Understanding Power Quality Standards

Dr.Ir.Mohamed Fuad Faisal
Asset Management Department
Distribution Division TNB
Objectives of presentation

Understanding Power Quality, Power Quality Standards, EC Codes, Guidebooks for managing Power Quality
The Malaysian Grid Code
The Malaysian Distribution Code
TNB’s Electricity Supply Application Handbook (ESAH)

IEEE 1100  Recommended Practice for Powering and Grounding Sensitive Electronic Equipment,
IEEE 1159  Recommended Practice For Monitoring Electric Power Quality
IEEE 519  Harmonic mitigation

IEC 60364  Electrical Installations of Buildings

IEC 61000-2-X  EMC
IEC 61000-3-X  EMC
IEC 61000-4-X  EMC

SEMI STD  SEMI F42/47/49/50
ENGR  Engineering Recommendation
EN 50160  Electromagnetic Environment
Presentation contents

• Understanding Normal Utility Grade Power
• Power Quality Standards
  – Definition of Power Quality
  – Mitigation of Power Quality
• PQ & EMC Requirement for Electrical Wiring
• Management of EMC according to Malaysian Grid & Distribution Codes
• TNB’s Power Quality Requirement
• TNB’s Power Quality Guidebooks
Understanding Normal Utility Grade Power
## Power System Connection In Peninsular Malaysia

<table>
<thead>
<tr>
<th>MD ranges of individual customer</th>
<th>Supply voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 12 kVA</td>
<td>230V</td>
</tr>
<tr>
<td>12kVA to 100kVA</td>
<td>400V</td>
</tr>
<tr>
<td>100kVA to 1000kVA</td>
<td>400V</td>
</tr>
<tr>
<td>1000kVA to 5000kVA</td>
<td>11kV</td>
</tr>
<tr>
<td>1000kVA to 10000kVA</td>
<td>22kV</td>
</tr>
<tr>
<td>5000kVA to 25000kVA</td>
<td>33kV</td>
</tr>
<tr>
<td>Above 25000kVA</td>
<td>132kV, 275 kV</td>
</tr>
</tbody>
</table>
Power utility provides normal utility grade power.
Steady State Voltage & Frequency Regulations

<table>
<thead>
<tr>
<th>Voltage level</th>
<th>% variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 Volt &amp; 230 Volt</td>
<td>+10 % to – 6 %</td>
</tr>
<tr>
<td>6.6, 11, 22 &amp; 33 kV</td>
<td>± 5 %</td>
</tr>
<tr>
<td>132 kV &amp; 275 kV</td>
<td>- 5 % to +5 %</td>
</tr>
<tr>
<td>500 kV</td>
<td>± 5 %</td>
</tr>
</tbody>
</table>

Voltage regulations (Contingency)

<table>
<thead>
<tr>
<th>Voltage level</th>
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<tr>
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<tr>
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<td>± 10 %</td>
</tr>
<tr>
<td>500 kV</td>
<td>- 10 % to 10 %</td>
</tr>
</tbody>
</table>

Sinusoidal voltage waveform

Frequency = 50 Hz (+/- 1 %)
Standard Power Reliability & Security

The restoration time will be based on defined security levels.
Power Quality Standards

Definition of Power Quality
Symptoms: Power Outage vs. Power Quality

**Symptoms of Power Quality**

- Lights blinking
- Sudden Equipment maloperation
- Sudden tripping of circuit breakers
- Premature equipment failure

**Symptom of Power Outage**

- No Electricity for more than 60 s
- Premature equipment failure
- Poor performance & unexpected shutdowns
- Lost data in electronics
- Capacitor bank failure
- High ground current
- Others
POWER QUALITY STANDARDS

IEC

IEEE

SEMI

ENGINEERING RECOMMENDATIONS
### Definitions of Power Quality

<table>
<thead>
<tr>
<th>IEC 61000 Series: Power Quality (PQ):</th>
</tr>
</thead>
<tbody>
<tr>
<td>“The ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Power quality (PQ):</strong></td>
</tr>
<tr>
<td>The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the supply system and other connected equipment.</td>
</tr>
</tbody>
</table>
Power Quality/Voltage Disturbances

- Voltage Dips / Sags
- Momentary Interruptions
- Swells
- Transients
- Harmonic Distortion
- Notches
- Voltage fluctuations
- Frequency Deviations

Normal voltage waveforms
POWER QUALITY STANDARDS

- IEC
- IEEE
- SEMI

ENGINEERING RECOMMENDATIONS
According to IEC, Electrical Power Quality is a compatibility problem between the source and load, not perfection of source.....

