

- Chapter 1 Introduction to Power Quality p. 1
- 1.1 Definition of Power Quality p. 1
- 1.2 Power Quality Progression p. 1
- 1.3 Power Quality Terminology p. 2
- 1.4 Power Quality Issues p. 9
- 1.5 Susceptibility Criteria p. 13
- 1.5.1 Cause and Effect p. 13
- 1.5.2 Treatment Criteria p. 13
- 1.5.3 Power Quality Weak Link p. 15
- 1.5.4 Interdependence p. 16
- 1.5.5 Stress-Strain Criteria p. 17
- 1.5.6 Power Quality vs. Equipment Immunity p. 17
- 1.6 Responsibilities of the Suppliers and Users of Electrical Power p. 18
- 1.7 Power Quality Standards p. 20
- 1.8 Conclusions p. 23
- Chapter 2 Power Frequency Disturbance p. 25
- 2.1 Introduction p. 25
- 2.2 Common Power Frequency Disturbances p. 25
- 2.2.1 Voltage Sags p. 25
- 2.3 Cures for Low-Frequency Disturbances p. 34
- 2.3.1 Isolation Transformers p. 34
- 2.3.2 Voltage Regulators p. 36
- 2.3.3 Static Uninterruptible Power Source Systems p. 37
- 2.3.4 Rotary Uninterruptible Power Source Units p. 39
- 2.4 Voltage Tolerance Criteria p. 40
- 2.5 Conclusions p. 44
- Chapter 3 Electrical Transients p. 45
- 3.1 Introduction p. 45
- 3.2 Transient System Model p. 46
- 3.3 Examples of Transient Models and Their Response p. 48
- 3.3.1 Application of DC Voltage to a Capacitor p. 48
- 3.3.2 Application of DC Voltage to an Inductor p. 49
- 3.4 Power System Transient Model p. 53
- 3.5 Types and Causes of Transients p. 56
- 3.5.1 Atmospheric Causes p. 56
- 3.5.2 Switching Loads On or Off p. 58
- 3.5.3 Interruption of Fault Circuits p. 60
- 3.5.4 Capacitor Bank Switching p. 61
- 3.6 Examples of Transient Waveforms p. 63
- 3.6.1 Motor Start Transient p. 63
- 3.6.2 Power Factor Correction Capacitor Switching Transient p. 63
- 3.6.3 Medium Voltage Capacitor Bank Switching Transient p. 64
- 3.6.4 Voltage Notch Due to Uninterruptible Power Source Unit p. 65
- 3.6.5 Neutral Voltage Swing p. 65
- 3.6.6 Sudden Application of Voltage p. 66
- 3.6.7 Self-Produced Transients p. 67

- 3.7 Conclusions p. 67
- Chapter 4 Harmonics p. 71
- 4.1 Definition of Harmonics p. 71
- 4.2 Harmonic Number (h) p. 75
- 4.3 Odd and Even Order Harmonics p. 75
- 4.4 Harmonic Phase Rotation and Phase Angle Relationship p. 76
- 4.5 Causes of Voltage and Current Harmonics p. 80
- 4.6 Individual and Total Harmonic Distortion p. 81
- 4.7 Harmonic Signatures p. 84
- 4.7.1 Fluorescent Lighting p. 84
- 4.7.2 Adjustable Speed Drives p. 84
- 4.7.3 Personal Computer and Monitor p. 90
- 4.8 Effect of Harmonics on Power System Devices p. 90
- 4.8.1 Transformers p. 92
- 4.8.2 AC Motors p. 94
- 4.8.3 Capacitor Banks p. 95
- 4.8.4 Cables p. 99
- 4.8.5 Busways p. 102
- 4.8.6 Protective Devices p. 102
- 4.9 Guidelines for Harmonic Voltage and Current Limitation p. 103
- 4.10 Harmonic Current Mitigation p. 104
- 4.10.1 Equipment Design p. 104
- 4.10.2 Harmonic Current Cancellation p. 105
- 4.10.3 Harmonic Filters p. 107
- 4.11 Conclusions p. 108
- Chapter 5 Grounding and Bonding p. 111
- 5.1 Introduction p. 111
- 5.2 Shock and Fire Hazards p. 111
- 5.3 National Electrical Code Grounding Requirements p. 113
- 5.4 Essentials of a Grounded System p. 114
- 5.5 Ground Electrodes p. 115
- 5.6 Earth Resistance Tests p. 115
- 5.7 Earth-Ground Grid Systems p. 119
- 5.7.1 Ground Rods p. 119
- 5.7.2 Plates p. 120
- 5.7.3 Ground Ring p. 120
- 5.8 Power Ground System p. 121
- 5.9 Signal Reference Ground p. 122
- 5.10 Signal Reference Ground Methods p. 124
- 5.11 Single-Point and Multipoint Grounding p. 126
- 5.12 Ground Loops p. 127
- 5.13 Electrochemical Reactions Due to Ground Grids p. 128
- 5.14 Examples of Grounding Anomalies or Problems p. 129
- 5.14.1 Loss of Ground Causes Fatality p. 129
- 5.14.2 Stray Ground Loop Currents Cause Computer Damage p. 130
- 5.14.3 Ground Noise Causes Adjustable Speed Drives to Shut Down p. 131

