Eliminating Harmonic Neutral Current Problems

Presented by
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HARMONIC SUPPRESSION TECHNOLOGY

Basic Premises

- Powering multiple computer loads creates problems in electrical distribution systems.
- Harmonic current flow generates heat in all parts of the distribution system, which wastes energy.
- Ridding the system of harmonic current flow saves energy and money.

Outline

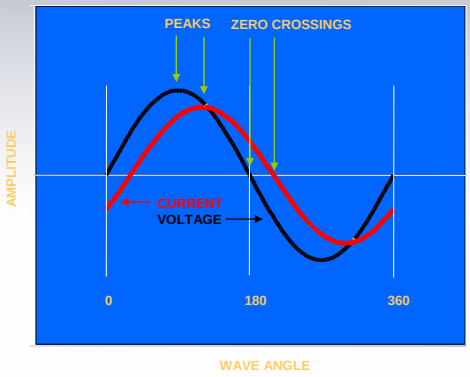
- **Why there is a problem**
- **Power distribution in a Wye system**
- **Powering computers**
- **Accommodating harmonic currents**
- **Preventing harmonic currents with the Harmonic Suppression System (HSS)**
- **Saving energy**
- **HSS products**
- **Who uses the HSS and the results they obtain**

Linear loads

- **When an electric motor is connected to the AC line, it draws its power directly from the line. The power is not treated in any way.**
- **The same is true for a resistive load such as an electric heater.**

Linear voltage-current relationship

Voltage & current have the same mathematical relationship across the entire cycle

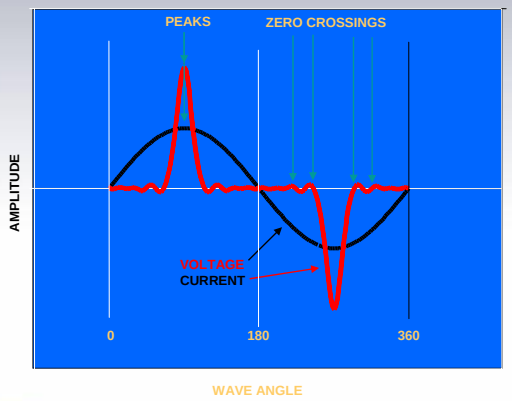


Non-linear loads

- **When a computer is connected to the AC line, it draws its power from an internal DC supply that contains rectifiers and capacitors.**

Non-linear voltage-current relationship

Mathematical relationships between voltage & current vary across the cycle



Linear & non-linear loads (1)

- **Linear Load – The current looks like the voltage**

- **Non-linear Load – The current does not look like the voltage**

- **The more the current looks like the voltage, the more linear is the load**

Linear & non-linear loads (2)

- Linear Loads get their kW power at 60 Hz.
- Non-linear loads get their kW power at 60 Hz and in addition draw harmonic currents

What are harmonics?

Harmonics are continuous integral multiples of the fundamental frequency

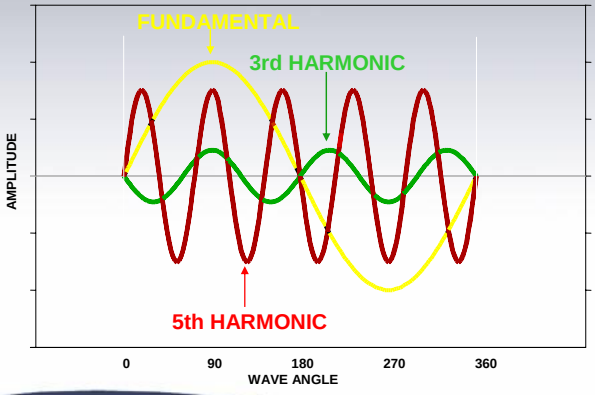
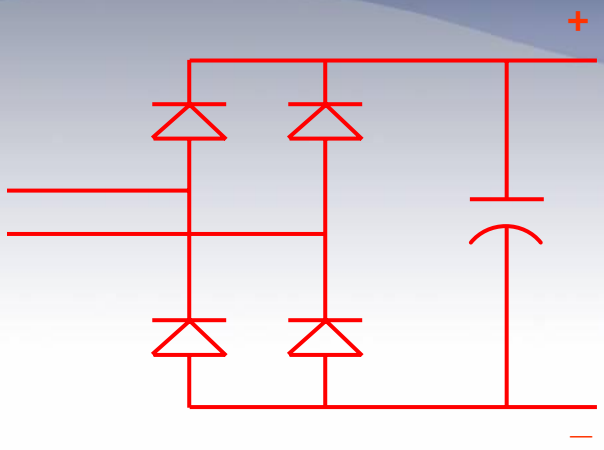


Table of harmonics

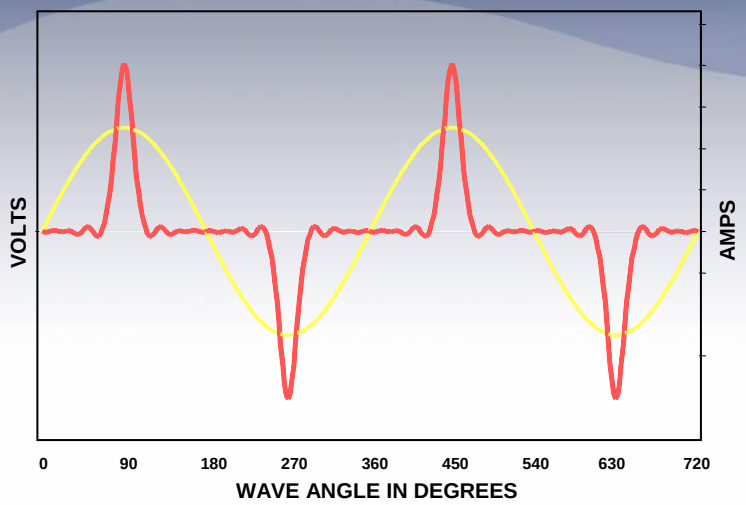
HARMONIC	FREQUENCY	FREQUENCY
1	60	400
2	120	800
3	180	1200
5	300	2000
7	420	2800
9	540	3600
11	660	4400
…	…	…
49 ↓	2940 ↓	19600 ↓

