



Technology Training that Works

Practical Power Quality: Problems & Solutions

Contents

Chapter 1

Overview of Power Quality

Chapter 2

Introduction to Power Quality and EMC

Section	Page No.
2.1	Introduction and FIPS PUB #94 2.1
2.2	The Importance of FIPS PUB #94 2.5
2.3	The CBEMA Curve 2.7
2.4	Disturbances in Microseconds 2.7
2.5	Zero Voltage Conditions 2.7
2.6	Time Exceeding Half Cycle 2.8
2.7	Voltage and Continuity 2.8
2.8	Summary of CBEMA Sensitivity 2.9
2.9	The Emerald Book 2.11
2.10	IEEE Chapter Chairpersons 2.11
2.11	Chapter Guidelines 2.16
2.12	Definitions 2.16
2.13	General Needs and Fundamentals 2.17
2.14	The Compatibility Challenge 2.17
2.15	Instrumentation and Surveying 2.18
2.16	Case Histories 2.18
2.17	Specifying and Selecting Equipment 2.18
2.18	Recommended Practices 2.19
2.19	Non-Recommended Practices 2.19
2.20	Colour Book Series 2.21
2.21	EC&M Power Quality Guide 2.22
2.22	Contractor Reference Guide 2.22
2.23	Quality and Reliability 2.23
2.24	Sags and Swells 2.24
2.25	Surges and Transients 2.26
2.26	Harmonics and Distortions 2.27
2.27	Interruptions 2.28
2.28	Noise Disturbances 2.29
2.29	Notching 2.30



Technology Training that Works

2.30	Noise Definitions	2.31
2.31	Earthing Conductor	2.33
2.32	Isolated/Insulated Connection	2.34
2.33	Loops	2.35
2.34	Site Examination Flow Chart	2.36
2.35	Program Survey Results	2.38
2.36	Sensitive Equipment Performance	2.39
2.37	Noise Picture Example.....	2.40
2.38	Speed Comparisons - MIPS Rate.....	2.41
2.39	Monitoring the Environment.....	2.42
2.40	Power Quality and Safety Codes.....	2.43
2.41	Safety Code Example.....	2.43
2.42	Sources of Disturbances.....	2.44
2.43	Utility Goals.....	2.45
2.44	Customer Expectations	2.46

Chapter 3

Recommended Design and Installation Practices

Section	Page No.
3.1	“Worst” to “Best” Wiring Diagrams..... 3.1
3.2	“Worst” Condition
3.3	“Fair” - Slightly Better..... 3.3
3.4	“Better” - Gets the Job Done
3.5	“Best” - May not be Available..... 3.3
3.6	Transformer Location
3.7	History of “Special” Earthing
3.8	“Better” - Cut Down the Separation..... 3.7
3.9	“Best” - The Power Centre Unit
3.10	The Earth Loop Path..... 3.9
3.11	Separate Lines but Common Earthing
3.12	Shielded Isolation Transformer Features
3.13	“Buffering” of “Softening” Interface
3.14	Noise Rejection..... 3.12
3.15	Stable Neutral Earthing..... 3.12
3.16	Voltage Transformation..... 3.12
3.17	Transformer Cross Section
3.18	Turning Noise Around
3.19	Which Way Does The Noise Flow?..... 3.15
3.20	Common Mode, High Speed Disturbance..... 3.16
3.21	Proper Wiring for the Shielded Transformer
3.22	Property Earth Return Paths..... 3.18
3.23	The “IG” Receptacle..... 3.20
3.24	“IG” Style Connection



Technology Training that Works

Chapter 4

Earthing and Noise Control

Section	Page No.
4.1 Case Study - Remote Terminal	4.1
4.2 Changes in Wiring	4.2
4.3 Use of the Balun Type “Transformer”	4.3
4.4 Common Mode Voltage.....	4.4
4.5 Bonding Separated Earths.....	4.5
4.6 Earth Loop Case Study - Before	4.6
4.7 Earth Loop Case Study - After.....	4.7
4.8 Simultaneous Impulse	4.8
4.9 Induced Noise Injection	4.9
4.10 Case Study - Induced Noise	4.10
4.11 Zero Signal Reference Grid	4.13
4.12 High Frequency Effects	4.13
4.13 Resonance Properties of Conductors	4.15
4.14 Raised Floor as ZSRG	4.18
4.15 ZSRG Test Results.....	4.19
4.16 Earth Noise Voltage Gradient.....	4.16