- 5.15 Conclusions p. 132
- Chapter 6 Power Factor p. 133
- 6.1 Introduction p. 133
- 6.2 Active and Reactive Power p. 133
- 6.3 Displacement and True Power Factor p. 137
- 6.4 Power Factor Improvement p. 137
- 6.5 Power Factor Correction p. 137
- 6.6 Power Factor Penalty p. 141
- 6.7 Other Advantages of Power Factor Correction p. 142
- 6.8 Voltage Rise Due to Capacitance p. 142
- 6.9 Application of Synchronous Condensers p. 143
- 6.10 Static VAR Compensators p. 144
- 6.11 Conclusions p. 145
- Chapter 7 Electromagnetic Interference p. 147
- 7.1 Introduction p. 147
- 7.2 Frequency Classification p. 147
- 7.3 Electrical Fields p. 148
- 7.4 Magnetic Fields p. 149
- 7.5 Electromagnetic Interference Terminology p. 151
- 7.5.1 Decibel (dB) p. 151
- 7.5.2 Radiated Emission p. 152
- 7.5.3 Conducted Emission p. 152
- 7.5.4 Attenuation p. 152
- 7.5.5 Common Mode Rejection Ratio p. 152
- 7.5.6 Noise p. 153
- 7.5.7 Common Mode Noise p. 153
- 7.5.8 Transverse Mode Noise p. 153
- 7.5.9 Bandwidth p. 154
- 7.5.10 Filter p. 154
- 7.5.11 Shielding p. 154
- 7.6 Power Frequency Fields p. 154
- 7.7 High-Frequency Interference p. 157
- 7.8 Electromagnetic Interference Susceptibility p. 160
- 7.9 EMI Mitigation p. 160
- 7.9.1 Shielding for Radiated Emission p. 160
- 7.9.2 Filters for Conducted Emission p. 160
- 7.9.3 Device Location to Minimize Interference p. 162
- 7.10 Cable Shielding to Minimize Electromagnetic Interference p. 162
- 7.11 Health Concerns of Electromagnetic Interference p. 162
- 7.12 Conclusions p. 164
- Chapter 8 Static Electricity p. 165
- 8.1 Introduction p. 165
- 8.2 Triboelectricity p. 165
- 8.3 Static Voltage Buildup Criteria p. 167
- 8.4 Static Model p. 169
- 8.5 Static Control p. 169

- 8.6 Static Control Floors p. 171
- 8.7 Humidity Control p. 171
- 8.8 Ion Compensation p. 171
- 8.9 Static-Preventative Casters p. 172
- 8.10 Static Floor Requirements p. 173
- 8.11 Measurement of Static Voltages p. 174
- 8.12 Discharge of Static Potentials p. 174
- 8.13 Conclusions p. 176
- Chapter 9 Measuring and Solving Power Quality Problems p. 177
- 9.1 Introduction p. 177
- 9.2 Power Quality Measurement Devices p. 177
- 9.2.1 Harmonic Analyzers p. 177
- 9.2.2 Transient-Disturbance Analyzers p. 179
- 9.2.3 Oscilloscopes p. 183
- 9.2.4 Data Loggers and Chart Recorders p. 185
- 9.2.5 True RMS Meters p. 187
- 9.3 Power Quality Measurements p. 188
- 9.4 Number of Test Locations p. 191
- 9.5 Test Duration p. 191
- 9.6 Instrument Setup p. 193
- 9.7 Instrument Setup Guidelines p. 194
- 9.8 Conclusions p. 195
- Index p. 197