• Power Quality or Electromagnetic compatibility (EMC) itself is defined as: "the ability of an equipment or system to function satisfactorily in its electromagnetic (EM) environment (immunity) without introducing intolerable electromagnetic disturbances to anything in that environment (emission)".
Concept of Electromagnetic Compatibility
Categories of EMC phenomena.
Low Frequency Disturbances (< 9 kHz) are Power Quality Disturbances

- Voltage Dips / Sags
- Momentary Interruptions
- Swells
- Transients
- Harmonic Distortion
- Notches
- Voltage fluctuations
- Frequency Deviations

Normal voltage waveforms
CATEGORIES OF POWER QUALITY DISTURBANCES

**Steady state Power Quality Variations**
- Harmonics distortion
- Flickers
- Voltage variations – unbalance
- Frequency variations

**Power Quality Disturbances**
- Voltage sag/Voltage swell
- Transients
- Momentary interruption
Part 1: General

- the safety function requirements (what the function does); and
- the safety integrity requirements (the likelihood of a safety function being performed satisfactorily).

Part 2: Environment

- Description of the environment
- Classification of the environment
- Compatibility levels

Part 3: Limits

- Emission limits
- Immunity limits (insofar as they do not fall under the responsibility of product committees)

Part 4: Testing and measurement techniques

- Measurement techniques
- Testing techniques

Part 5: Installation and mitigation guidelines

- Installation guidelines
- Mitigation methods and devices

Part 6: Generic standards
IEC Standards that define Electromagnetic Environment
### LF conducted disturbances

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC/TR 61000-2-1</td>
<td>Electromagnetic compatibility (EMC) - Part 2: Environment - Section 1: Description of the environment - Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems</td>
</tr>
<tr>
<td>IEC 61000-2-2</td>
<td>Electromagnetic compatibility (EMC) - Part 2-2: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems</td>
</tr>
<tr>
<td>IEC 61000-2-4</td>
<td>Electromagnetic compatibility (EMC) - Part 2-4: Environment - Compatibility levels in industrial plants for low-frequency conducted disturbances</td>
</tr>
<tr>
<td>IEC/TR 61000-2-6</td>
<td>Electromagnetic compatibility (EMC) - Part 2: Environment - Section 6: Assessment of the emission levels in the power supply of industrial plants as regards low-frequency conducted disturbances</td>
</tr>
<tr>
<td>IEC/TR 61000-2-8</td>
<td>Electromagnetic compatibility (EMC) - Part 2-8: Environment - Voltage dips and short interruptions on public electric power supply systems with statistical measurement results</td>
</tr>
<tr>
<td>IEC 61000-2-12</td>
<td>Electromagnetic compatibility (EMC) - Part 2-12: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems</td>
</tr>
<tr>
<td>IEC/TR 61000-2-14</td>
<td>Electromagnetic compatibility (EMC) - Part 2-14: Environment - Overvoltages on public electricity distribution networks</td>
</tr>
<tr>
<td>IEC/TR 60725</td>
<td>Consideration of reference impedances and public supply network impedances for use in determining disturbance characteristics of electrical equipment having a rated current = &lt; 75 A per phase</td>
</tr>
</tbody>
</table>

### LF radiated disturbances

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<th>Standard</th>
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<tbody>
<tr>
<td>IEC/TR 61000-2-7</td>
<td>Electromagnetic compatibility (EMC) - Part 2: Environment - Section 7: Low frequency magnetic fields in various environments</td>
</tr>
</tbody>
</table>
IEC 61000-2-4: Electromagnetic Environment

Sinusoidal voltage waveform

Nonsinusoidal voltage waveforms
### IEC 61000-2-4: Electromagnetic Environment

<table>
<thead>
<tr>
<th>Supply Voltage Phenomenon</th>
<th>Acceptable limits</th>
<th>Measurement Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid frequency</td>
<td>49.5Hz to 50.5Hz</td>
<td>10 s</td>
</tr>
<tr>
<td>Slow voltage changes</td>
<td>230Volt ± 8%</td>
<td>10 min</td>
</tr>
<tr>
<td><strong>Voltage Sags or Dips (≤1min)</strong></td>
<td>100 times (Rural / Overhead system)</td>
<td>10 ms</td>
</tr>
<tr>
<td></td>
<td>10-100 times (Urban/Underground system)</td>
<td></td>
</tr>
<tr>
<td>Short Interruptions (≤ 3min)</td>
<td>10 to 100 times per year (under 1% of nominal)</td>
<td>10 ms</td>
</tr>
<tr>
<td>Transient over-voltages</td>
<td>Mostly &lt; 6kV</td>
<td>N/A</td>
</tr>
<tr>
<td>(line-to-ground)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage unbalance</td>
<td>2%</td>
<td>10 min</td>
</tr>
<tr>
<td>Harmonic Voltages</td>
<td>8% Total Harmonic Distortion</td>
<td>10 min</td>
</tr>
</tbody>
</table>

This part of IEC 61000 is concerned with conducted disturbances in the frequency range from 0 kHz to 9 kHz. It gives numerical compatibility levels for industrial and non-public power distribution systems at nominal voltages up to 38 kV and a nominal frequency of 50 Hz or 60 Hz.

