

Harmonics

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Progress Energy

Harmonics

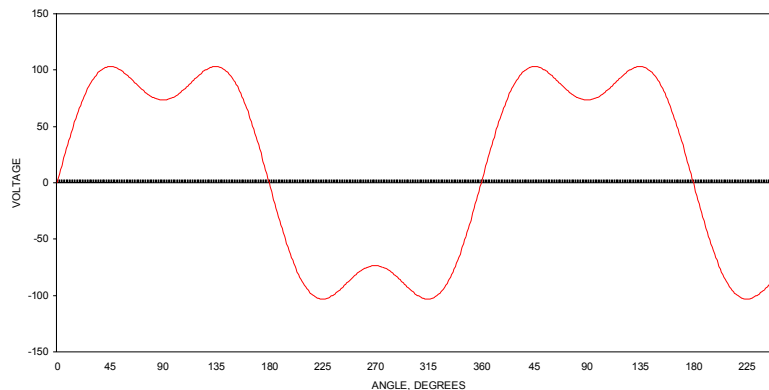
- What are Harmonics
- Where do Harmonics Originate
- What are some effects of Harmonics
- Mitigation Techniques
- Deep River Filter

What are Harmonics?

- Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to operate, that combine with the fundamental voltage or current, and produce waveform distortion.

What Are Harmonics

- Frequencies other than the fundamental
- Fundamental is 60 Hz.
- Harmonic order are Multiples of the Fundamental Frequency.
- Typical Harmonics are the 3rd, 5th, and 7th.
 - ◆ 3rd = 180 Hz 5th = 300 Hz 7th = 420 Hz
- Voltage harmonics and Current Harmonics are very different.
- The harmonics sum with the fundamental resulting in waveform distortion.



Where do they Originate

- Typically from Non-Linear Loads
- Some Non-Linear Loads are
 - ◆ Variable Speed Drive
 - ◆ Computers
 - ◆ SCR Devices
 - ◆ IR Heaters
 - ◆ Induction heaters
 - ◆ DC Furnaces

What are some effects of Harmonics

- Over-heating of Transformers
- Resonance Circuit with Capacitors
 - ◆ Parallel
 - ◆ Series
- Malfunction of Equipment
- UPS alarms

IEEE 519 Voltage Limits

Voltage Distortion Limits		
	Individual Voltage	Total Voltage
Bus Voltage at PCC	Distortion (%)	Distortion THD (%)
69 kV and Below	3.0	5.0
69.001kV through 161kV	1.5	2.5
161.001kV and above	1.0	1.5

NOTE: High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

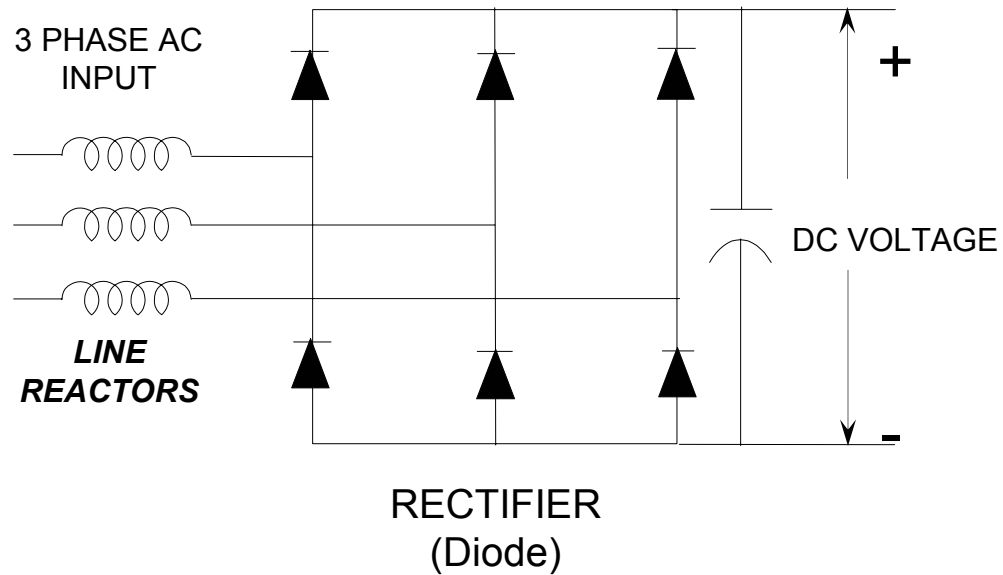
IEEE 519 Current Limits

Current Distortion Limits for General Distribution Systems (120 V Through 69,000 V)						
Maximum Harmonic Current Distortion in Percent of IL						
Isc/IL	<11	11_h<17	17_h<23	23_h<35	35_h	TDD
<20	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
Even harmonics are limited to 25% of the odd harmonics limits above						
Current distortions that results in a dc offset, e.g., half-wave converters, are not allowed						
*All power generation equipment is limited to these values of current distortions, regardless of actual Isc/IL.						
where						
Isc = Maximum short-circuit current at PCC						
IL = Maximum demand load current (fundamental frequency components) at PCC.						