Single-phase 2-pulse diode bridge
(computer power supply)

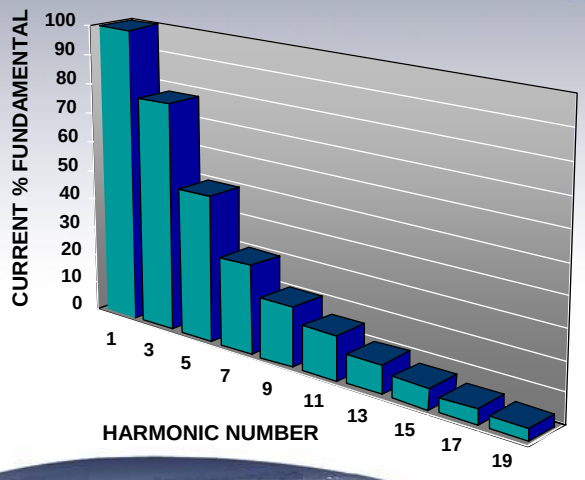


CAPACITIVE LOAD

Single-phase 2-pulse diode bridge
(waveform)



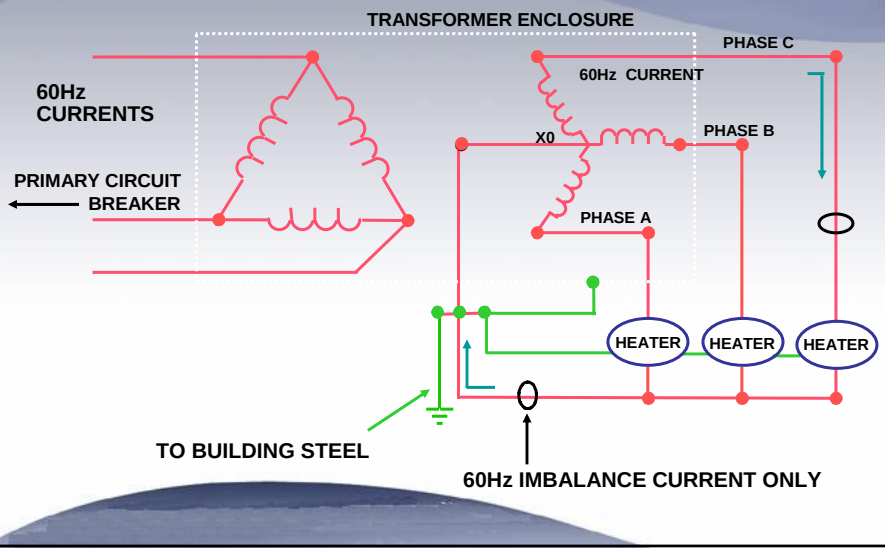
Single-phase harmonic spectrum
(typical for personal computers)



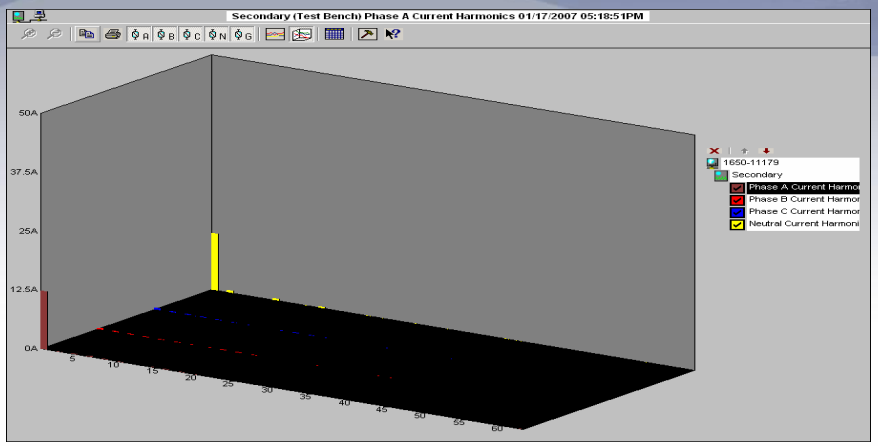
3-phase wye distribution systems

(with phase-to-neutral loads)