Power supply systems on ships, aircraft, offshore platforms and railways are not included.

The compatibility levels specified in this standard apply at the in-plant point of coupling. At the power input terminals of equipment receiving its supply from the above systems, the severity levels of the disturbances can, for the most part, be taken to be the same as the levels at the in-plant point of coupling. In some situations this is not so, particularly in the case of a long feeder dedicated to the supply of a particular load, or in the case of a disturbance generated or amplified within the installation of which the equipment forms a part.

Compatibility levels are specified for electromagnetic disturbances of the types which can be expected at any in-plant point of coupling (IPC) within industrial plants or other non-public networks, for guidance in:

- a) limits to be set for disturbance emission onto industrial power supply systems (including the planning levels defined in 3.1.5);
- NOTE 1: A very wide range of conditions is possible in the electromagnetic environments of industrial and other non-public networks. These are approximated in this standard by the three classes described in Clause 4. However, it is the responsibility of the operator of such a network to take account of the particular electromagnetic and economic conditions, including equipment characteristics, in setting the above-mentioned limits.
- b) the choice of immunity levels for the equipment within these systems.

The disturbance phenomena considered are:

- voltage deviations;
- voltage dips and short interruptions;
- voltage unbalance;
- power-frequency variations;
- harmonics up to order 50;
- interharmonics up to the 50th harmonic;
- voltage components at higher frequencies (above 50th harmonic);
- d.c. component;
- transient overvoltages.
IEC standards that define measurement Technique/Emission

<table>
<thead>
<tr>
<th>LF conducted disturbances</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61000-4-7</td>
</tr>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-7: Testing and measurement techniques - General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto</td>
</tr>
<tr>
<td>IEC 61000-4-15</td>
</tr>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 15: Flickermeter - Functional and design specifications</td>
</tr>
</tbody>
</table>
**LF conducted disturbances**

<table>
<thead>
<tr>
<th>Standard</th>
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<tbody>
<tr>
<td>IEC 61000-3-2</td>
<td>Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)</td>
</tr>
<tr>
<td>IEC 61000-3-3</td>
<td>Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection</td>
</tr>
<tr>
<td>IEC/T 61000-3-4</td>
<td>Electromagnetic compatibility (EMC) - Part 3-4: Limits - Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A</td>
</tr>
<tr>
<td>IEC/T 61000-3-5</td>
<td>Electromagnetic compatibility (EMC) - Part 3-5: Limits - Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 75 A</td>
</tr>
<tr>
<td>IEC/TR 61000-3-6</td>
<td>Electromagnetic compatibility (EMC) - Part 3-6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems</td>
</tr>
<tr>
<td>IEC/TR 61000-3-7</td>
<td>Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems</td>
</tr>
<tr>
<td>IEC 61000-3-8</td>
<td>Electromagnetic compatibility (EMC) - Part 3: Limits - Section 8: Signalling on low-voltage electrical installations - Emission levels, frequency bands and electromagnetic disturbance levels</td>
</tr>
<tr>
<td>IEC 61000-3-12</td>
<td>Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current &gt; 16 A and ≤ 75 A per phase</td>
</tr>
</tbody>
</table>
Power quality phenomena

• The term *power quality* refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location on the power system.

• IEEE uses the electromagnetic compatibility approach to describe power quality phenomena. The electromagnetic compatibility approach has been accepted by the international community in International Electrotechnical Commission (IEC) standards produced by IEC Technical Committee 77.
## Principal phenomena causing electromagnetic disturbances