Chapter 5

Surge & Transient Protection

Section	Page No.
5.1 Earth Current Transients	5.1
5.2 Transient Impact	5.4
5.3 Lightning Phenomena	5.5
5.4 Where do we place an Arrestor?.....	5.6
5.5 Arrestor and Supplementary Protection	5.7
5.6 Transient Clipping	5.8
5.7 Protection Locations	5.9
5.8 Site Overview	5.15
5.9 Current Protective Elements & Transient Phenomena.....	5.25
5.10 Codes and Guidelines	5.26

Chapter 6

Conducting a Site Analysis

Section	Page No.
6.1 Site Study Format	6.1
6.2 Survey Objectives	6.3
6.3 Defining the Problem.....	6.3
6.4 Site Co-ordination.....	6.4
6.5 Conducting the Survey.....	6.5
6.6 Condition of Power and Earthing.....	6.7
6.7 Testing and Verification	6.17
6.8 Dedicated Feeders and Direct Paths	6.23
6.9 Separately Derived Systems.....	6.27



Technology Training that Works

Chapter 7

Harmonic Sources and Their Effects

Section	Page No.
7.1	Linear Sine Waves 7.1
7.2	Non-Linear Waves 7.2
7.3	Sequences and Frequencies..... 7.2
7.4	Groups of Harmonic Orders..... 7.5
7.5	Three Phase Harmonics 7.6
7.6	Elimination of Dangerous Harmonics..... 7.6
7.7	Backward Torque Problems..... 7.7
7.8	Single Phase Harmonics 7.7
7.9	Wave Shape Composition..... 7.8
7.10	Distorted Currents First 7.10
7.11	Distorted Voltages Next..... 7.11
7.12	Non-Linear Loads 7.12
7.13	Effects of Harmonic Disturbances 7.13
7.14	Variable Frequency Drives 7.14
7.15	Diode Input Circuit 7.15
7.16	SCR Input Circuit 7.16
7.17	Currents and Voltages for SCR Converters 7.17
7.18	Typical Harmonic Structure..... 7.18
7.19	Induction Motor Problems 7.19
7.20	Harmonic Current Filter - “Trap” 7.21
7.21	High Frequency Removal 7.22
7.22	Capacitor Switching Surge..... 7.23

Chapter 8

Power System Capacitive/Inductive Relationships

Section	Page No.
8.1	Review of Displacement Power Factor 8.1
8.2	Capacitive Addition to Improve Power Factor 8.2
8.3	New Total Power Factor Triangle..... 8.3
8.4	Capacity “Release” with Power Factor Help 8.3
8.5	Resonance Conditions..... 8.4
8.6	Too Many Capacitors 8.5
8.7	Reduce Pure Capacitance - Use Traps 8.6
8.8	Case Study - Massive Harmonics Interactions 8.7
8.9	Resonant Frequency versus Capacitance 8.10
8.10	Current “THD” - Field Measurements 8.11
8.11	Power Factor - Field Measurement 8.13
8.12	Case Study - Lift (Elevator) Controls 8.14



