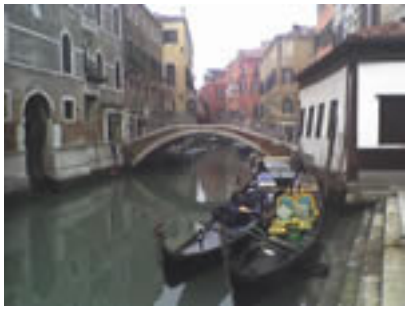
UIE working group
Power Quality

Voltage Dip Immunity of Equipment and Installations



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

ENERGY 2011

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

TUTORIAL

Characterization and Compliance Testing

(Part 4)

DIP IMMUNITY CHARACTERIZATION AND COMPLIANCE TESTING

- Two Types of Tests: Compliance Testing and Characterization Testing
- Voltage Dip Characteristics
  - Which dip characteristics to include in tests?
- Test Vectors: Type I, Type II, Type III Dips
- Test Results: Voltage Tolerance Curves/Tables
  - Purpose, Meaning, Limitations
  - Curves for Single-phase and Three-phase Equipment
- Compliance Testing
  - Adding Type III tests in the requirements

Purpose of Testing

- The resulting relationship – presented in the form of voltage tolerance curves – can be used as a tool in assessing the compatibility between equipment and power supply
- Knowing the dip performance of equipment allows to select most appropriate equipment
  - Equipment with greater immunity may be more expensive ... Today
- Importance of malfunction criteria in tests: equipment performs “as intended”

Compliance Testing

- **Compliance** testing is performed by a certified test laboratories, in order to prove compliance of the equipment with national, international, or industry standards:
  - SEMI F47
  - IEC 61000-4-11, IEC 61000-4-34
  - IEEE P1668
- Requires a limited number of well-defined and carefully executed reproducible test.

Characterization Testing

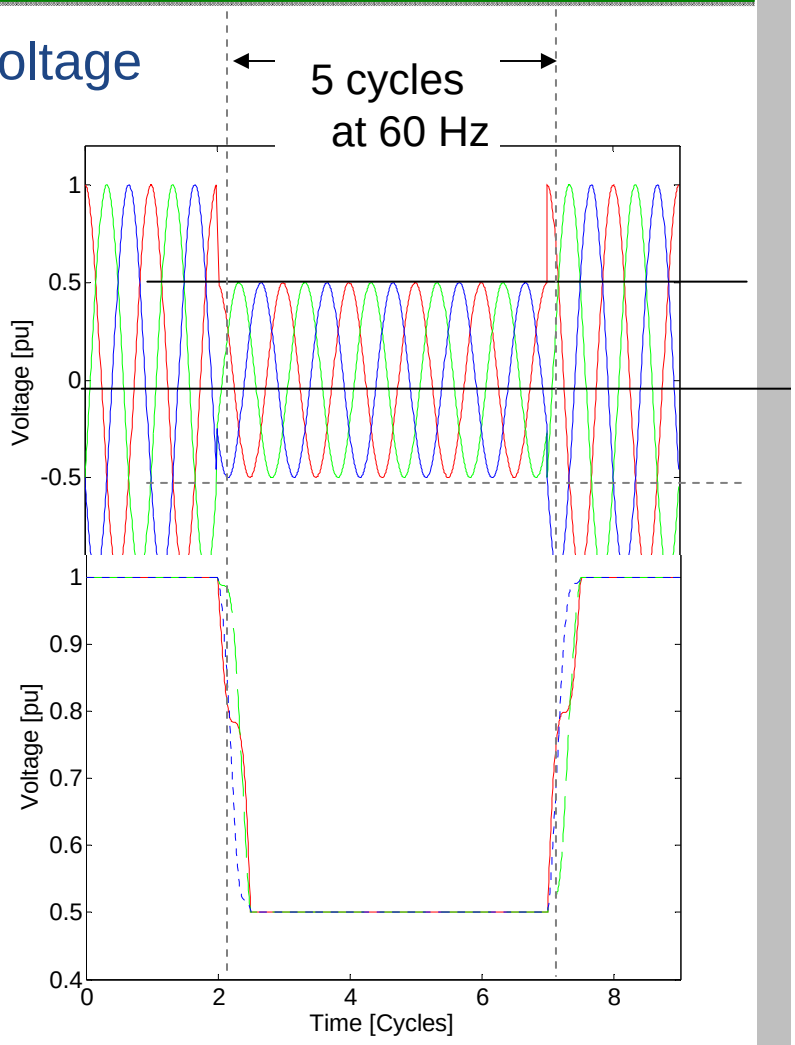
- **Characterization** testing should provide more detailed information about dip performance of tested equipment
- More tests (test points), but with fewer requirements on the specific details of each test
- Allows the use of analytical results where testing would be difficult
- Recommended way of exchanging information between the equipment manufacturers and end-users of the equipment