<table>
<thead>
<tr>
<th>Group</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conducted low-frequency phenomena</td>
<td>Harmonics, interharmonics</td>
</tr>
<tr>
<td></td>
<td>Signal systems (power line carrier)</td>
</tr>
<tr>
<td></td>
<td>Voltage fluctuations</td>
</tr>
<tr>
<td></td>
<td>Voltage dips and interruptions</td>
</tr>
<tr>
<td></td>
<td>Voltage imbalance</td>
</tr>
<tr>
<td></td>
<td>Power-frequency variations</td>
</tr>
<tr>
<td></td>
<td>Induced low-frequency voltages</td>
</tr>
<tr>
<td></td>
<td>DC in AC networks</td>
</tr>
<tr>
<td>Radiated low-frequency phenomena</td>
<td>Magnetic fields</td>
</tr>
<tr>
<td></td>
<td>Electric fields</td>
</tr>
<tr>
<td>Conducted high-frequency phenomena</td>
<td>Induced continuous wave (CW) voltages or currents</td>
</tr>
<tr>
<td></td>
<td>Unidirectional transients</td>
</tr>
<tr>
<td></td>
<td>Oscillatory transients</td>
</tr>
<tr>
<td>Radiated high-frequency phenomena</td>
<td>Magnetic fields</td>
</tr>
<tr>
<td></td>
<td>Electric fields</td>
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<tr>
<td></td>
<td>Electromagnetic fields</td>
</tr>
<tr>
<td></td>
<td>Continuous waves</td>
</tr>
<tr>
<td></td>
<td>Transients</td>
</tr>
<tr>
<td>Electrostatic discharge phenomena (ESD)</td>
<td>—</td>
</tr>
<tr>
<td>Nuclear electromagnetic pulse (NEMP)</td>
<td>—</td>
</tr>
</tbody>
</table>
POWER QUALITY STANDARDS

IEC

IEEE

SEMI

ENGINEERING RECOMMENDATIONS
SEMI F50: Electromagnetic Environment for voltage sags

[Graph showing compatibility of percentage of nominal voltage with duration in milliseconds.]

- 25-30 events
- 15-20 events
- 10-15 events
- 5-10 events per site per year
- 0-5 events per site per year

Nominal Voltage Base: 480
Power Quality Standards

Mitigation of Power Quality
POWER QUALITY STANDARDS

- IEC
- IEEE
- SEMI

ENGINEERING RECOMMENDATIONS
Understanding EMC Testing

EMC Testing is necessary in ensuring that a device, equipment or system does not emit electromagnetic disturbances more than the levels determined in limits established by regulatory / standard bodies, and ...

at the same time it is able to withstand an expected level of electromagnetic disturbances from various sources of transient phenomena and continuous radio frequency phenomena that are present in its intended electromagnetic environment.
<table>
<thead>
<tr>
<th>IEC 61000-4-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-13: Testing and measurement techniques - Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests</td>
</tr>
</tbody>
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<table>
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<tr>
<th>IEC 61000-4-14</th>
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<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-14: Testing and measurement techniques - Voltage fluctuation immunity test for equipment with input current not exceeding 16 A per phase</td>
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<table>
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<tr>
<th>IEC 61000-4-16</th>
</tr>
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<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-16: Testing and measurement techniques - Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz</td>
</tr>
</tbody>
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<tr>
<th>IEC 61000-4-17</th>
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<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-17: Testing and measurement techniques - Ripple on d.c. input power port immunity test</td>
</tr>
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<tr>
<th>IEC 61000-4-27</th>
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<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-27: Testing and measurement techniques - Unbalance, immunity test for equipment with input current not exceeding 16 A per phase</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>IEC 61000-4-28</th>
</tr>
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<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-28: Testing and measurement techniques - Variation of power frequency, immunity test for equipment with input current not exceeding 16 A per phase</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>IEC 61000-4-29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port immunity test</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IEC 61000-4-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-30: Testing and measurement techniques - Power quality measurement methods</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IEC 61000-4-34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic compatibility (EMC) - Part 4-34: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with mains current more than 16 A per phase</td>
</tr>
<tr>
<td><strong>LF radiated disturbances</strong></td>
</tr>
<tr>
<td>--------------------------------</td>
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</tbody>
</table>
| **IEC 61000-4-8**  
Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test |

<table>
<thead>
<tr>
<th><strong>HF conducted disturbances</strong></th>
</tr>
</thead>
</table>
| **IEC 61000-4-4**  
Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test |
| **IEC/TR 61000-4-5**  
Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test |
| **IEC/TR 61000-4-6**  
Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields |
| **IEC/TR 61000-4-12**  
Electromagnetic compatibility (EMC) - Part 1-5: General - High power electromagnetic (HPEM) effects on civil systems |
| **IEC 61000-4-18** |

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<thead>
<tr>
<th><strong>HF radiated disturbances</strong></th>
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</table>
| **IEC 61000-4-3**  
Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test |
| **IEC 61000-4-9**  
Electromagnetic compatibility (EMC) - Part 4-9: Testing and measurement techniques - Pulse magnetic field immunity test |
Summary of EMC Testing