Wye distribution system Serving Linear Loads

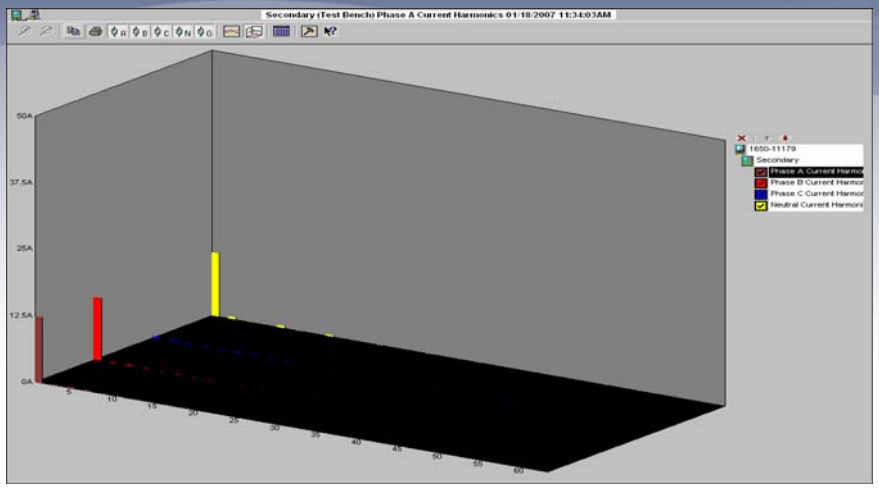


Standard transformer, phase A linear load



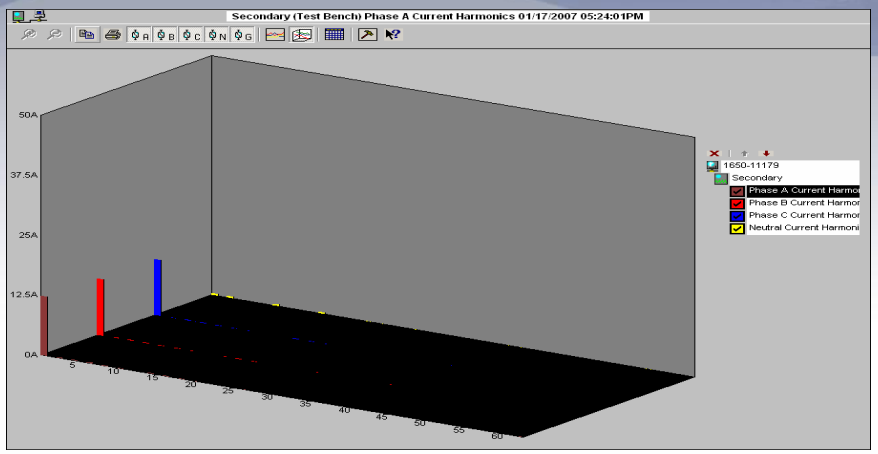
A = 12.4 Amps; B = 0.8 Amps; C = 0.8 Amps; N = 12.2 Amps

Standard transformer, phases A + B linear load



A = 12.4 Amps; B = 11.9 Amps; C = 0.7 Amps; N = 11.9 Amps

Standard transformer, phases A + B + C linear load

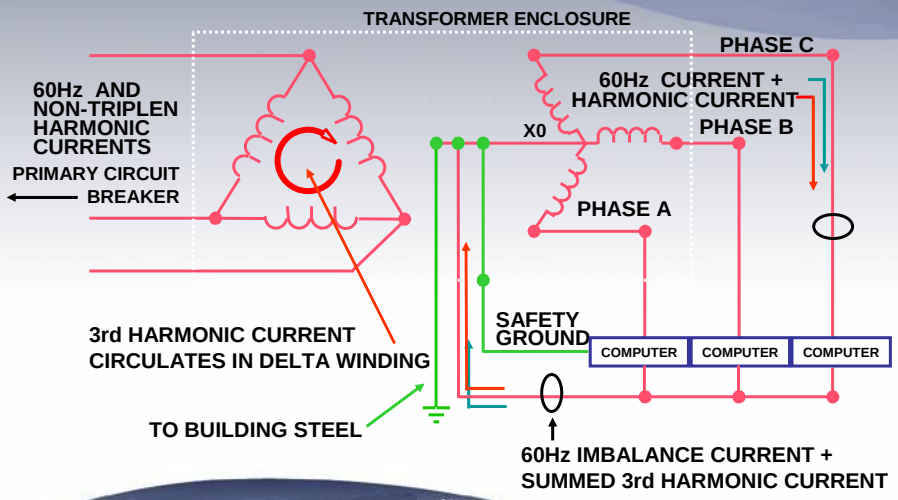


A = 12.5 Amps; B = 11.9 Amps; C = 11.8 Amps; N = 0.8 Amps

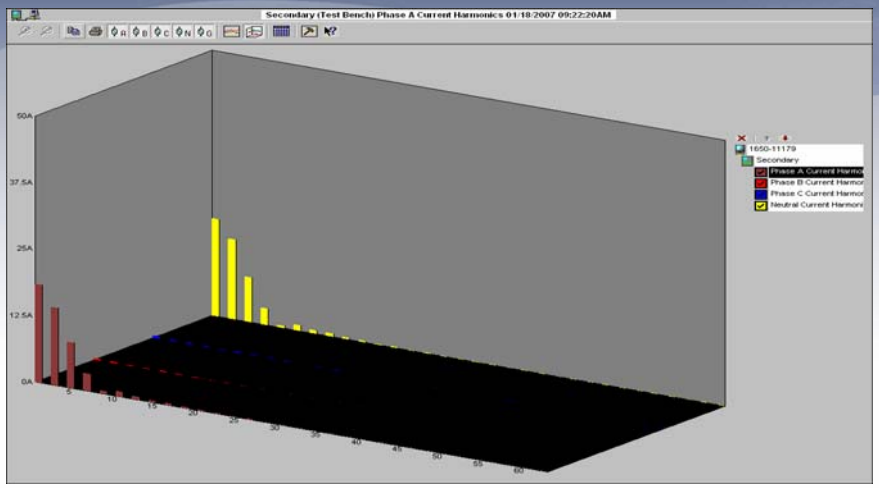
Reasons to be concerned about harmonic currents

- **Harmonics currents do no work, but do contribute to the rms current the system must carry**
- **3rd harmonic currents are additive in the system neutral**
- **3rd harmonic currents return to the transformer over the neutral and are dissipated as heat in the transformer, cables and load devices**

