Power Quality

1. Power Quality Defined

a) Quality of Voltage

b) Sufficient

- Magnitude
- Frequency
- Waveshape

c) Sufficient Power Quality

- Equipment Should Operate Properly

2. Alternate Definition

a) Power Quality

b) We have *Quality Power* when the user is satisfied with the cost, and with the operation of equipment.

c) *Qualitative!*

3. Voltage Magnitude

a) Steady State Voltage

b) IEEE

c) CBEMA

4. Magnitude

a) Levels (Steady State)

b) Standards - Can be affected by equipment ratings

c) IEEE

- Typically ± 5%

d) CBEMA

- +6% -13%

5. Items to remember

a) Voltage level ranges often dictated by individual equipment

b) Steady State over/under voltage often the problem

c) Equipment doesn't always subscribe to CBEMA or IEEE

d) +6 to -10% as a Guideline

6. Harmonics

a) Primer

- Fourier - French Mathematician
- Fundamental and Third Harmonic
- Fundamental and Fifth Harmonic
- Fundamental and Seventh Harmonic

b) Ohms Law

- E = I * Z

c) Linear Vs. Non-Linear

d) Load (I) and Source (Z)

e) Linear Load ⇨ Linear Voltage Drop

- No Waveshape Distortion

f) Non Linear Loads ⇨ Non Linear Voltage Drop

- Waveshape Distortion

7. Harmonics Individual

Effects on Power System

a) Need to further refine understanding of individual waveforms that make up the overall waveshape, and how they combine.
b) Fundamental plus Third Harmonic
c) Fundamental minus Third Harmonic
d) Fundamental with Voltage Drop at the Fifth and Seventh Harmonic

8. Drive Harmonics - Waveforms

9. Harmonic Rotation

Fundamental	Positive
Second	Negative
Third	Zero
Fourth	Positive
Fifth	Negative
Sixth	Zero
Seventh	Positive
Eighth	Negative
Ninth	Zero
Tenth	Positive
Eleventh	Negative
Twelfth	Zero
Thirteenth	Positive
Fourteenth	Negative
Fifteenth	Zero

10. Consequences

a) Motors

- Reverse Torque
- Overheating
- Shortened life

b) Transformers

- Increased Losses
- Overheating
- Shortened life

c) Capacitors

- Increased Current
- Overheating
- Shortened life

d) Plant Electronics

- Disoperation
- Failure
- Downtime

11. Distortion Levels

a) IEEE 519-1992

- All Harmonics - Voltage (THD) <5% (<10%)

b) Current Distortion

12. Review

a) Harmonics are a way to describe the result of non-linear loads on the power system

b) Basic Limit of 5% (10%) for Voltage Distortion

c) Current Distortion Limit Depends on System, Currently under review

13. Source Issues

a) Source Impedance has been assumed to be constant/linear

b) Look at the Source of our loads

- Determine itõs characteristics
- How these characteristics impact the Distortion Equation
- How we can affect the characteristics
- Filtering

c) Capacitors/Ratings/Issues

- Capacitor Tolerances
    - a) In harmonic rich environments, capacitors for the low impedance path to source current
    - b) In filter applications, capacitors also must tolerate higher voltages
    - c) United States: IEEE 18-1992
        - Line to Neutral 110% Continuous
    - d) Europe: CE Standards call for 8 hour period

d) Remember that these standards are *recommendations, not Code,* and can therefore be ignored by manufacturers

14. Capacitors - Two types

a) Dry - usually polyester film dielectric

b) Oil Filled - oil impregnated Kraft paper dielectric

15. Dry Type Capacitors

a) Pros

- Inexpensive
- Lightweight
- Environmentally friendly

b) Cons

- Do not meet IEEE 18-1992 standards
- Poor Thermal Characteristics

16. Oil Filled Capacitors

a) Pros:

- Meet or exceed IEEE 18-1992 Standard
- Excellent Thermal Characteristics

b) Cons

- Environmental issues

17. Adding Reactors to Drives

a) Strategy reduces harmonic current, and voltage drop through the supply

b) Can increase distortion to the drive

18. Power System Transients

a) By definition, any voltage variation that is temporary. Type I or Type I on CBEMA

b) Sources of Transients

- Lightning
  - a) On Supply Conductors
  - b) Grounded entrances
- Switching Capacitors
- Motor Starting/Stopping
- XFMR Switching
- Faults
- System switching
- Mechanical Load Changes
- SCR Operation (Notching)
- Drive Startup
- Welding
- Others

19. Consequences of Transients

a) Equipment Failure

b) Equipment Malfunction

c) Equipment Degradation (ultimately lead to failure)

d) Blown Supply Fuse

e) Degradation to TVSS (Transient Voltage Surge Suppressor) Devices

20. Power System Transients - Divided into Two Categories

a) Common Mode - Noise that is common to the phase conductors. Cannot be measured line to line, only phase to ground. Often *comes in* on the Ground

b) Normal Mode - Not balanced on all three phases, may be measured phase to phase or phase to ground.