Voltage Dip Characteristics – 1/4

VOLTAGE DIP CHARACTERISTIC	RECOMMENDATION
Pre-event segment	
Characteristics of the pre-event segment	Nominal voltage, with low distortion
During-event segment	
Dip magnitude	**Test variable** (vertical axis)
Dip duration	**Test variable** (horizontal axis)
Dip shape	Rectangular
Dip voltage magnitude unbalance (3-ph.)	Test for each case: Type I, II, and III[5]
Dip phase angle unbalance (3-ph.)	Test for each case: Type I, II, and III[3]
Dip phase shift (phase-angle jump)	None for single-phase equipment tests. For 3-phase equipment, test for each case: Type I, II, and III
Dip waveform distortion and transients	Test waveform should have low distortion

Voltage Dip Characteristics – 2/4

- **Dip Magnitude**: Residual/remaining rms voltage
  - Consistent units should be used: V, kV, per unit, or percent
- **Dip Duration**: Time from initiation (start) to recovery (end) of instantaneous voltage
  - Start and End at voltage zero crossing
  - Consistent reference voltage choice
- **Dip Shape**: Rectangular rms voltages
  - Start: Immediate drop to set dip magnitude
  - Constant sag magnitude during event
  - End: Immediate rise to nominal magnitude



Voltage Dip Characteristics – 3/4

VOLTAGE SAG CHARACTERISTIC	RECOMMENDATION
Transition segment	
Point-on-wave of dip initiation	Voltage zero-crossing of the reference voltage (choose one of the L-N or L-L voltages as the reference).
Phase shift at the dip initiation	None for single-phase equipment tests. For three-phase equipment, test for each case: Type I, Type II and Type III
Multistage dip initiation	Not tested
Point-on-wave of dip ending	Not specified: determined by dip duration and point on wave of initiation
Phase shift at the dip ending	Not specified: determined by phase shift at dip initiation (the two should cancel each other).
Multistage dip ending	Not tested
Rate-of-change of voltage	Not tested or specified
Damped oscillations	Not tested

Voltage Dip Characteristics – 4/4

VOLTAGE DIP CHARACTERISTIC	RECOMMENDATION
Voltage recovery (post-event) segment	
Voltage recovery	Immediate
Post-fault dip (prolonged voltage recovery)	Not tested
Post-dip phase shift	None
Multiple dip events (sag sequences)	Not tested
Composite events	Not tested

These recommendations apply to both Compliance Testing & Characterization Testing

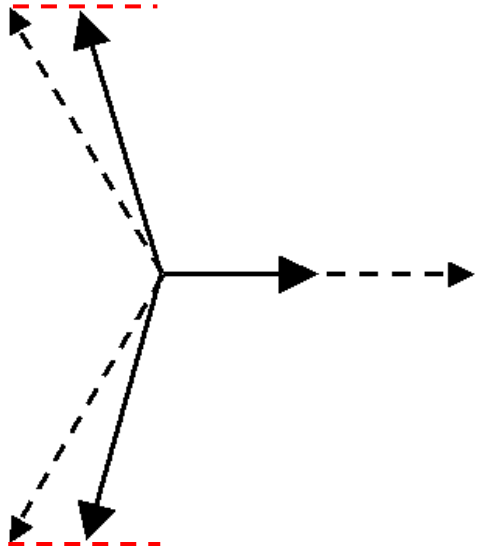
Test Vectors for Testing Three-phase Equipment