Wye Distribution System Serving Non-Linear Loads

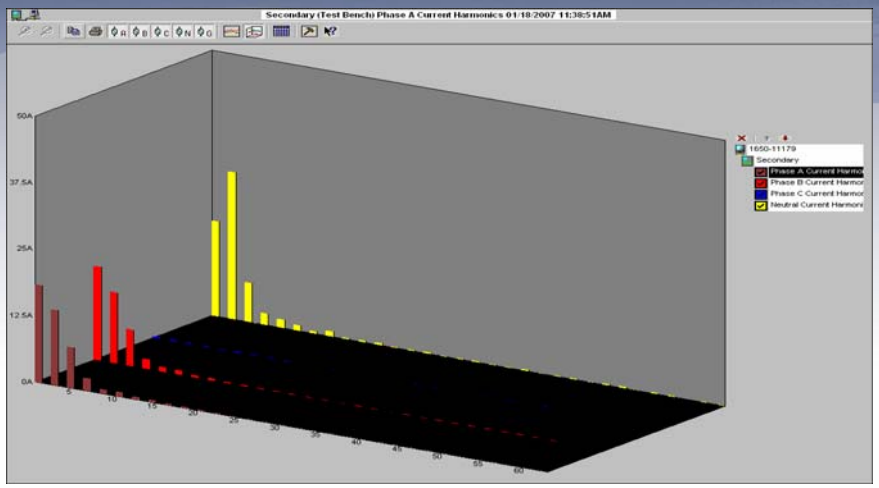


Standard Transformer, 10 non-linear loads, phase A



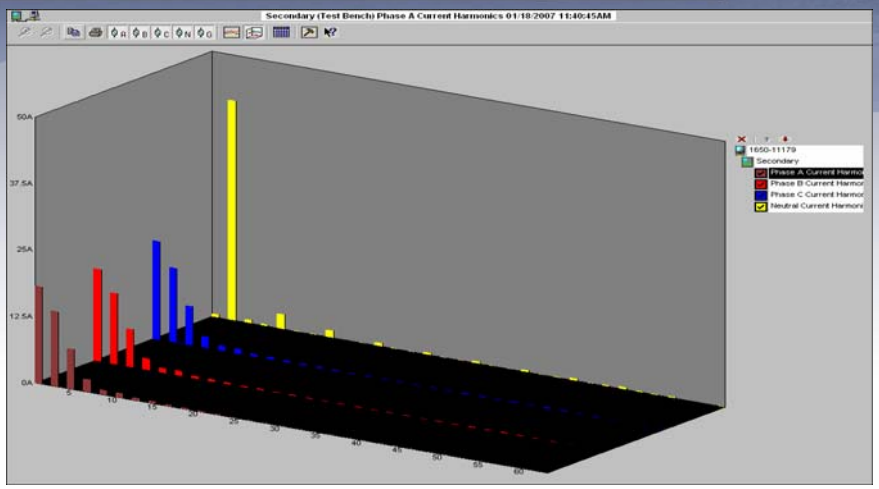
A = 24.8 Amps; B = 0.8 Amps; C = 0.8 Amps; N = 24.7 Amps

Standard Transformer, 10 non-linear loads, phases A + B



A = 24.7 Amps; B = 23.4 Amps; C = 0.7 Amps; N = 33.9 Amps

Standard Transformer, 10 non-linear loads, phases A + B + C

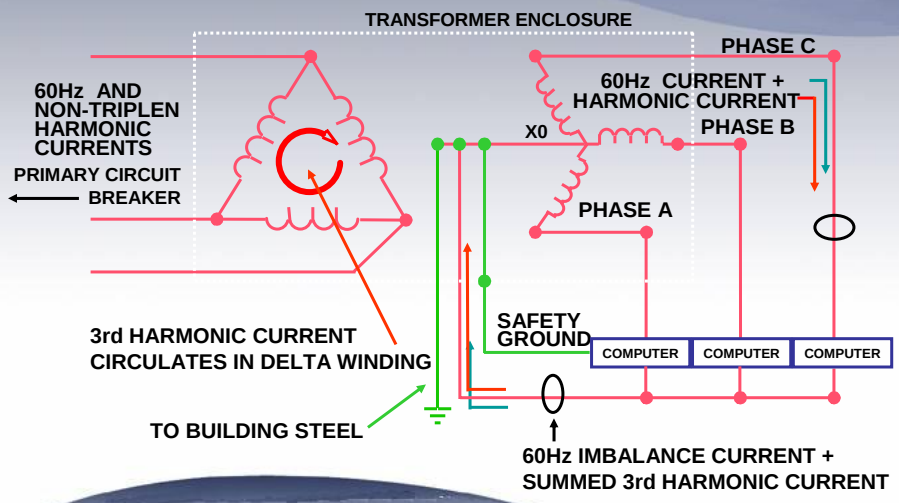


A = 24.6 Amps; B = 23.4 Amps; C = 24.5 Amps; N = 41.5 Amps

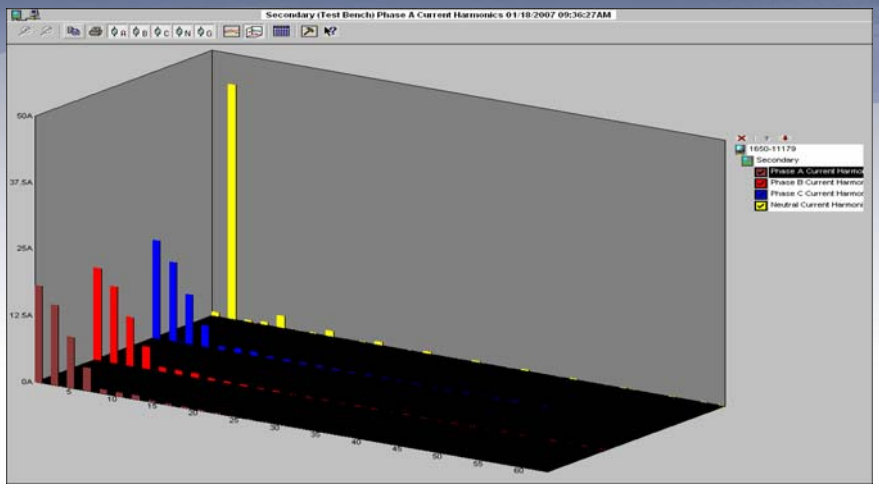
Avoiding Harmonic Problems (Accommodation)

