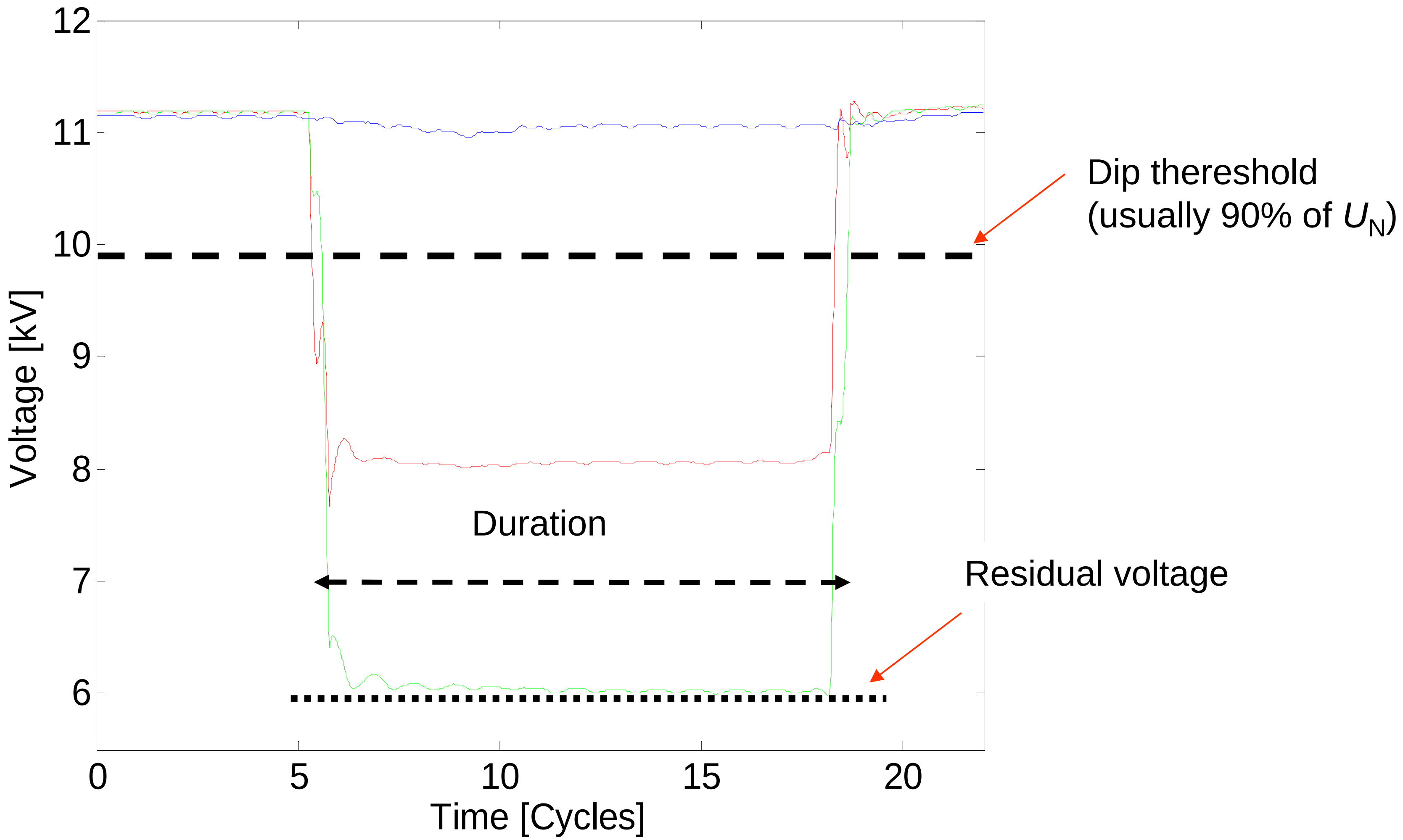
A Typical Voltage Dip



Voltage Magnitude (rms) vs Time



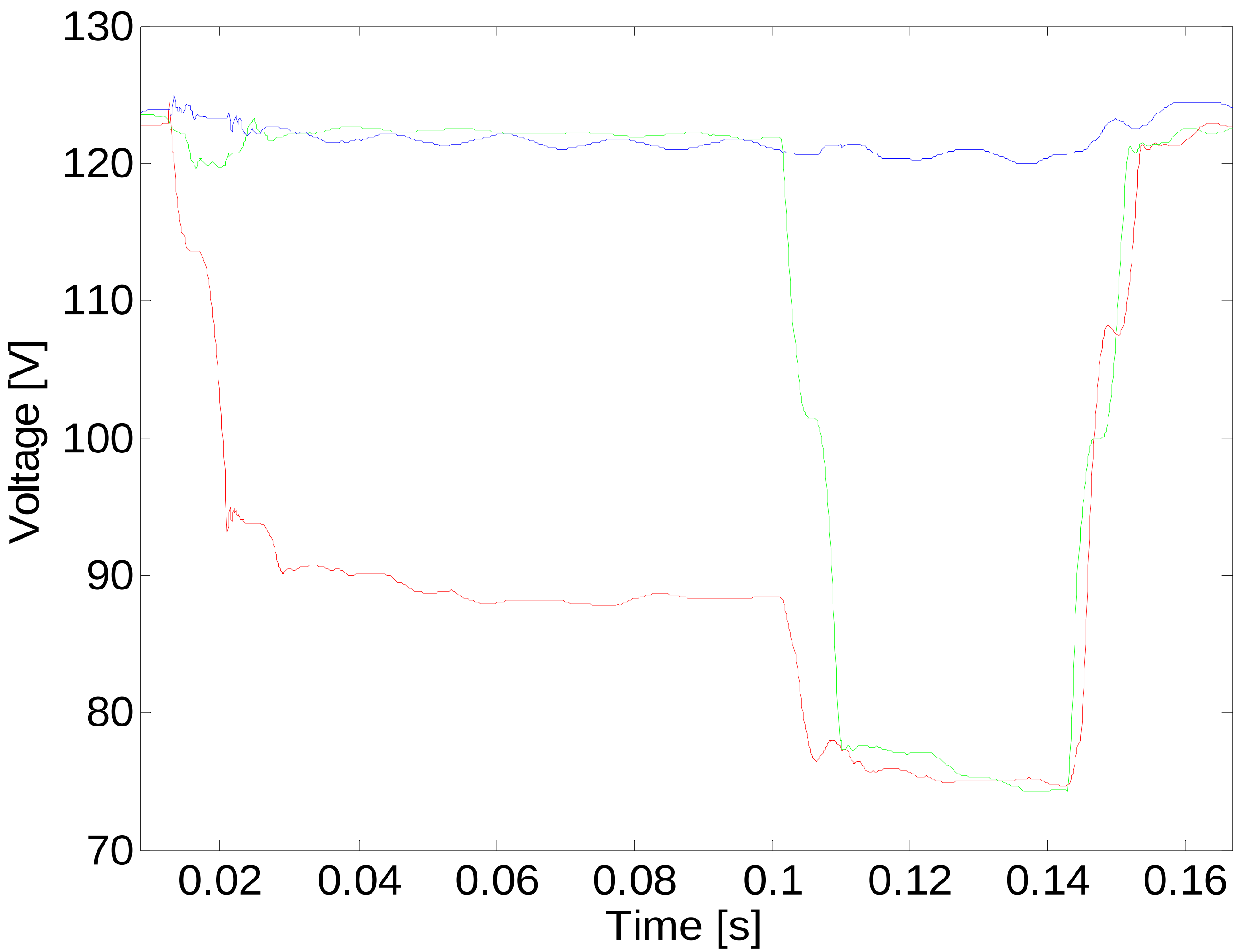
IEC 61000-4-30



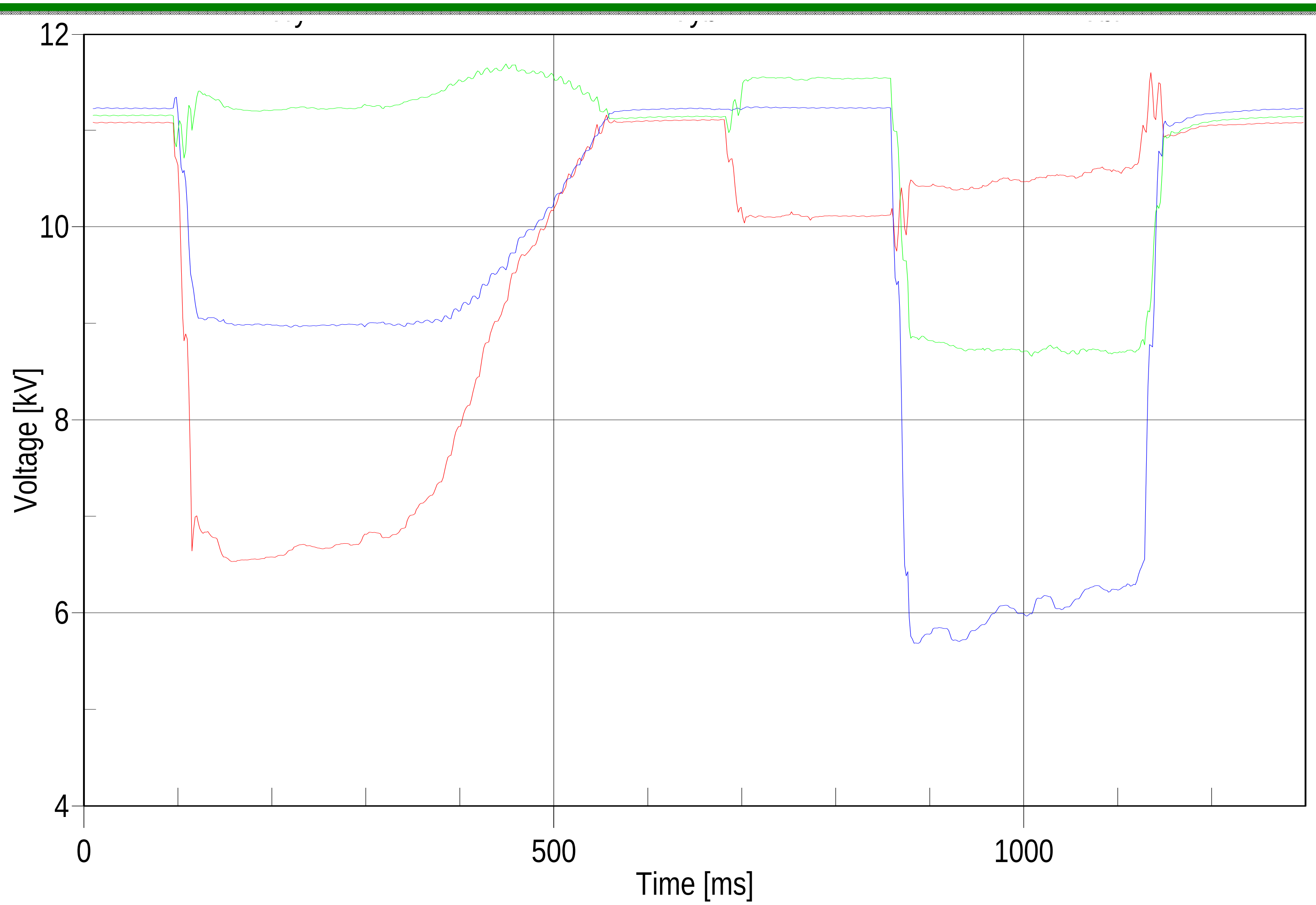
IEC 61000-4-30

- The voltage waveform should be obtained in three channels (phase-to-ground, phase-to-neutral or phase-to-phase voltages)
- The one-cycle rms voltage is calculated every half-cycle in every channel
- A voltage dip threshold is defined, typically 90% of the nominal voltage
- The *duration* is the time during which the voltage is below the threshold in at least one of the channels
- The *residual voltage* is the lowest rms voltage in any of the channels during the event