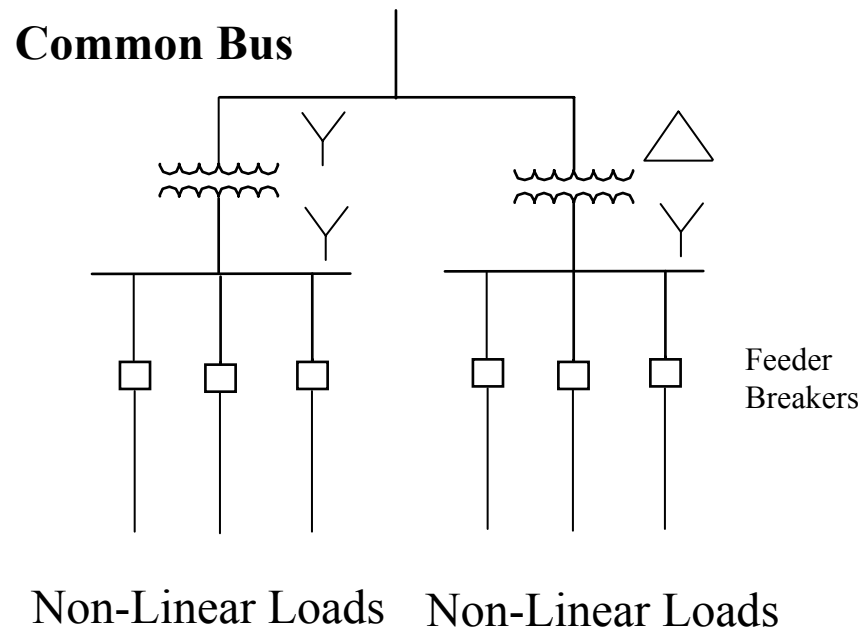
Mitigation Techniques

- Designed Low Distortion Inputs
- Line Reactor
- Phase shifting Transformers
- K-Factor Transformers
- De-Rating Transformers
- Filters

Line Reactors on Drives



Phase Shifting Transformers



K-Factor on Transformers

Rule of thumb for determining what transformer K-factor

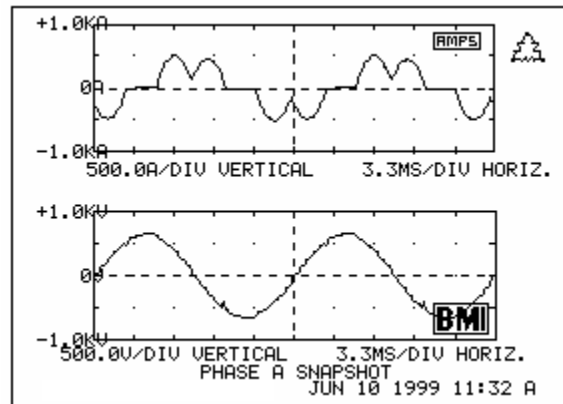
- **0% "electronic", 100% "electrical" - Use a standard (K-1 rated) transformer.**
- **25% "electronic", 75% "electrical" - Use a K-4 rated transformer.**
- **50% "electronic", 50% "electrical" - Use a K-9 rated transformer.**
- **75% "electronic", 25% "electrical" - Use a K-13 rated transformer.**
- **100% "electronic", 0% "electrical" - Use a K-20 rated transformer.**

“electronic” = Nonlinear Loads

“electrical” = Inductive and Resistive Loads

Harmonic Overheating Transformer

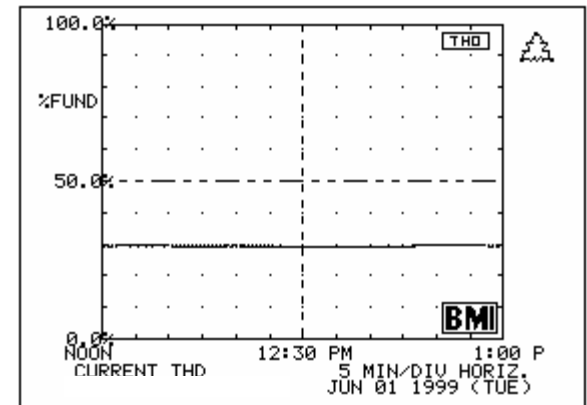
- Transformer oil test showed overheating
- 750 kVA Transformer load was Max 617 kVA
- Load below kVA of transformer
- Transformer serving ASD



Transformer Overheating

- 750kVA with 10% eddy current losses needed to be derated by 77.5 % to a 578kVA transformer
- Six pulse drive was the only load on the transformer
- No room for a harmonic filter in drive room (NEMA 3R plus connection)
- Install 1000kVA transformer.