- **k-Rated Transformers**
- **Double Neutrals**
- **Oversized switch gear**
- **De-rated UPSs, and Power Distribution Units (PDUs)**
- **Zig-zag or phase shifting transformers**

K-rated transformer to accommodate harmonic currents



K-rated transformer, 10 non-linear loads, phases A+B+C



A = 26.0 Amps; B = 24.9 Amps; C = 25.8 Amps; N = 44.3 Amps

Avoiding Harmonic Problems
(Accommodation)

- k-Rated Transformers
- **Double Neutrals**
- **Oversized switch gear**
- **De-rated UPSs, and Power Distribution Units (PDUs)**
- Zig-zag or phase shifting transformers

Avoiding Harmonic Problems
(Accommodation)

- k-Rated Transformers
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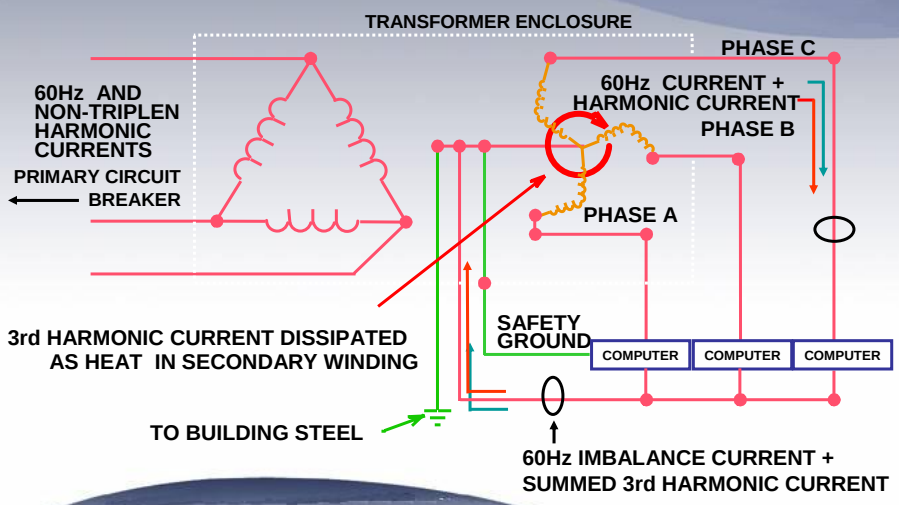
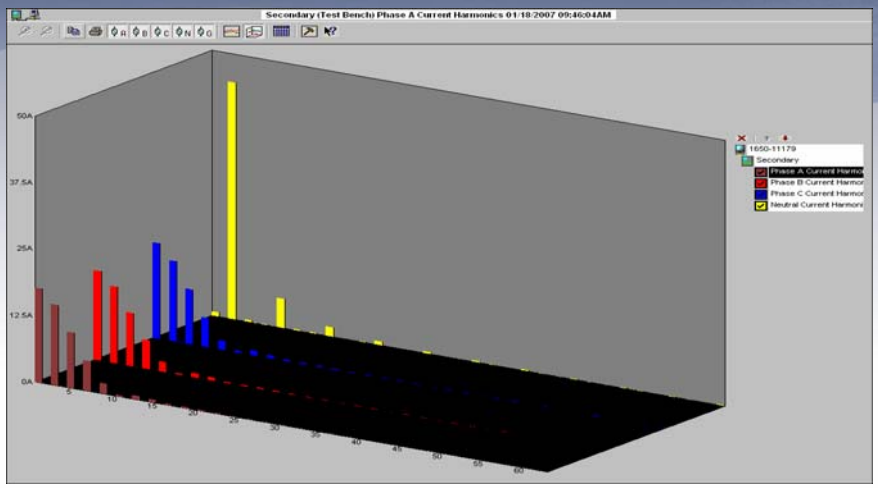
- **Zig-zag or phase shifting transformers**

Zig-zag transformer to accommodate harmonic currents



zig-zag transformer, 10 non-linear loads, phases A+B+C

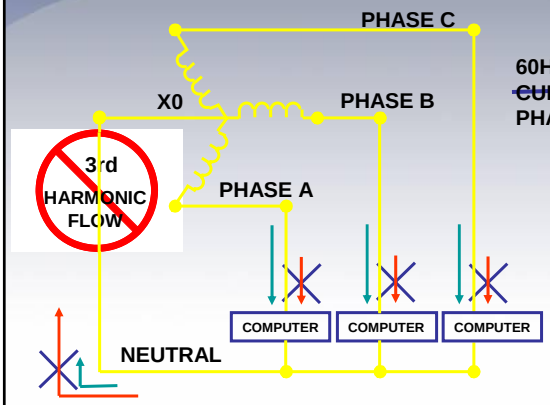


A = 26.4 Amps; B = 25.2 Amps; C = 26.4 Amps; N = 45.0 Amps

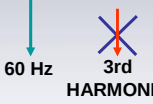
Eliminating Harmonic Problems

- **Introducing the Harmonic Suppression System (HSS)**
- **Blocks 3rd harmonic currents and prevents their flow anywhere in the system**
- **Eliminates need for oversized components and doubled neutrals.**
- **Minimizes waste heat from the transformer out to the furthest outlet.**