A Less Typical, but Not Uncommon Voltage Dip



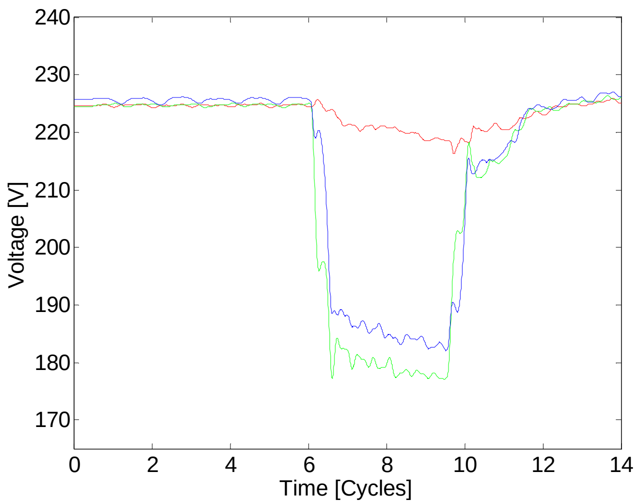
A Not So Common, but Still Realistic Voltage Dip

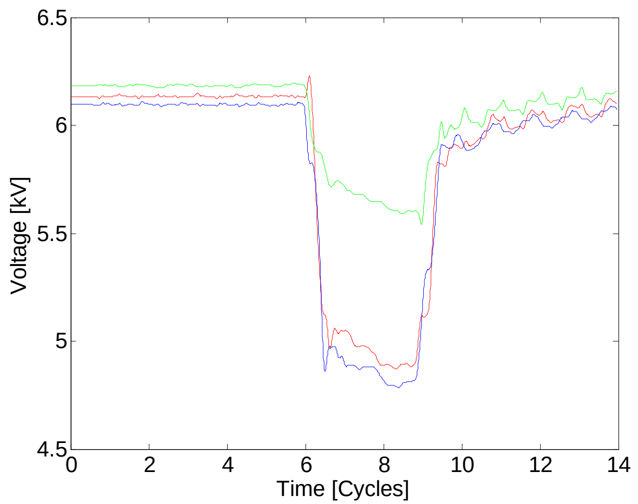


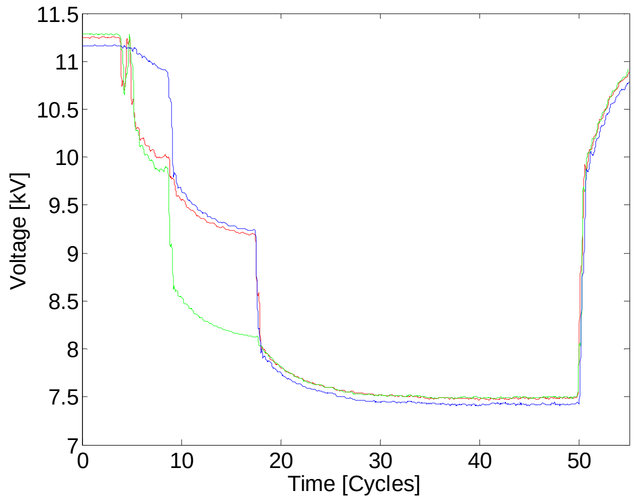
Beyond IEC 61000-4-30

- There is more to voltage dips than one voltage magnitude and one duration value
- Main contributions of JWG C4.110
  - Classification of dips into three types in a three-phase system
  - Voltage-dip segmentation for dip description and characterisation
- Additional dip characteristics
  - Point-on-wave
  - Phase-angle jump
  - Voltage recovery

