Outline

Power Quality in Electrical Systems

by

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Authors

- Alexander Kusko, Sc.D, Corporate Vice President, Exponent Failure Analysis Associates, Natick, MA. Forty years experience on UPS, power-system design, and power quality. Former associate professor of Electrical Engineering at MIT, Author, co-author, 150 papers, 7 books; IEEE Life Fellow.

- 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 independent 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
TABLE OF CONTENTS

Chapter 1. Introduction

- Definitions of term, “Power Quality”
  - 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
  - IEEE Stds 519 and 1159
  - 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**

- Definitions
  - Amplitude, sags, swells, transients
  - Harmonic distortion
  - Interruptions
- Causes, External to Facility
  - Utility outages
  - Lightning
  - Utility switching
- Causes, Internal to Facility
  - Converters
  - Non-linear loads
  - Motor starts
- Impact on Connected Equipment
  - Compliance with CBEMA Curve
  - Erratic operation and shutdown of equipment
  - Damage

**Chapter 4. Harmonics**

- Definitions
  - Multiples of line frequency, characteristics.
  - Non-characteristic
- Fourier Analysis
  - Combined waveforms
- Total harmonic distortion, THD
- IEEE Std. 519
- Effects on equipment; case study
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- Converters, definitions
  - Single-phase rectifiers
  - Multi-phase rectifiers
  - Controlled rectifiers

- Single-phase rectifiers
  - Inductor filter
  - Capacitor filter
  - Commutation, waveform notching
  - Voltage effect

- Multi-phase rectifiers, applications
  - Motor drives
  - UPS
  - Industry, transit, electrochemical

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  - Control
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  - Harmonics

- Three-phase rectifiers

- Analysis
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- System Effects
  - Line and neutral current
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- IEEE Std. 519
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  - Total Harmonics, THD
• Case study

Chapter 6. Power Capacitors

• Purpose
  - Utility, facility, location
  - Power factor correction
  - Power harmonic filter
  - Switching

• Ratings
  - Reactive power, kvar
  - Voltage, current

• Resonance
  - Circuit
  - Calculation
  - Prevention

Chapter 7. Corrections for Power Quality Problems

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  - 12 pulse

• Power Harmonic Filters
  - Passive
  - Active

• Uninterruptible Power Supplies, UPS
  - Static
  - Rotating

• Transformers
  - Harmonic Cancellation
  - Saturable Magnetic, SOLA

• Standby Power Systems

Chapter 8. Switch-Mode Power Supplies
• Applications
• Sources of EMI
• Standards
  - US and European
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Chapter 9. Uninterruptible Power Supplies
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  - Isolate load from line
  - Features
• Types
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• Systems
  - Engine-generator sets
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  - Maintenance, 24/7 concept

Chapter 10. Power Quality Events
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  - Motors
  - Transformers
• 12-Pulse Motor Drives, Examples
  - Elevators
  - Power plant boiler feed pump
• Resonance, Example
Chapter 11. Standby Power Systems

• Purpose
  - Emergency power, long time outages
  - Economic, rate supplement, peak power
  - Back up UPS, batteries
  - Independent supply

• Types of power sources
  - Diesel/gas engine-generator sets
  - Combustion-turbine generator sets
  - Batteries

• Typical systems
  - Single E/G set, emergency power
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  - Combined cycle
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Chapter 12. Power Quality Measurement

• Purpose
  - Trouble analysis
  - Contractual

• Commercial equipment
  - Power factor
  - Harmonics

• Recorders
  - Sampling
  - Presentation
Attachment A
Representative Figures

Typical Lightning-Induced Transient

Figure 1—Lightning stroke current that can result in impulsive transients on the power system


UPS: Static Inverter

Phase Current and Voltage

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>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (Hz)</td>
<td>250</td>
<td>350</td>
<td>450</td>
<td>550</td>
<td>650</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td>$U_{1n} ($) (%)</td>
<td>1.1</td>
<td>0.72</td>
<td>0.11</td>
<td>0.072</td>
<td>0.097</td>
<td>0.056</td>
<td>0.018</td>
</tr>
<tr>
<td>$U_{2n} ($) (%)</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

\[ \rho_f B \to 1 \text{ at } n = 5 \]

\[ \rho_s B \to 0 \text{ at } n = 5 \]

Dugan has nearly 40 years' experience in electric power quality and distribution system analysis. He was elected a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) for his work in harmonics and transients. H. Wayne Beaty is the former managing editor of Electric Light and Power and editor of McGraw-Hill's Standard Handbook of Electrical Engineering, Thirteenth Edition. Read more. Product details. Power Quality and Voltage Sag Indices in Electrical Power Systems, Electrical Generation and Distribution Systems and Power Quality Disturbances, Gregorio Romero Rey and Luisa Martinez Muneta, IntechOpen, DOI: 10.5772/18181. Available from Electric Power Systems Harmonics - Identification and Measurements. By Soliman Abdelhady Soliman and Ahmad Mohammad Alkandari. We are IntechOpen, the world's leading publisher of Open Access books.