HSS blocking 3rd harmonic currents



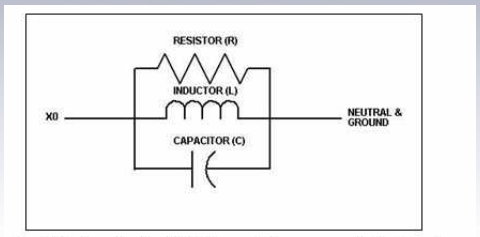
60Hz CURRENT ~~and 3rd HARMONIC CURRENT~~ FLOWING IN ALL THREE PHASES



SINCE NO 3rd HARMONIC CURRENT CAN RETURN IN THE NEUTRAL WIRE, NO 3rd HARMONIC CURRENT CAN FLOW IN THE PHASE WIRES.

60Hz IMBALANCE CURRENT ~~PLUS 3RD HARMONIC CURRENT, COMBINED FROM ALL THREE PHASES~~, MUST RETURN TO THE TRANSFORMER ON THE NEUTRAL WIRE`

RLC Parallel-Resonant Tank Circuit HSS)

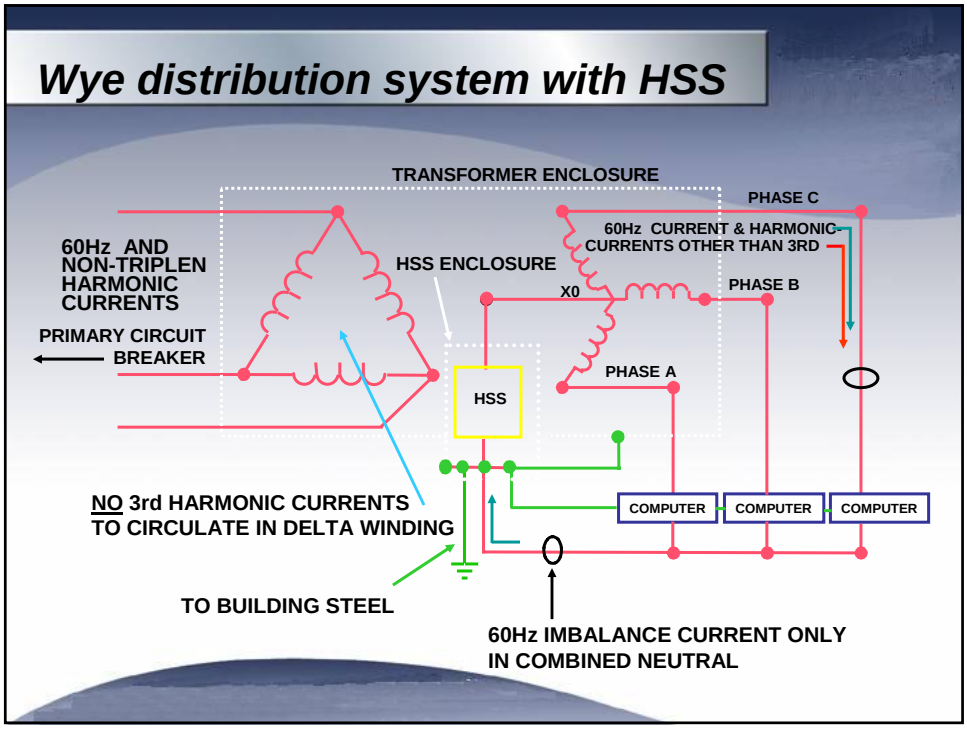


1. This is a standard RLC parallel resonance tank circuit
2. The equation for calculating the tuning frequency is:

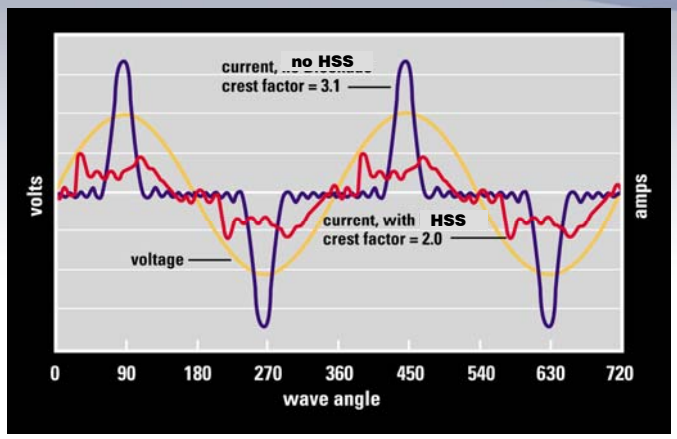
$$f = \frac{1}{2\pi\sqrt{LC}}$$

3. This circuit has a high impedance at the tuning frequency
4. This circuit has a low impedance at all other frequencies
5. When tuned to the 3rd harmonic, this circuit will block the flow of 3rd harmonic current