- Type I Voltage Dips:
  - Drop in voltage is mainly in **one** phase-to-neutral voltage
  - V is the *characteristic residual voltage* or **magnitude** of the L-N dip. E is the nominal voltage

$$V_a = V$$

$$V_b = -\tfrac{1}{2}V - \tfrac{1}{2}\, jE\sqrt{3}$$

$$V_c = -\tfrac{1}{2}V + \tfrac{1}{2}\, jE\sqrt{3}$$



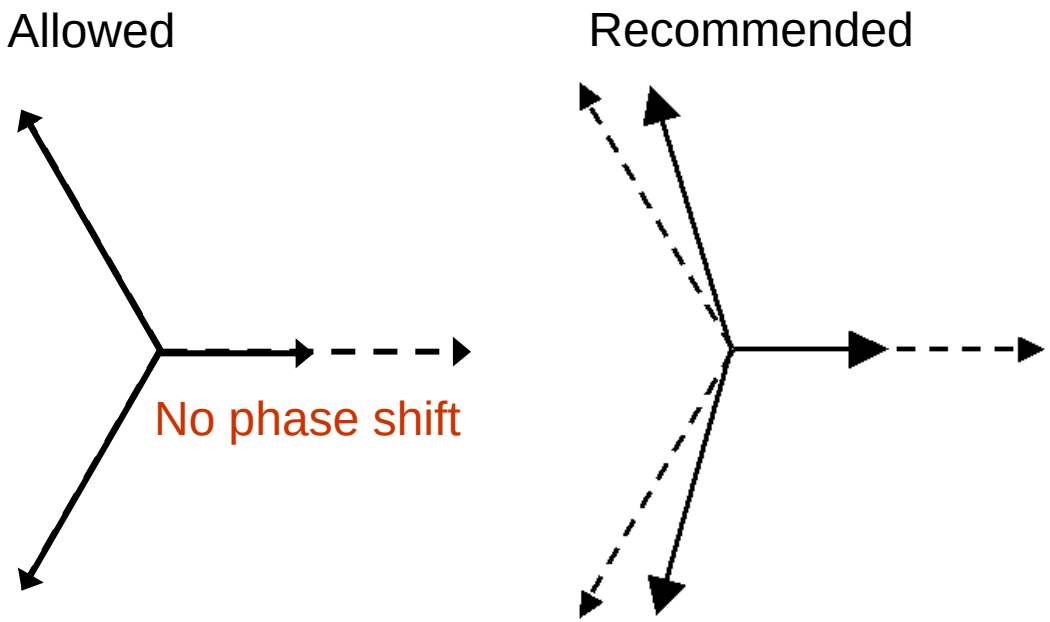
Alternative Test Vectors

- Type I Voltage Dip tests:
  - X is the alternative magnitude of the imposed L-N sag

$$V_a = X$$

$$V_b = -\tfrac{1}{2}E - \tfrac{1}{2}\,jE\sqrt{3}$$

$$V_c = -\tfrac{1}{2}E + \tfrac{1}{2}\,jE\sqrt{3}$$



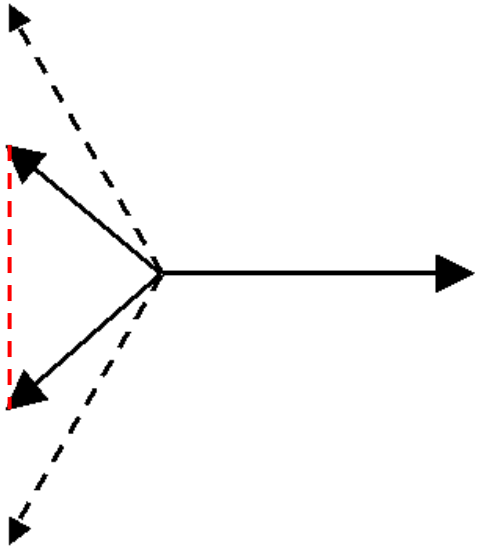
Test Vectors for Testing Three-phase Equipment