EMC

Interference

Conducted & Radiated emission
IEC 55011, 55012, 55013, 55014, 55015, 55022, 55025, 61000-6-3, 61000-6-4

Harmonic current emission
IEC 61000-3-2, 61000-3-4, IEC 61000-3-12

Voltage changes, fluctuation & flickers
IEC 61000-3-3, 61000-3-7

Susceptibility

Electrostatic Discharge IEC 61000-4-2
Radiated EM Field Immunity IEC 61000-4-3
Burst/ Electrical Fast Transient IEC 61000-4-4
Surge IEC 61000-4-5
Conducted Disturbance RF fields IEC 61000-4-6
Power Frequency Magnetic fields IEC 61000-4-8
Pulse Magnetic field IEC 61000-4-9
Voltage Dips, Short Interruption & Voltage variations IEC 61000-4-11, IEC 61000-4-34
Harmonics IEC 61000-4-13
IEC standards for Evaluating Equipment Sensitivity against voltage dips

IEC 61000-4-34 Low Frequency Phenomena (International Electrotechnical Commission)

IEC 61000-4-11 is Intended to be used for Equipment LESS Then 16A

IEC 61000-4-34 is Intended to be used for Equipment GREATER Then 16A

The Intent of IEC 61000-4-11 and -34 is to define Voltage Dip Test Levels, not for Specific Types of Equipment, but Attempts to Define the Environment of the Equipment

IEC 61000-4-34 applies to Equipment over 16A and IEC 61000-4-11 for Equipment Under 16A
Class 1 - This class applies to protected supplies and has compatibility levels lower than public network levels. It relates to the use of equipment very sensitive to disturbances in the power supply for instance the instrumentation of technological laboratories, some automation and protection equipment, some computers, etc.

NOTE Class 1 environments normally contain equipment which requires protection by such apparatus as uninterruptible power supplies (UPS), filters, or surge suppressors.
Class 2 - This class applies to points of common coupling (PCC’s for consumer systems) and points of common internal point of coupling (IPC’s) in the industrial environment in general.

The compatibility levels in this class are identical to those of public networks; therefore components designed for application in public networks may be used in this class of industrial environment.
IEC 61000-4-11 / 34 Class 3

Class 3 - This class applies only to IPC’s in industrial environments. It has higher compatibility levels than those of class 2 for some disturbance phenomena.

For instance, this class should be considered when any of the following conditions are met:

• a major part of the load is fed through converters;
• welding machines are present;
• large motors are frequently started;
• loads vary rapidly
Class X – User Defined and in case of SEMI F47-0706, the test Points are Defined in the SEMI F47 Standard
IEC 61000-2-8 PROPOSES MITIGATION MEASURES FOR VOLTAGE SAG
IEC Standard on Surge Protection

IEC 61643-1-1998

Diapositive de protection contre les surtensions connectés aux réseaux de distribution basse tension –
Partie 1: Prescriptions de fonctionnement et méthodes d’essai

Surge protective devices connected to low-voltage power distribution systems –
Part 1: Performance requirements and testing methods
Overview of IEEE 1000: 2005

• IEEE 1100 describes the many types of power correction devices that accept electrical power in whatever form it is available and modify the power to improve the quality or reliability required for electronic & voltage sensitive equipment.

• IEEE 1100 recommends proper grounding practices to minimize equipment maloperation, high ground current, etc.
<table>
<thead>
<tr>
<th>POWER QUALITY CONDITION</th>
<th>TRANSIENT VOLTAGE SURGE</th>
<th>EMIF</th>
<th>ISOLATION TRANSFORMER</th>
<th>VOLTAGE REGULATOR (ELECTRONIC)</th>
<th>VOLTAGE REGULATOR (FERRORESONANT)</th>
<th>MOTOR GENERATOR</th>
<th>STANDBY POWER</th>
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<th>STANDBY ENGINE GENERATOR</th>
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<td>Transient Voltage Surge</td>
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Specification and selection of equipment and materials

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7.2 Commonly used power correction devices
7.3 Equipment specifications
7.4 Procurement specifications
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IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

Sponsor
Transmission and Distribution Committee of the IEEE Power Engineering Society

and

Static Power Converter Committee of the IEEE Industry Applications Society

Approved June 18, 1992
IEEE Standards Board
Approved January 4, 1993
American National Standards Institute
SEMI Standards for Managing Voltage Sags

SEMI F47-0200
SPECIFICATION FOR SEMICONDUCTOR PROCESSING EQUIPMENT VOLTAGE SAG IMMUNITY

This specification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Subcommittee on December 15, 1998. It is available online at SEMI Online. It is expected to be published in February 2002. Originally published in September 1999.