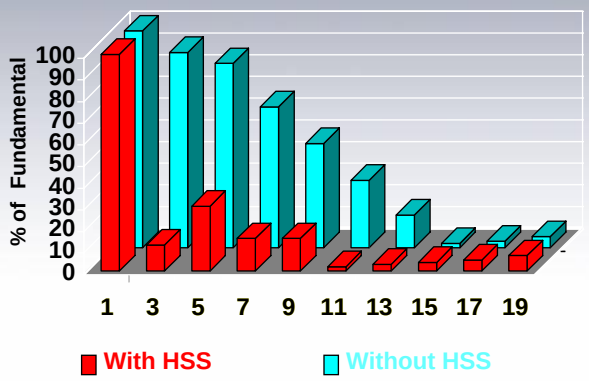
Wye distribution system with HSS



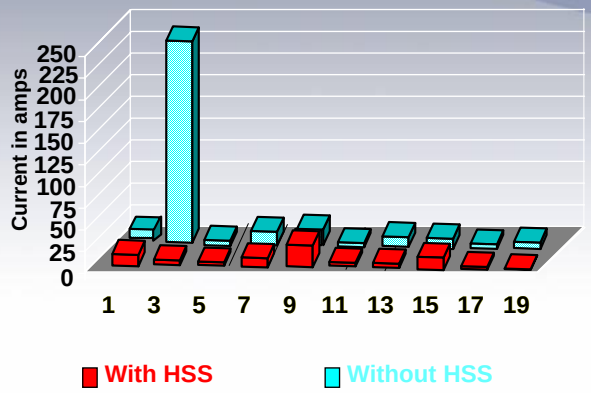
Computer Current (With & Without HSS)



Phase Harmonic Currents With & Without Harmonic Suppression System



Neutral Harmonic Currents With & Without Harmonic Suppression System



What the HSS Does (for your system)

- **Reduces neutral currents by more than 90% by preventing 3rd harmonic current flow (from the transformer out to the furthest outlet)**
- **Lowers rms phase currents, leading to more useable capacity without the need to install a larger system.**
- **Reduces energy losses throughout the system**

"Proper Sizing" of the Distribution System

- **System over-sizing to "handle" harmonic currents is eliminated.**
- **Useable system capacity is increased (single phase power factor is improved.)**

Single-phase power factor

- **Power factor is defined as “active power divided by apparent power”**
- **Power factor can be described as “a measure of the effective utilization of electrical system capacity”**

Unloaded system

System Capacity

Low power factor

System Capacity

Harmonics

kW Power

Slightly improved power factor

System Capacity

Harmonics

kW Power

High power factor

Single-phase power factor
(with and without the HSS)

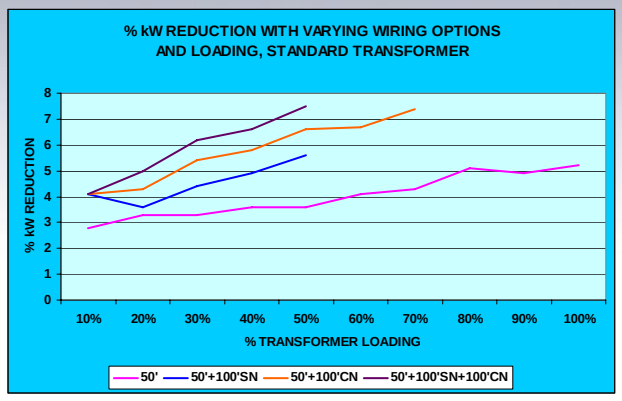
TEST	VOLTAGE (rms volts)	CURRENT (rms amps)	WATTS	VOLT-AMPS	POWER FACTOR*
No HSS	116.7	4.972	360.4	580.4	0.62
With HSS	117.2	3.173	355.9	371.8	0.96

*Single-phase power factor, is a measure of the efficiency of system capacity utilization.

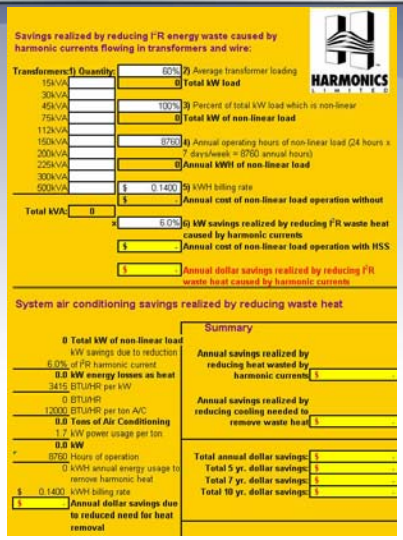
System-wide I^2R energy losses

- **Losses due to system-wide heating show up on the energy bill as increased kWH usage**
- **The HSS reduces system-wide heating and provides real energy savings.**
- **This savings can be measured by examining a system with and without an HSS installed**
- **Measurements both in the laboratory and in the field confirm system-wide energy savings.**

Power saved by removing harmonic currents varies with system loading and wiring method



The Energy Savings Estimator



The energy savings estimator
(I^2R waste heat savings)

Savings realized by reducing I^2R energy waste caused by harmonic currents flowing in transformers and wire:

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Transformers: 1) Quantity:			
15kVA		60%	2) Average transformer loading
30kVA		90	Total kW load
45kVA			
75kVA		100%	3) Percent of total kW load which is non-linear
112kVA		90	Total kW of non-linear load
150kVA	1		
200kVA		8760	4) Annual operating hours of non-linear load (24 hours x 7 days/week = 8760 annual hours)
225kVA		788400	Annual kWH of non-linear load
300kVA			
500kVA		$ 0.1400	5) kWH billing rate
		$ 110,376	Annual cost of non-linear load operation without
Total kVA:	150		
		x 6.0%	6) kW savings realized by reducing I^2R waste heat caused by harmonic currents
		$ 103,753	Annual cost of non-linear load operation with HSS
		$ 6,623	Annual dollar savings realized by reducing I^2R waste heat caused by harmonic currents

The energy savings estimator
(avoided air conditioning)