- Type II Voltage Dips:
  - Drop in voltage is mainly in **two** phase-to-neutral voltages, or one phase-phase voltage
  - V is the **magnitude** of the L-L dip

$$V_a = E$$

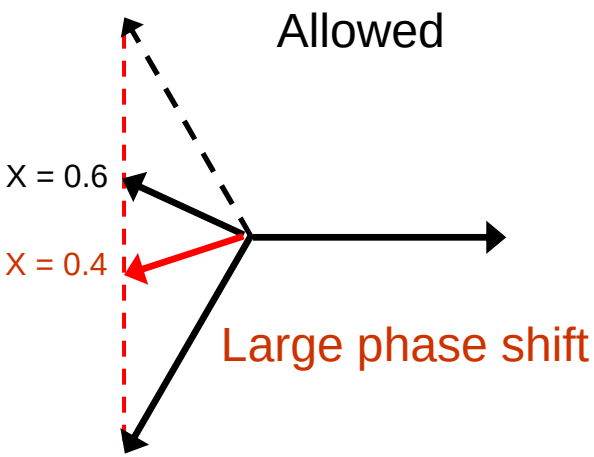
$$V_b = -\tfrac{1}{2}E - \tfrac{1}{2}\,jV\sqrt{3}$$

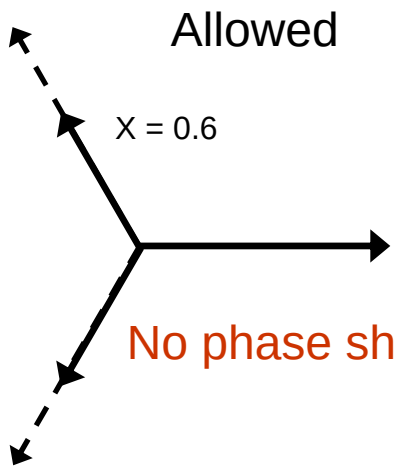
$$V_c = -\tfrac{1}{2}E + \tfrac{1}{2}\,jV\sqrt{3}$$

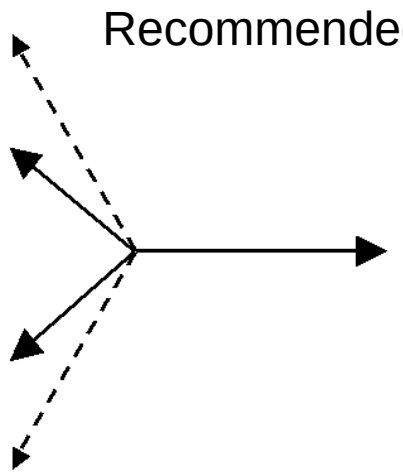


Alternative Test Vectors

- Type II Voltage Dip tests:
  - X is the alternative magnitude of the imposed L-L dip





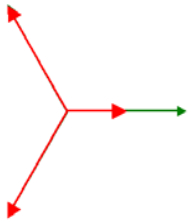


$$V_a = E$$
$$V_b = -\tfrac{1}{2}E - \tfrac{1}{2}\,jE\sqrt{3}$$
$$V_c = -\tfrac{1}{2}E + \tfrac{1}{2}\,j(2X - E)\sqrt{3}$$

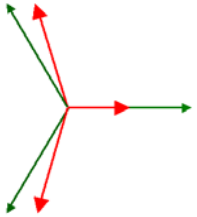
$$V_a = E$$
$$V_b = -\tfrac{1}{2}X - \tfrac{1}{2}\,jX\sqrt{3}$$
$$V_c = -\tfrac{1}{2}X + \tfrac{1}{2}\,jX\sqrt{3}$$

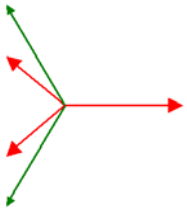
Voltage Dip Event Example

- Delta-Wye transformers change Type I to Type II, and change Type II to Type I
- Example: line to ground fault on grounded-Neutral system