1 Purpose

1.1. Semiconductor factories require high levels of power quality due to the sensitivity of equipment and process control. Semiconductor processing equipment is especially vulnerable to voltage sags. This document defines the voltage sag ride-through capability required for semiconductor processing, metrology, and automated test equipment.

1.2. The requirements in this international standard were developed to satisfy semiconductor industry needs. While more stringent than existing generic standards, this industry-specific specification is not in conflict with known generic equipment regulations from other regions or generic equipment standards from other organizations (see Related Information section).

1.3. It is the intent of this standard to provide specifications for semiconductor processing equipment that will lead to improved solution criteria for subcomponents and improvements in equipment design and installation. While it is recognized that in certain extreme cases or for specific functions battery storage devices may be appropriate, it is not the intent of this standard to increase the size or use of battery storage devices provided with equipment. Focus on improvements in equipment component and system design should lead to a reduction or elimination in the use of battery storage devices to achieve equipment reliability during voltage sag events.

2 Scope

2.1. This document specifies the minimum voltage sag ride-through capability design requirements for equipment used in the semiconductor industry. The expected equipment performance capability is shown graphically on a short term basis, where voltage sag duration and percent deviation of equipment nominal voltage. Standard evaluation test methods and test cases are included.

2.2. The primary focus for this specification is semiconductor processing equipment including but not limited to the following test types:
   - ISF equipment (Dry & Wet)
   - Film deposition equipment (CVD & PVD)

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SEMI F42 - Test Methodology
(Superseded by SEMI F47-0706)

SEMI F50 - Guide for Electric Utilities

SEMI F49 - Guide for Semiconductor Factory Systems

SEMI F50 - Guide for Electric Utilities

Guide for the Design of Semiconductor Equipment to Meet Voltage Sag Immunity Standards

International SEMATECH Technology Transfer #
99063760B-TR
Technical Standard for Evaluating Equipment Sensitivity for voltage sags

SEMI F47-0706 Specification for Semiconductor Processing Equipment Voltage Sag Immunity

This specification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 15, 2009. Initially available on SEI Online January 2000, to be published February 2006. Originally published September 1999.

1 Purpose
1.1 Semiconductor factories require high levels of power quality due to the sensitivity of equipment and process controls. Semiconductor processing equipment is especially vulnerable to voltage sags. This document defines the voltage sag ride-through capability required for semiconductor processing, metrology, and semiconductor test equipment.

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1.3 It is the intent of this standard to provide specifications for semiconductor processing equipment that will lead to improved selection criteria for subcomponents and improvements in equipment systems design. While it is recognized that in certain extreme cases or for specific functions battery storage devices may be appropriate, it is not the intent of this standard to increase the size or use of battery storage devices provided with equipment. Focus on improvements in equipment component and system design should lead to a reduction or elimination in the use of battery storage devices to achieve equipment reliability during voltage sag events.

2 Scope
2.1 This document specifies the minimum voltage sag ride-through capability design requirements for equipment used in the semiconductor industry. The expected equipment performance capability is shown graphically on a chart representing voltage sag duration and percent deviation of equipment nominal voltage. Standard evaluation test method references are also included.

2.2 The primary focus for this specification is semiconductor processing equipment including but not limited to the following tool types:
- Etch equipment (Dry & Wet)
- Film deposition equipment (CVD & PVD)
- Thermal equipment
- Surface prep and clean
- Photolithography equipment (Staple & Track)
- Chemical Mechanical Polishing equipment
- Ion implant equipment
- Metrology equipment, and
- Automated test equipment.

2.3 This specification applies to semiconductor processing equipment to include the equipment mainframe and all subsystems whose electrical power is directly affected by the operation of the equipment’s EMS system.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations
3.1 Not included in this standard are over voltage conditions, voltage sag duration of less than 0.05 seconds (50 milliseconds), and voltage sag duration of greater than 1.0 seconds. If necessary, the Information Technology Industry Council (ITIC) “SEMI-A-5” or “SEMI-A-5A” contained in EEU 446, IEEE 1159, and SEMI E10 can be used to specify additional requirements outside the range of this document (see Related Information, Section R1-4).

3.2 This specification does not address wafer quality with regard to process variations caused by voltage sags. It is recommended that each equipment supplier consider the effects of voltage sags on their equipment processes. If voltage sags above the defined line can result in known wafer quality problems, then an appropriate notification-only scheme should be considered in the equipment design. To be in conformance with this standard that notification scheme should not be classified in an equipment equivalent per SEMI E10.