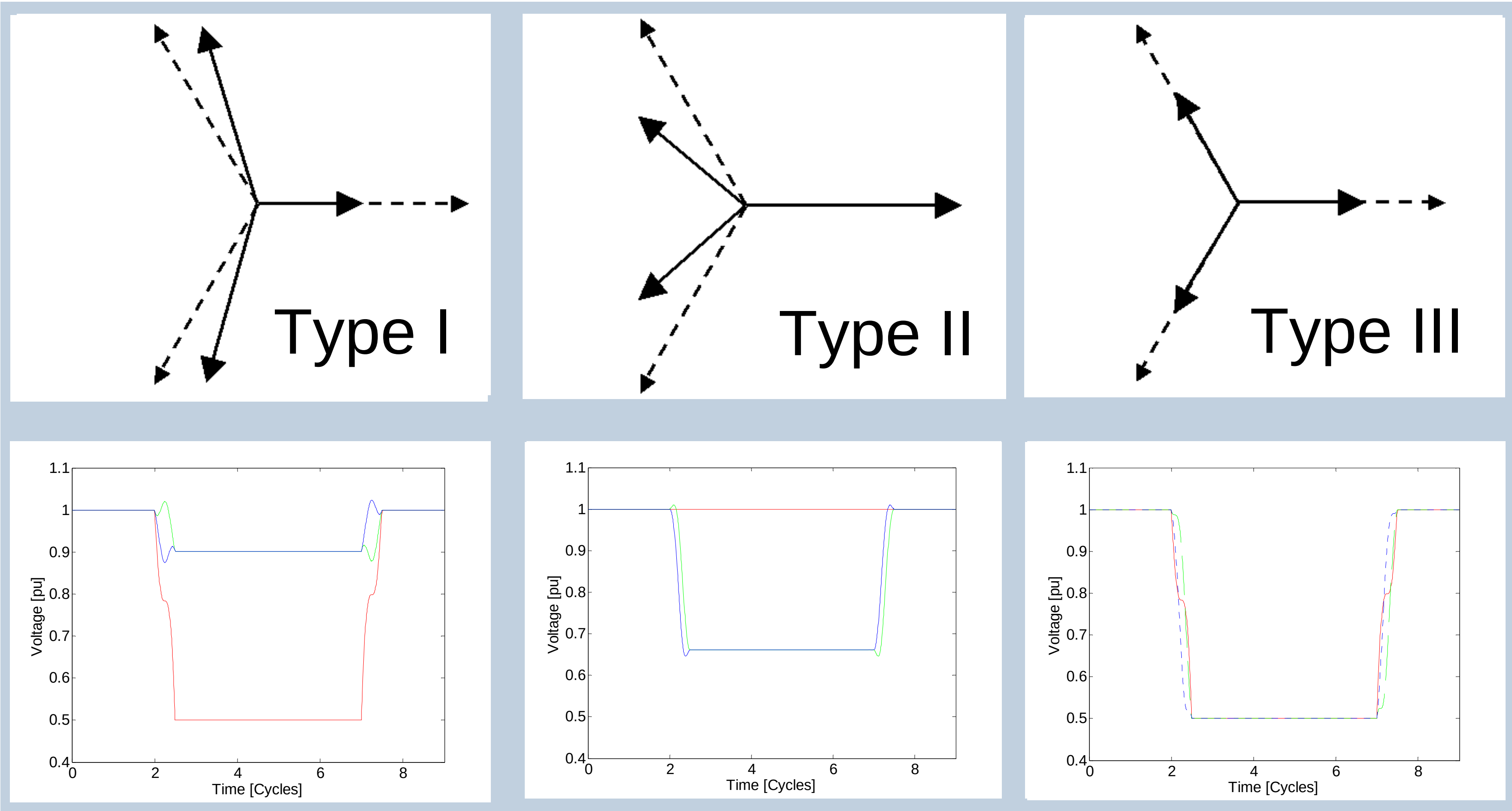
Voltage Dips in Three-phase Systems



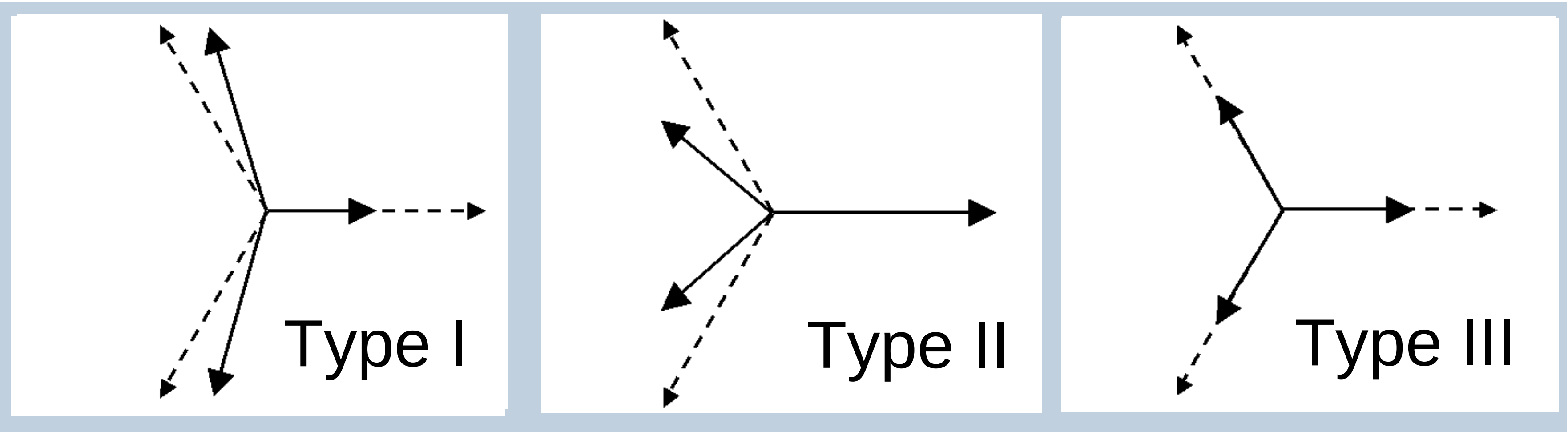




Classification proposed by JWG C4.110



Classification Proposed by JWG C4.110



Networks \ Type	I	II	III
MV and HV	27%	53%	20%
LV	64%	25%	11%

Table 6-5 Overall distribution of voltage dips types.