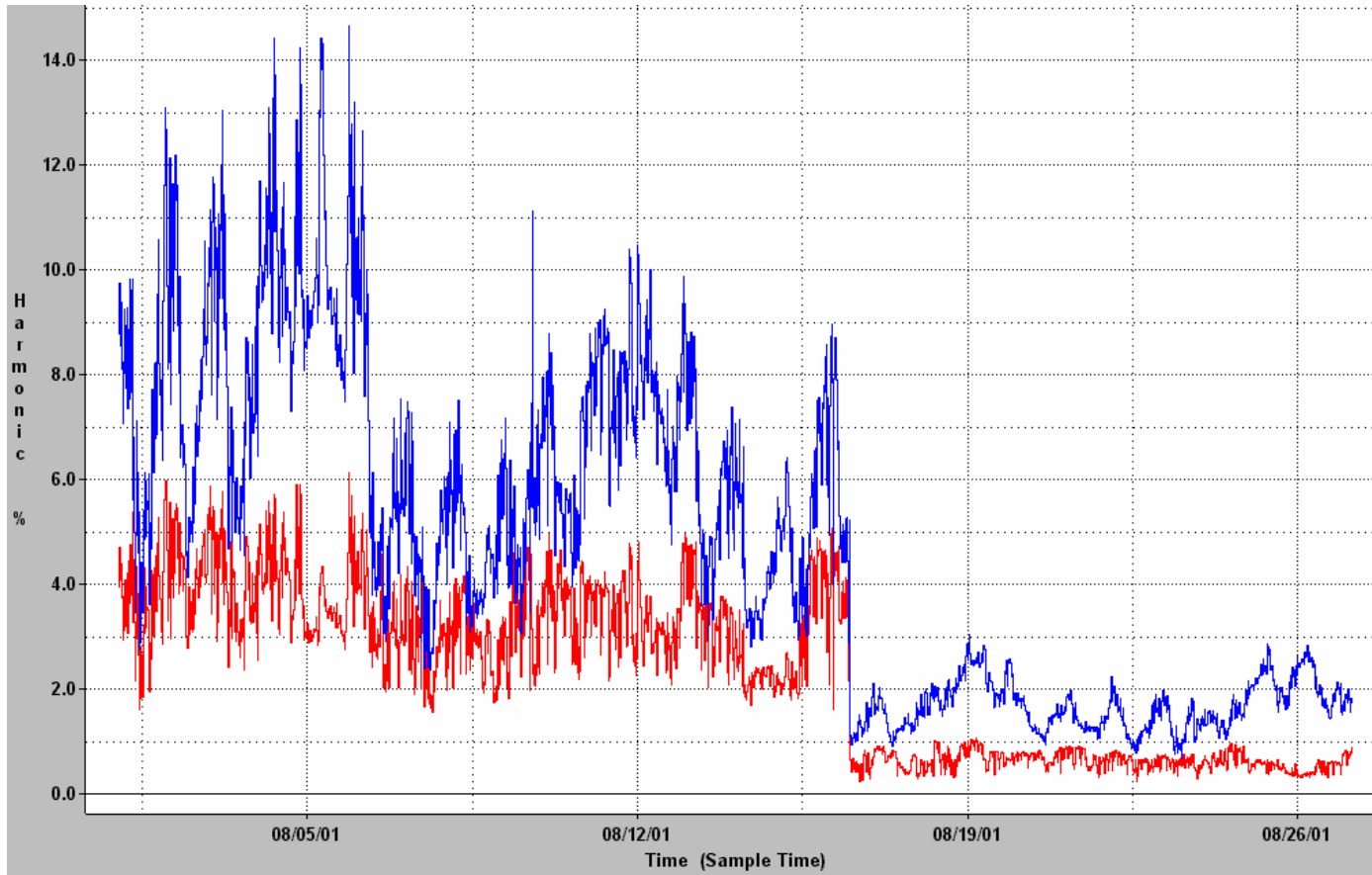
```
----- Jun 01 1999 (Tue)
CURRENT THD 1:02:03 PM
FROM: NOON Jun 01 1999 (Tue)
To: 1:00 PM Jun 01 1999 (Tue)
Average:
MAX: 29.5% THD: 12:49 PM
MIN: 29.1% THD: 12:26 PM
Phase A:
MAX: 29.2% THD: 12:49 PM
MIN: 28.8% THD: 12:26 PM
Phase B:
MAX: 29.7% THD: 12:49 PM
MIN: 29.3% THD: 12:26 PM
Phase C:
MAX: 29.6% THD: 12:49 PM
MIN: 29.2% THD: 12:26 PM
```



Deep-River Substation



Graph of Harmonic Distortion



Harmonics Causing Failures

- Customer asked to add 7200 kVAR for Generator support.
- Customer had a 10MW non-linear load
- Set up resonance circuit in 50MVA substation
- Capacitor bank failure