21. Power System Transients

Can be further broken down into:

a) Transient Overvoltage

- TVSS
- Grounding

b) Transient Undervoltage

- System Design

22. Coping with Transients Properly designed system minimizes transients

a) Source with Sufficient Capacity

b) Proper Grounding

23. Properly designed system minimizes problems associated with transients

a) Harmonic Resonance Issues

b) Installation of TVSS devices

24. System Design

a) Voltage Drop through system is within NEC (<5%)

b) Voltage Drop during motor starts is within IEEE

- 20 % at motor terminals
- 10% at adjacent electronic devices

c) Proper protective device coordination

d) Switched transformer feeders sized properly

e) Welding sufficiently isolated

f) System Properly Grounded

- Often the underestimated and overlooked portion of the system

25. System Grounding

a) Building Systems - FIPS Pub 94

- Consider Building as an ñenvelopeò
- Should have a contiguous grounding system
- All metallic supplies into or out of that envelope should be bonded to the building ground.
- Building Ground Bonded at Electric Entrance

b) Metallic Supplies

- Gas Lines
- Water Lines
- Fire Protection Lines
- Telephone Lines
- Sanitary lines
- Storm Drains
- Power Lines Parking lot lighting
- Truck Scales
- Data Lines

- Building Sub-Feeds

26. Grounding Ring

a) Encircles Building

- IEEE Recommended for ῀Data Centersὸ
  - 20 years ago, we would not have considered putting an IBM VM 370 in a plant environment, but today we think nothing of it.

b) 30 inches deep, 2 foot out from footer, bonded to building steel at intervals, ground rods.

c) Bonds all incoming and outgoing equipment

d) Results:

- All equipment referenced to a common ground
- Ground borne transient is effectively distributed throughout system simultaneously
- Plant equipment not subjected to overvoltage

e) Effective with *Most* Common Mode Noise Problems

27. Surge Suppression

a) NFC 780 Mean Days of Thunderstorm Activity

b) ANSI 62.4 - 1991 Attempted to establish standards for the industry

• Category C	20 kV	50 µs
	20 kA	20 µs
• Category B	6 kV	50 µs
	3 kA	20 µs
	6 kV, 500 A, 100 kHz Ring Wave	
• Category A	6 kV, 200 A, 100 kHz Ring Wave	

28. Surge Suppressors

- Beware of Manufacturers literature
- Can be misleading
  - a) UL 1449 approved!! (UL Listed)
  - b) Response Time < 2 ns (in circuit 20 - 50 ns)
  - c) Current Capacity 250,000 Amps (ANSI Cat C - 20 kAmps for 20 µs)
  - d) ñLevel I, Level II, and Level III protection (ANSI - Category C, B, and A)
  - e) Category A, B, and C by ANSI, Category D, and E by ñusò

29. Device types

a) Arc Gap devices - Usually Medium Voltage, or for Communication Towers

b) Gas tubes - Used widely in communication industry

c) MOVôs - Metal Oxide Varistors

d) SADSôs - Silicon Avalanche Diode Suppressor

e) Hybrids

30. Surge Suppressors

Device	Response Time	Clamping	Capacity	Cost
Gas tubes	µsôs	400-900 Volts	High	Low
MOV	35 ns	500-600 Volts	High	Low
SADS	5 ns	< 300 Volts	Low	High

31. Surge Suppressors Summary

a) Gas Tubes - Low cost, slower than MOV’s

b) MOV’s - Low cost, high clamping voltage, high capacity:
Good for heavy duty application

c) SADS’s - High cost, excellent clamping, low capacity:

d) Good in network products, reserve for specialized applications

32. Configuration Issues

a) Watch for 3 and 4 wire units

b) Common Mode / Normal Mode devices

c) Use Fused Disconnects ahead of Suppressors on Mains to aid replacement

d) End of line devices

e) Use arrestors on Medium Voltage ï Arrestors ≠Suppressor

f) Particularly on end of line and next to end of line devices

33. Design

a) Keep Wiring SHORT

b) Minimize bends on leads

c) Cascade of devices

34. Surge Suppressors – Review

a) UL 1449 is for UL Listing of Suppressors

b) ANSI 62.4 - 1991 Set Standards for Suppressor Capability

c) Category C - Main Entrance, Large Subpanel

d) Category B - Large Subpanel, Small Panel

e) Category C - Terminal Device

f) Use Arrestors on Medium Voltage

g) MOV Devices - Look for ANSI Class Rating.

h) SADS Devices - Use on sensitive electronics where loss costs are high, Look for ANSI Class ratings

35. Summary

a) Defined Power Quality

b) Magnitude (Steady State)

c) Waveshape (harmonics, System Impedance, Capacitor Issues)

d) Transients (Sources, Strategies, Issues)

e) Grounding

f) Surge Suppression Devices