The Classification in Words

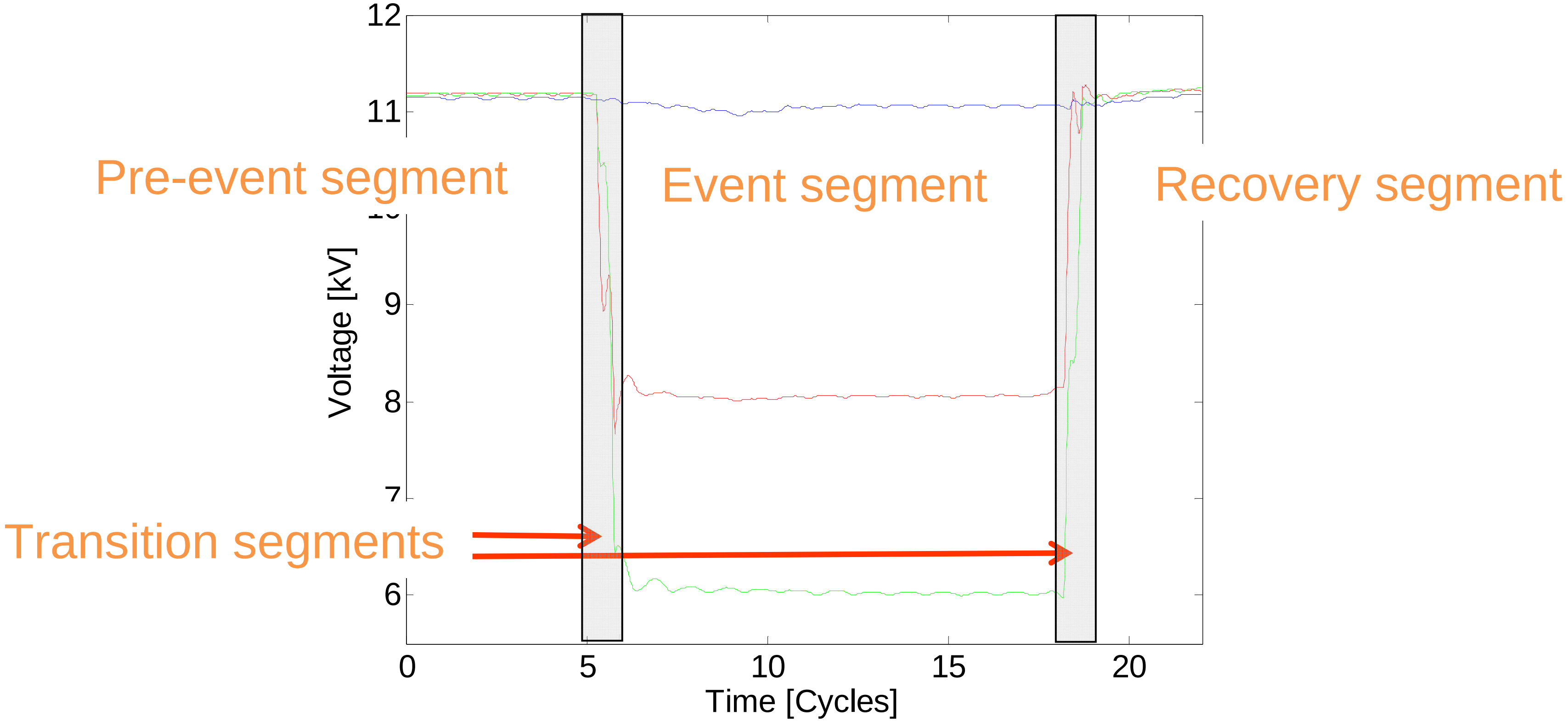
- Type I: A major drop in magnitude of one of the three phase-to-ground voltages, and no drop, or a much lesser drop in the other two
- Type II: A major drop in magnitude of two of the three phase-to-ground voltages, and no drop, or a much lesser drop in one
- Type III: An almost identical drop in magnitude in all three phase-to-ground voltages

Read the Report to Find Out

- How to know the dip type from the voltage waveforms.

- How to know the dip types from the rms voltages.

Dip Segmentation Method



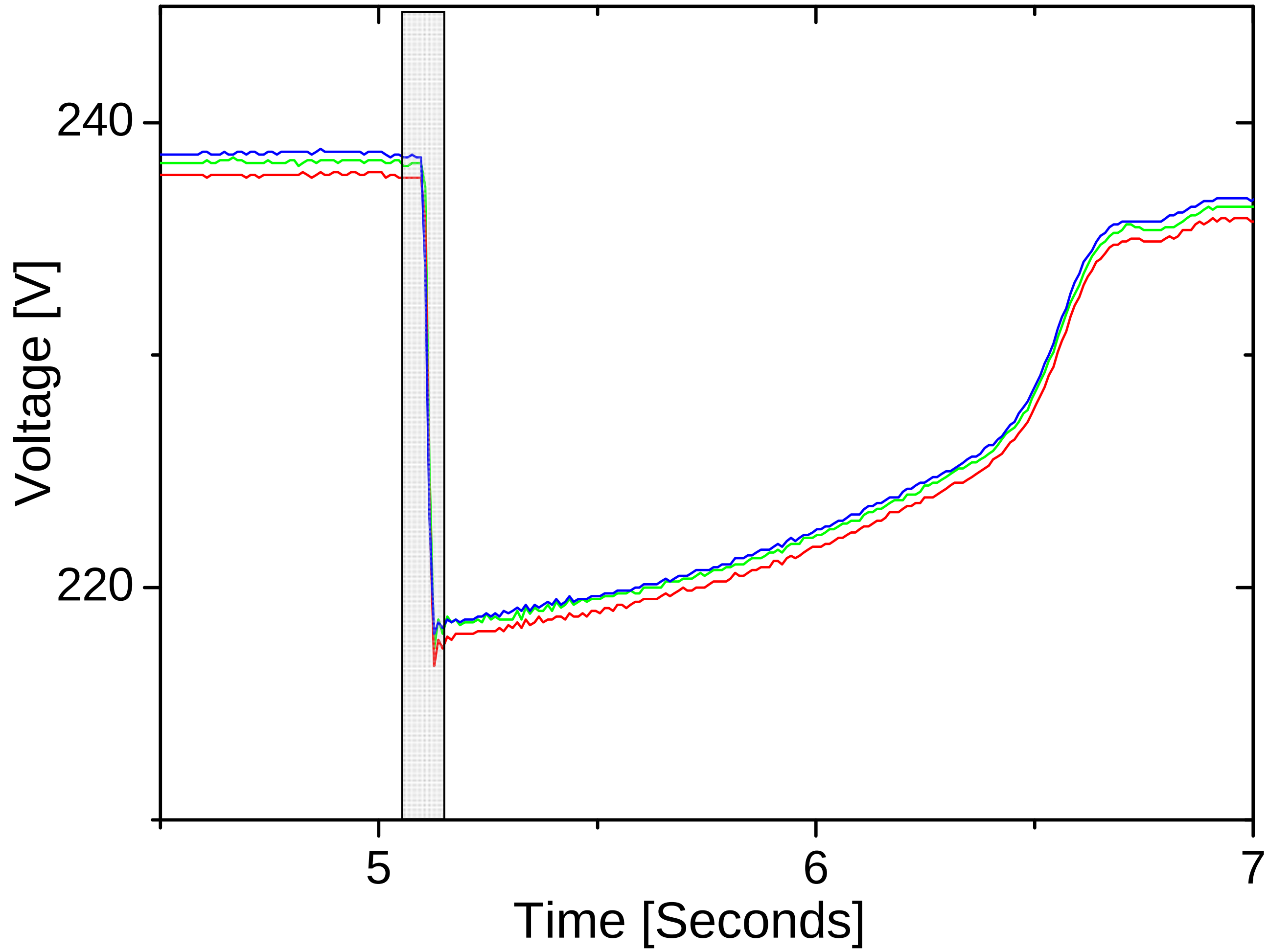
In Words:

- The ”Transition Segment” is where the voltage suddenly changes in magnitude
  - Signal processing: the signal is non-stationary; advanced detection methods use this property.
- The ”Event Segments” are the periods between the transition segments
  - Signal processing: the signal is quasi-stationary
  - Power systems: we can use our normal tools like rms, FFT and symmetrical components

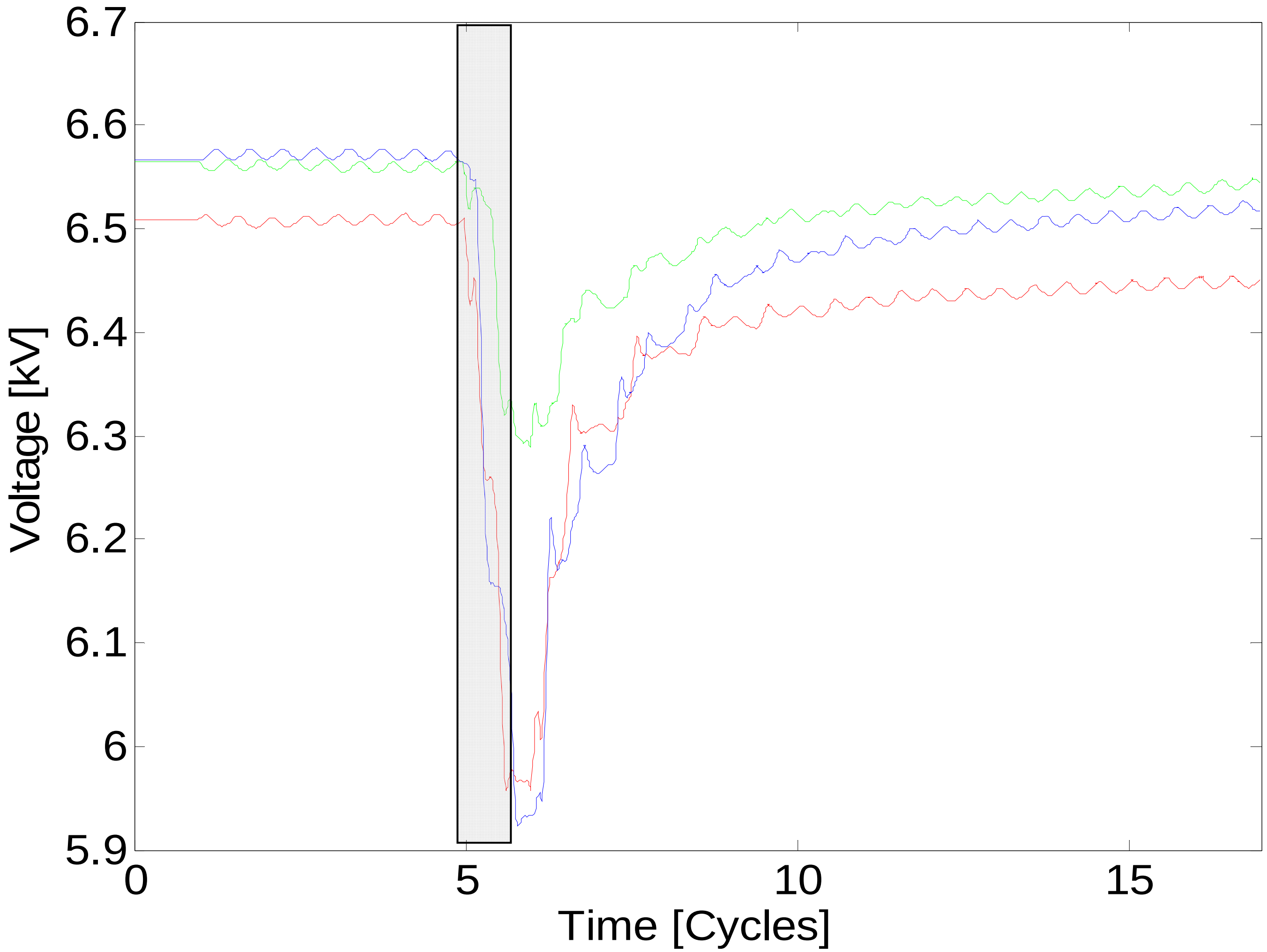
Different Transition Segments

- Dips with only one transition segment (switching events):
  - Motor starting
  - Transformer energizing
  - Capacitor switching (very short duration)
- Dips with two transition segments:
  - Short-circuit faults with succesful clearing
- Dips with three (more) transition segments:
  - Developing short-circuit faults or cleared by different circuit breakers

