Outline

Power Quality in Electrical Systems

by

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Authors

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- Marc Thompson, Ph.D, President, Thompson Consulting, Inc., Harvard MA and Adjunct Associate Professor of Electrical Engineering, Worcester Polytechnic Institute. Teaches graduate-level power electronics and analog circuit design; twenty years industrial experience in analog and power electronics design; author, co-author, 10 papers; 7 US Patents.
Overview

- Tremendous requirement for reliable, uninterruptible electric power service for all consumers, particularly manufacturing facilities, data-processing centers, and other locations with critical and sensitive loads.
- Power Quality is a measure of the reliability of electric power service.
- Multi-million dollar industry to provide engineering and equipment to resolve Power Quality problems.
- Book is based on a professional course sponsored by IEEE and taught by the authors.
- Book is directed toward real problems and solutions, rather than a total theoretical treatment.
- Book can be used as the text for a course and as a reference.
- Book will include treatment of switch-mode power supplies and other loads that produce conducted and radiated interference. Levels are regulated by FCC and other codes.
- Book will include description of standby power systems for emergency and indepen operation to solve Power Quality problems.

Market

- Managers, concerned with reliable electric power service
  - Computers/Date Centers
  - Manufacturers
  - Manufacturing facilities
  - Office buildings
  - Electric utility companies
  - Government/Military agencies
  - Healthcare facilities

- Engineers concerned with standards compliance and reliable operation of equipment and systems
  - Electrical design
  - Electric and telecom utilities
- Transportation
- Computer/Telecom
- Unconventional power (e.g. wind)

- Students seeking knowledge and entrance to an active field
  - Fourth year and graduate engineer
  - Two-year associate engineer
  - Professional engineer

Focus

- Identification and correction of power quality problems.
- Listing of definitions and standards
- Case studies from authors’ experience and in references of power quality problems and solutions.
- References to significant articles in the professional and trade journals.

Organization of Book

- See Table of Contents
- Based on original six lectures expanded to 12 chapters.
- Figures suitable for PowerPoint presentation; can be emailed to students prior to each class.
- Preface of book will describe how the book can be used, for example, for a six-lecture professional course or for an 18-plus lecture academic course.
- Estimated length of book, 400 pages, including up to 100 figures (already done). See Attachment A for some representative figures.

Competitive Books

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  - Voltage sag, swell, transients, flicker
  - Harmonics
  - Frequency Deviations
  - Interference

- Examples of poor power quality
  - Interruptions
  - Voltage distortion
  - Capacitor failures
  - Flicker
  - EMI, conducted and radiated

- Need for corrections
  - Customer needs
  - Standards and codes

- Scope
  - Events
  - Corrective measures

### Chapter 2. Power Quality

- Factors causing poor power quality
  - Power outages
  - Inherent equipment design
  - Non linear loads, converters, arcing
  - Motor starts, utility switching
  - Standards non-compliance

- Relevant standards
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  - CBEMA curve
  - Engine-generator standards
  - UPS standards
- Utility, state and federal standards
- EMI standards
  - US: FCC Class A and B
  - International: CISPR 16-1, EN 61000

**Chapter 3. Voltage Distortion**

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  - Amplitude, sags, swells, transients
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  - Lightning
  - Utility switching
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  - Converters
  - Non-linear loads
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- Effects on equipment; case study
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- Three-phase rectifiers

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- Power Harmonic Filters
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- Uninterruptible Power Supplies, UPS
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  - Rotating

- Transformers
  - Harmonic Cancellation
  - Saturable Magnetic, SOLA

- Standby Power Systems

Chapter 8. Switch-Mode Power Supplies
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• Types
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• Systems
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  - Maintenance, 24/7 concept

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• Resonance, Example
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  - Back up UPS, batteries
  - Independent supply

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- Typical systems
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Attachment A
Representative Figures

Typical Lightning-Induced Transient

![Figure 1 — Lightning stroke current that can result in impulsive transients on the power system](image)


UPS: Static Inverter

![Figure 2.3 — Emergency system with a static UPS](image)

Phase Current and Voltage

![Graph showing phase current and voltage](image)

Fig. 9. Measured current (solid) and voltage (dashed) at 5 m/s.

Table 1. Relative harmonic content of the voltages.

<table>
<thead>
<tr>
<th>order n</th>
<th>5</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>11</th>
<th>13</th>
<th>15</th>
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</thead>
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<tr>
<td>frequency (Hz)</td>
<td>250</td>
<td>350</td>
<td>400</td>
<td>450</td>
<td>550</td>
<td>650</td>
<td>750</td>
</tr>
<tr>
<td>U_{1m} (%)</td>
<td>1.1</td>
<td>0.72</td>
<td>0.11</td>
<td>0.072</td>
<td>0.092</td>
<td>0.056</td>
<td>0.018</td>
</tr>
<tr>
<td>U_{2m} (%)</td>
<td>1.0</td>
<td>0.54</td>
<td>0.09</td>
<td>0.048</td>
<td>0.047</td>
<td>0.016</td>
<td>0.008</td>
</tr>
</tbody>
</table>


Resonance: Distribution Factor, with Reactor

\[ \rho_{fB} \rightarrow 1 \text{ at } n = 5 \]
\[ \rho_{sB} \rightarrow 0 \text{ at } n = 5 \]

![Graph showing resonance distribution factors](image)