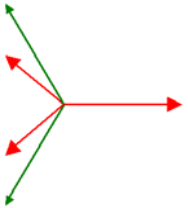


VLN	At Fault	One Δ-Y transf.	Two Δ-Y transf.
AN	0%	58%	88%
BN	100%	58%	33%
CN	100%	100%	88%
Sag Type	**I**	**II**	**I**





VLL	At Fault	One Δ-Y transf.	Two Δ-Y transf.
AB	58%	33%	58%
BC	100%	88%	58%
CA	58%	88%	100%
Sag Type	**II**	**I**	**II**



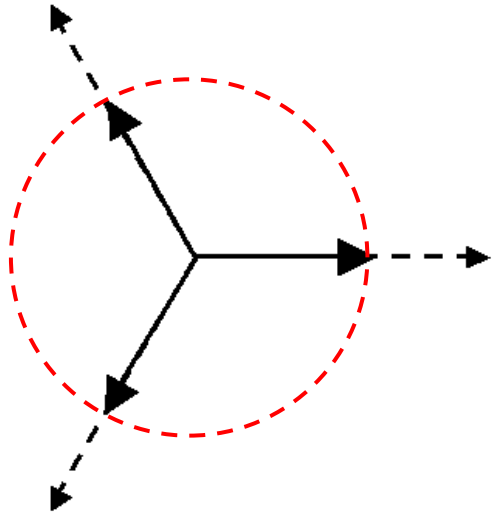
Test Vectors for Testing Three-Phase Equipment

- Type III Voltage Dips:
  - Drop in voltage equally in all **three** phase-neutral voltages, or all three phase-phase voltages