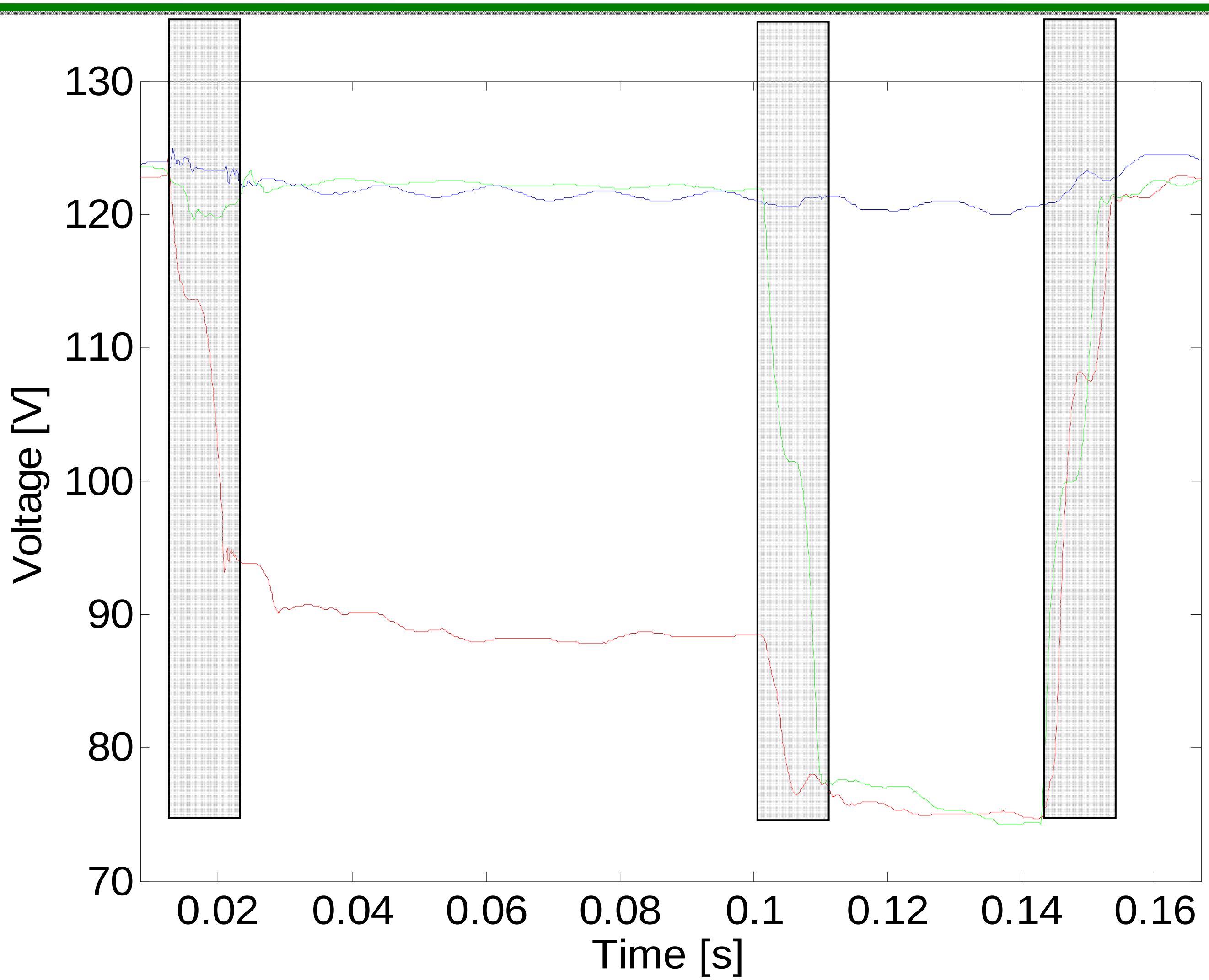
Dips with One Transition Segment: Motor Starting



Dips with One Transition Segment: Transformer Energizing



Dip with Three Transition Segments



Characterization of Voltage Dips

- Number of transition segments
- Time between transition segments
- Pre-event segment: rms voltage, distortion, unbalance
  – Using e.g. IEC 61000-4-30 3-sec values
- During-event segments: dip type, residual voltage, phase angle, etc.
- Recovery segment: unbalance, time to recover, phase shift, etc.

Characterization of Voltage Dips Checklist

Dip Characteristic	Description
	Pre-event segment
Characteristics of the pre-event segment	The actual or expected values of the pre-event voltage magnitudes, voltage phase angles, harmonics and other waveform distortions, voltage magnitude/phase angle unbalances and frequency variations.
	During-event segment
Dip magnitude	Quantifies the reduction in voltage magnitude below the "dip magnitude threshold", usually expressed as a root mean square (rms) value of the measured or calculated instantaneous voltage in any of the affected input voltage channels.
Dip duration	The time for which a reduction in voltage magnitude that is qualified as a voltage dip is present in a single voltage channel (per-phase/per-channel dip duration), or in at least one of the affected voltage channels (the total dip duration).
Dip shape	Dips with the constant during-event rms voltage magnitudes are rectangular dips, while non-rectangular dips have variable rms voltage magnitude.
Dip voltage magnitude unbalance	In case of polyphase dip events, voltage magnitudes in different channels are typically different.
Dip phase shift (phase-angle jump)	Change of during-dip voltage magnitudes is often associated with a change in corresponding voltage phase angles. In case of polyphase dips, voltage channels with different voltage magnitudes will typically have different phase shifts
Dip phase angle unbalance	For polyphase dips with different voltage magnitudes and/or different phase shifts in different channels, during-dip voltages will also experience voltage phase angle unbalance.
Dip waveform distortion and transients	Dips due to transformer energising are associated with a high level of harmonic distortion, while some dips have high-frequency transients imposed to the fundamental component of the during-dip instantaneous voltage.