3.3 This standard addresses specifications for semiconductor processing equipment voltage sag immunity. Factory systems voltage sag immunity and utility voltage sag performance are covered in
Note: All the blue dots signified voltage sags recorded at 15 number of semiconductor plants in USA.
SEMI F47 System approach

SEMI standards address voltage dips at different levels

- Utility Services
  - Utility Supplied Power
  - Power Monitoring and Conditioning

- Facilities Systems
  - Facilities Electrical Distribution System
  - Power Monitoring and Conditioning
  - Ride-Through Techniques

- Wafer Processing Systems
  - Infrastructure Equipment
  - Support Equipment
  - Process Equipment
  - Ride-Through Techniques

- Standards:
  - SEMI F50
  - SEMI E51 & F49
  - SEMI F42 & F47

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SEMI F47 Compliance Strategies

- Use “Selective Power Conditioners” on susceptible loads
- Embed the Solution through proper design, configuration and component selection strategies
- Utilize a *Combination* of both strategies

These equipment exceed SEMI F47
PQ & EMC Requirement for Electrical Wiring
ELECTRICAL INSTALLATIONS OF BUILDING
– GUIDE TO MS IEC 60364
Low-voltage electrical installations –
Part 1:
Fundamental principles, assessment of general characteristics, definitions

This English-language version is derived from the original bilingual publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.
Management of EMC according to Malaysian Grid & Distribution Codes
The Malaysian Codes address the existence of voltage disturbances and EMC requirement for Power Quality.
TNB’s Power Quality Requirement
Electricity Supply Application Handbook
address the power quality requirement

Vision
To be among the leading corporations in energy and related businesses globally

Mission
We are committed to excellence in our products and services

Shared values
Our shared values provide us with a principle that will shape our business ethics and operations
- Customer first
- Business excellence
- Integrity
- Caring
1.3 POWER QUALITY

1.3.1 Power Quality Requirement

1.3.1.1 TNB supplies electricity by the alternating current (ac) system with system frequency of 50 Hz with specified regulated voltage levels. The ranges of voltage regulations available are explained in section 2.1 of this guideline.

1.3.1.2 TNB shall supply electricity to the main incoming terminals or point of common couplings (PCC) between the consumers and TNB with voltage sag performance as indicated in standards IEC 61000-2-4 and IEC/TR 61000-2-8.
1.3.2.1 TNB specifies requirement that the consumer’s must comply with in order to limit the impact of the potential short duration voltage and frequency fluctuations.

1.3.2.2 The requirements are:

Table 1-4: TNB Power Quality Requirements

<table>
<thead>
<tr>
<th>Type Of Disturbance</th>
<th>Indices</th>
<th>Acceptable permissible values at point of common coupling (PCC)</th>
<th>Reference Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Step Change</td>
<td>$\Delta V \ %$</td>
<td>1% - Frequent starting/switching and/or disconnection of load. 3% - Infrequent single starting/switching or disconnection of Load – once in two hours or more hours. 6% - Starting/switching once or twice a year.</td>
<td>UK’s Engineering Recommendation P28</td>
</tr>
<tr>
<td>Voltage Fluctuation and Flicker</td>
<td>Absolute Short Term Flicker Severity ($P_{st}$)</td>
<td>1.0 (at 132kV and below) 0.8 (Above 132kV) 0.8 (at 132kV and below) 0.6 (Above 132kV)</td>
<td>UK’s Engineering Recommendation P28</td>
</tr>
<tr>
<td></td>
<td>Absolute Long Term Flicker Severity ($P_{lt}$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harmonic Distortion$^2$</td>
<td>Total Harmonic Distortion Voltage (THDV) $%$</td>
<td>5% at $\leq$ 400 Volt 4% at 11kV to 22kV 3% at 33kV 3% at 132kV</td>
<td>Engineering Recommendation ER G5/4</td>
</tr>
<tr>
<td>Voltage Unbalance</td>
<td>Negative Phase Sequence Voltage $%$</td>
<td>2% for 1 minute</td>
<td>UK’s Engineering Recommendation P29</td>
</tr>
</tbody>
</table>
1.3.2.3 It is the responsibility of the consumer to ensure that his/her voltage sensitive equipment is able to function continuously through unanticipated voltage sags, caused when the system is subject to external interference such as lightning, 3\textsuperscript{rd} party cable damage, other consumer’s equipment fault, TNB equipment fault etc.

1.3.2.4 The consumer must select modern equipment that is able to ride through many of these voltage sags. Consumers should ask their equipment manufacturers whether their equipment can function properly during the voltage sag conditions illustrated in the European Standard EN 50160, IEC Standard 61000-2-2 and IEC Standard IEC 61000-2-4. If the equipment does not have any immunity to voltage sags, then the consumer should request from the manufacturers on measures to immune the equipment against voltage sags.