$$V_a = V$$

$$V_b = -\tfrac{1}{2}V - \tfrac{1}{2}\,jV\sqrt{3}$$

$$V_c = -\tfrac{1}{2}V + \tfrac{1}{2}\,jV\sqrt{3}$$

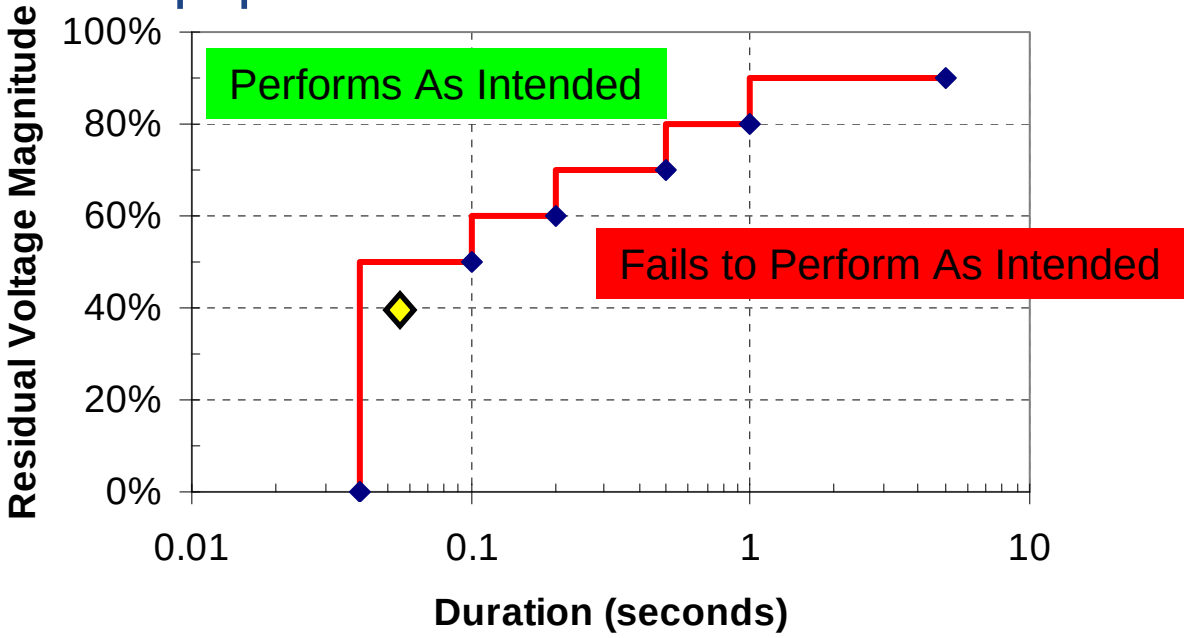


Performing Tests

- Test Equipment (“Dip/Sag Generators”) capable of generating test vectors is available
  - Several manufacturers
- Clearly define equipment operational state during test
- Clearly define immunity test pass/fail (malfunction) criteria:
  - *Equipment performs “as intended”*
    - Automatic reset without damage?
  - *Equipment fails to perform as intended*
    - Equipment “trips”
    - Data loss, data corruption
    - Assisted recovery

Voltage Tolerance Curves

- Actual test points are plotted, connected by a “curve”
- One curve for each of stated/declared nominal input voltage ratings (e.g., 120V and 230V, if 90V-250V)
- One curve for each of Type I, Type II, Type III testing of three-phase equipment

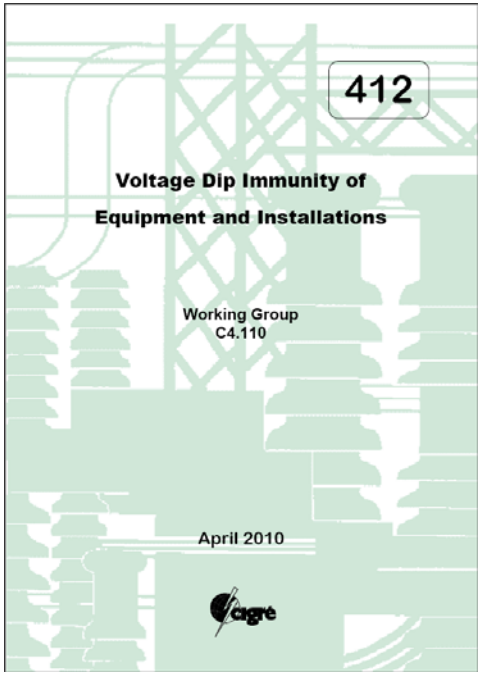


Test Vectors for Compliance Testing

- For compliance testing of three-phase equipment, it is recommended to include tests for Type I, Type II **and Type III** dips
- Testing with Type III dips is not presently required by SEMI, IEC, or IEEE standards
- No recommendations given about the form in which Type III dips should be included in the compliance testing

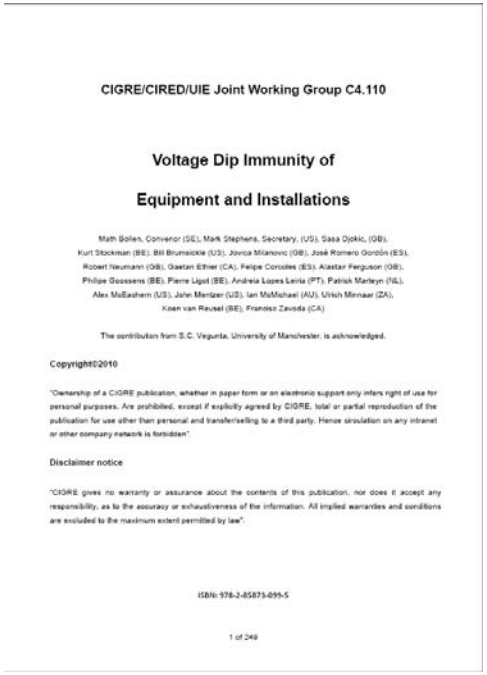
Conclusions

- Characterization testing and Compliance testing are different (different requirements and tests)
- Voltage Tolerance Curves for communicating characterization test results
- Recommended and Allowed Test Vectors options for three-phase equipment testing
  - Allows the use of available test equipment
- Three-phase equipment immunity should be characterized, or compliance tested, with each of Type I, Type II, and Type III voltage dips



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

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



Francisc Zavoda

Hydro Québec

Robert Neumann

QUALITROL®
Defining Reliability