Technology Training that Works

Chapter 9

Harmonic Site Analysis Procedures

Section	Page No.
9.1	Waveform Distortion Limits - IEEE Std 519-1992 9.1
9.2	Case Study - Hospital “Closed” Transition Transfer 9.3
9.3	Case Study - UPS and Generator Interaction 9.4
9.4	Transformer Loss of Efficiency 9.5
9.5	K Factor Computation 9.6
9.6	Harmonic Cancellation Design 9.7
9.7	Summary of Practical Rules about Distortion 9.9
9.8	Single Phase Harmonics on Three Phase Wiring 9.10
9.9	Oversizing and Derating 9.12
9.10	Delta Circulating Currents 9.12
9.11	Third Harmonic Canceller 9.13
9.12	Before and After Results 9.14
9.13	Lightning and Power Readings 9.14
9.14	Current “THD” Reduction in Electronic Ballast 9.15
9.15	Summary of Recommended Remedies 9.17
9.16	Comparison of Instrument Readings 9.18
9.17	Calculation of Per Cent “THD” and Reading Samples 9.19
9.18	Harmonic Site Analysis 9.23
9.19	Harmonic Analysis Study 9.26

Chapter 10

Power Conditioning

Section	Page No.
10.1	Concept versus Reality in Power Conditioning 10.1
10.2	Regular Stability Problems 10.2
10.3	Disturbance Count and Sample Bell System Report 10.3
10.4	Summary of Powering Devices 10.5
10.5	Shielded Isolation Transformer 10.7
10.6	Voltage Regulators - CVT Style 10.9
10.7	Saturable Magnetic Curve 10.11
10.8	Harmonic Filter or “Trap” 10.12
10.9	Magnetic Synthesiser Line Conditioner 10.13
10.10	Saturable Design and Precautions 10.14
10.11	Motor Generator Line Conditioners 10.14
10.12	Synchronous Motor Generator with Pony Motor 10.15
10.13	Synchronous Motor Operation 10.16
10.14	Protection Provisions 10.17
10.15	Three Phase Qualities 10.17
10.16	Parallel Motor Generator Operation on Dual Line Service 10.18
10.17	Longer Term Ride Through 10.19
10.18	Transfer Switch Arrangement 10.20
10.19	Written Pole Construction 10.21
10.20	Comparison of Ride Through Times 10.22
10.21	Basic “Stator” and “Rotor” Concepts 10.23
10.22	SMG with “Hydraulic” Energy Storage 10.24
10.23	Separated Generator for Critical Load 10.25
10.24	Continuous Power System with Diesel 10.26



Technology Training that Works

10.25	Speed and Ride Through Time for “CPS” System.....	10.27
10.26	Energy Storage Systems.....	10.28
10.27	Superconducting Energy Storage.....	10.29
10.28	Solid State UPS Diagram.....	10.30
10.29	“On-Line” Applications.....	10.30
10.30	“Off-Line” UPS.....	10.31
10.31	Multiple Units for Redundancy.....	10.32
10.32	Lesson on Batteries.....	10.33
10.33	The Solid State UPS with Non-Linear Loading.....	10.33
10.34	No Longer Need for a “Sine Wave”.....	10.34
10.35	Output Harmonic Conditioning UPS.....	10.36
10.36	Static Switching Applications.....	10.37
10.37	Variety of Ampere Sizes.....	10.37
10.38	New Medium Voltage Applications.....	10.38
10.39	14 MW Switching Operations.....	10.38
10.40	Transfer Under Actual Conditions.....	10.40
10.41	Switchgear Size Element.....	10.41
10.42	Vault Layout for 15kV Line-Up.....	10.42
10.43	Application Locations.....	10.43
10.44	High Rise Buildings and Industrial Parks.....	10.44
10.45	Combination Switch and Stored Energy Device.....	10.45
10.46	Comparison of Features and Cost Savings.....	10.46
10.47	Power Problem Solution Comparison.....	10.46
10.48	Cost versus Problems Solved.....	10.47

Chapter 11

Installation Guidelines

Section		Page No.
11.1	Checklist of Considerations for Power Quality.....	11.1
11.2	Equipment Selection Specifications.....	11.20
11.3	Building Maintenance Analysis.....	11.23
11.4	Power Quality versus Reliability.....	11.24
11.5	Typical Project Approach.....	11.26

<i>Appendix A</i>	Power Recorder Systems
<i>Appendix B</i>	Fluke 41 Sample Readings and Summary Report
<i>Appendix C</i>	Guidelines on Electrical Power for ADP Installation (FIPS PUB 94)
<i>Appendix D</i>	Glossary of Terms