1.3.2.5 The recommended standards to refer for evaluating equipments’ sensitivities and identifying immunity solutions to voltage sags, short interruption and voltage variations are IEC Standard 61000-4-11 and IEC Standard 61000-4-34.

1.3.2.6 Guidelines on some immunity measures against voltage sags can be referred to TNB Power Quality Guidebook at http://www.tnb.com.my/tnb/con_quality.htm

1.3.3 Declaration to Power Quality Requirement

1.3.3.1 The consumer is required to declare his equipment compatibility and compliance with regards to the required power quality standard using the Power Quality Compliance Declaration Form in Appendix 8.
TNB’s Power Quality Guidebooks
TNB GUIDEBOOKS ON VOLTAGE SAG SOLUTIONS

Power Quality (PQ) GUIDEBOOK

VOLTAGE SAG SOLUTIONS FOR INDUSTRIAL CUSTOMERS

Voltage Sag Solutions for Industrial Customers
2nd edition

A guidebook by Tenaga Nasional Berhad
improving power quality for sensitive customers

Distribution Network

Transmission Network

system improvement

mitigation equipment

Supply Side

Load Side

improvement of equipment immunity
Categories for Voltage Sag Solutions

Utility Solutions

Whole Plant Solution
Protect Entire Facility

Panel Feeder Solution
Protect Feeder or Group of Machines

Machine Solutions
Protect Whole Machine or Machine Control Circuits

Control Level Solutions
Small Power Conditioners, More Robust Relays, Power Supplies, Contactors, Sensors, etc.

Relative Cost of Solution

Knowledge of Equipment Sensitivity
EMC Embedded Solutions for Voltage Sags

Simple 8 solutions

– Tip #1: Use DC supply (if applicable)
– Tip #2: Wire load devices in a phase-to-phase configuration
– Tip #3: Identify & improve sensitive ice cube relays
– Tip #4: Do not use phase monitoring relays or undervoltage relays (UVR) in the interlock circuit, VCB etc.
– Tip #5: Install auto restart schemes (if applicable)
– Tip #6: Use a SEMI F47/IEC61000 compliance power supply
  – Range #1 (95V-250V (Japan and Europe)),
  – Range #2, 110V-270V (North America and Australia)
– Tip #7: Employ Delay tripping for Motors, Contactors, UVR etc (Voltage 70%, t=2 to 3 seconds)
Tip #8: VFD calibration instead of scalar to set DFC (direct fly start) ere flying start is automatic
Control Level Solution for control systems:

Improvement in UVR, improvement in control program settings, auto restart, built in immunity & application of single phase Power Conditioner (PC)

Please evaluate the undervoltage relay (UVR) in the control system.

No Power conditioner  
With Power conditioner
Machine or Panel Level Solutions

415 Volt Machine or Panel Level Solutions

11 kV and 415 Volt

Cursor: -1ms -95.26 Volts

www.PowerStandards.com

With Power conditioner

PC: Power Conditioner

No Power conditioner

415 Volt

415 Volt

PC: Power Conditioner
TNB Guidebook on Managing Harmonics
Chapter 10  
HARMONICS SIMULATION SOFTWARE

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Types of harmonic mitigation

A. AC Line reactors

B. Passive harmonic filters
   - Series – single phase filters – 3rd harmonic filters (Zero Sequence)
   - Shunt – Tuned filter – 5th, 7th, 11th, 13th harmonic filter
   - Low pass broad band harmonic filters

C. Active harmonic filters

D. Isolation transformers

E. Others
AC LINE REACTORS

(a) Single Motor

(b) Multiple Motors
Passive Harmonic Filter

Active Harmonic Filter
SUMMARY
According to IEC & IEEE, Electrical Power Quality is a compatibility problem between the source and load, not perfection of source…..

- Power Quality or Electromagnetic compatibility (EMC) itself is defined as: "the ability of an equipment or system to function satisfactorily in its electromagnetic (EM) environment (immunity) without introducing intolerable electromagnetic disturbances to anything in that environment (emission)".
POWER QUALITY STANDARDS

IEC

IEEE

SEMI

ENGINEERING RECOMMENDATIONS
Planning/Design Stage

- Power Quality Environment Surveys and Calculations
- Equipment Specifications Development
- Facility Design/Power Conditioning Specifications

Solving Power Quality Problems

- Power Quality Site Surveys/Investigations
- Equipment Performance Testing/Characterizing
- Design of Solutions
- Implementation and Maintenance of Solutions
The Malaysian Codes highlight the EMC responsibility for both power utility & customers.