Transition segment	
Dip initiation	The first transition segment marks the instant of dip initiation (i.e. the transition from pre-dip voltage to during-dip voltage), manifested as a sudden drop in voltage magnitude at the start of the dip.
Point-on-wave of dip initiation	Phase angle of the instantaneous pre-dip voltage waveform at which (main) transition from pre-dip voltage to during-dip voltage is initiated.
Phase shift at the dip initiation	The majority of fault-caused voltage dips are associated with a change in voltage phase angles. Accordingly, sudden drop in voltage at the start of the dip event is usually accompanied by a distinctive shift/jump in corresponding phase angle.
Multistage dip initiation	At the dip initiation, the drop in voltage magnitude in affected channels may take place in several steps due to e.g. developing faults. The corresponding multiple stages may occur at a sub-cycle time scale, or at a time scale of several seconds.
Dip ending	The last transition segment marks the instant at which underlying cause of the dip is cleared, manifested as a sudden voltage rise. It is followed by a voltage recovery segment, during which voltage may be still below the dip magnitude threshold.
Point-on-wave of dip ending	Phase angle of the post-dip instantaneous voltage waveform at which (main) transition from during-dip voltage to post-dip voltage is finished.
Phase shift at the dip ending	Sudden rise in voltage at the end of the dip event is usually accompanied by a distinctive shift/jump in corresponding phase angle, which usually cancels all the changes in phase angles in affected channels, except for the post-dip phase shift.
Multistage dip ending	The voltage magnitude rise at the end of fault-caused dips may take place in several steps due to e.g. difference in circuit breaker opening instants in different phases or at different network locations. The corresponding multiple stages may occur at a sub-cycle time scale, or at a time scale of up to one second.
Rate-of-change of voltage	The transition from one steady state to another steady state (or from one quasi-steady state to another quasi-steady state) takes place with a certain speed. Corresponding temporal change of voltage is denoted as the rate-of-change.
Damped oscillations	Transition segments are often associated with damped oscillations, whose frequency of oscillation and damping time constant depend on the location/type of the fault and characteristics of system load and generation.

Characterization of Voltage Dips Checklist

Voltage recovery (post-event) segment	
Voltage recovery	During the voltage recovery segment, the voltages are usually balanced and with close to nominal magnitude, but they may show more or less prolonged trend towards their steady state values, with voltages still below the dip magnitude threshold.
Post-fault dip (prolonged voltage recovery)	After the initial cause of the dip (e.g. short circuit fault) has been cleared and after the affected voltages already experienced main rise in magnitudes, the voltage magnitudes in affected channels may be still below the dip magnitude threshold. This part of the voltage recovery segment is termed as the post-fault dip.
Post-dip phase shift	Phase angle difference between the steady state pre-dip and post-dip voltages. Typically occurs when a (faulted) part of the network is disconnected in order to clear the underlying cause of the dip, influencing a change in system impedances.
Multiple dip events (dip sequences)	Multiple dip events occur within a short period of time, ranging from less than one second up to one minute. Examples include successive dips due to adverse weather (e.g. lightning storms), or dips due to automatic reclosing actions after the occurrence of a short circuit fault.
Composite dip events	In case of polyphase events, voltage dips in some of the affected channels may be accompanied by interruptions and/or swells in the other channels.

Read the Report to

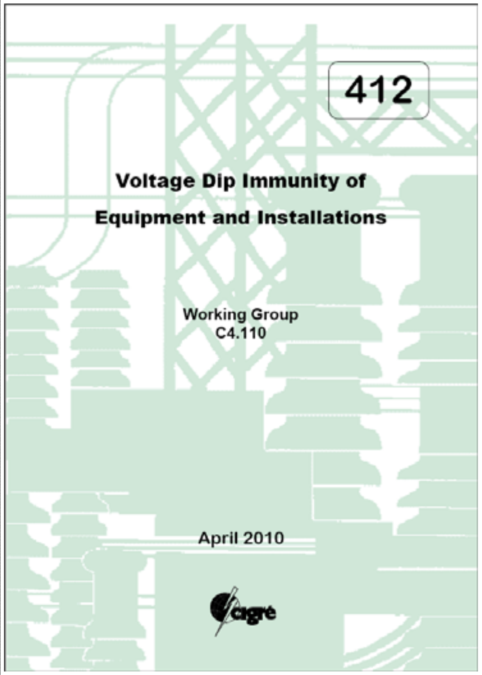
- Find out more about how dip characteristics change when propagating through the power system
- Learn more about characteristics for event segments
- Read a discussion on characteristics for transition segments

Summary of Voltage Dip Characteristics

- A detailed list of voltage dip characteristics, without commenting on their importance
- The aim is to act as a check-list that equipment designers and manufacturers can use in a very early stage of the design of power electronic equipment
- The list is also used as a basis for the discussions on equipment testing

Conclusions

- Voltage dip duration and residual voltage are used in IEC 61000-4-30, but that is not enough.
- Three types of dips are to be distinguished in a three-phase system:
  - To be included in statistics on voltage dips.
- Voltage-dip segmentation
  - As a method to characterize dips in more detail
  - As a basis to define more characteristics
- Checklist of voltage-dip characteristics
  - To help in capturing the complexity of voltage dips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Voltage Dip Immunity of

Equipment and Installations

Working Group
C4.110

April 2010

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The report can be obtained in electronic format for free from: www.uie.org;

a hardcopy can be purchased from www.e-cigre.org


CIGRE/CIRED/UIE Joint Working Group C4.110

Voltage Dip Immunity of

Equipment and Installations

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