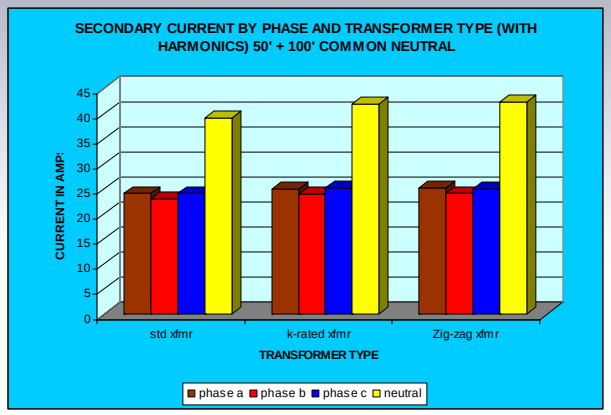
System air conditioning savings realized by reducing waste heat

90	**Total kW of non-linear load**	
	kW savings due to reduction	
6.0%	of I^2R harmonic current	
5.4	**kW energy losses as heat**	
3415	BTU/HR per kW	
18441	BTU/HR	
12000	BTU/HR per ton A/C	
1.5	**Tons of Air Conditioning**	
1.7	kW power usage per ton	
2.6	**kW**	
8760	Hours of operation	
22885	kWH annual energy usage to remove harmonic heat	
$ 0.1400	kWH billing rate	
$ 3,204	**Annual dollar savings due to reduced need for heat removal**	

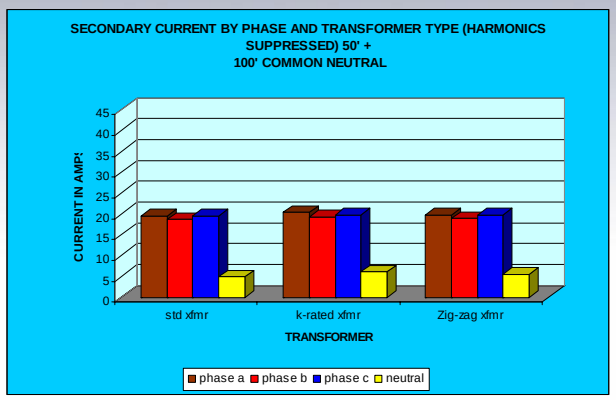
Summary

Annual savings realized by reducing heat wasted by harmonic currents	$ 6,623
Annual savings realized by reducing cooling needed to remove waste heat	$ 3,204
Total annual dollar savings:	$ 9,826
Total 5 yr. dollar savings:	$ 49,132
Total 7 yr. dollar savings:	$ 68,785
Total 10 yr. dollar savings:	$ 98,265

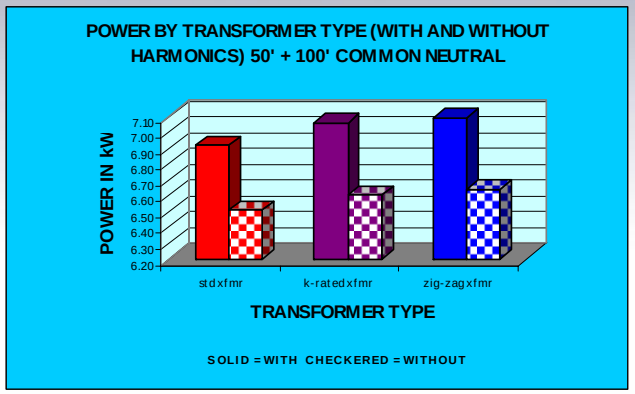
Secondary currents *(by transformer type)*



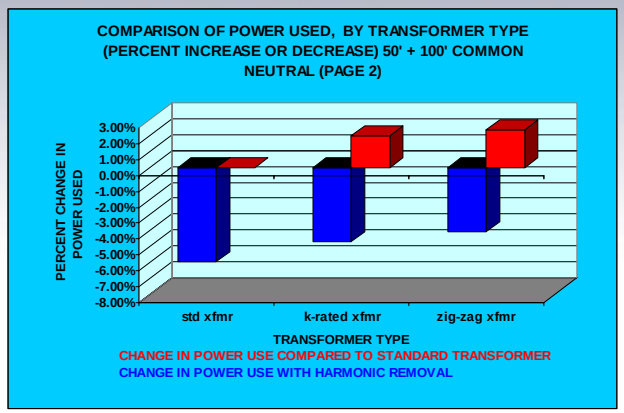
Secondary currents *(by transformer type) with HSS*



Power with and without HSS *(by transformer type)*



Power used with and without HSS, change (by transformer type)



Harmonic Suppression Products

The SysteMax

is an add-on Harmonic Suppression System That can be added to your present transformer to remove harmonic currents

The TransMax

combines a high quality TP-1 (formerly energy star) transformer with the Harmonic Suppression System in a single easy-to-install enclosure.

500 kVA TransMax
(installed in a basement vault)

Who uses the HSS and why?

- ***Data Centers***
- ***Financial institutions***
- ***Government institutions***
- ***Casinos***
- ***Educational institutions***
- ***Hospitals***
- ***Research laboratories***

Stock exchange trading room floor

- **Transformers**
  - **2- 112 kVA & 1-75 kVA, K-20 Transformers**
  - **Avg. transformer loading 64% of Rated Capacity**
- **Combined Neutral Current reduced by 75%, from 750 amps., to 186 amps..**
- **3rd Harmonic Neutral Current reduced by 98%, from 712 amps., *to 15 amps.*,**
- **RMS Phase Current reduced by 9%**
- **Using energy savings estimator-- ROI, 19 months**
- **3 Portable A/C units removed ($54,000.00 per yr.)**

Software development center
(before and after HSS)

Transformer location, size, kVA	Average Load		Phase Current average amps rms		rms Neutral Current total amps		Neutral Current 3rd harmonic amps	
	Before	After	Before	After	Before	After	Before	After
A2, 150	54%	63%	225	263	203	28	189	3
A3, 150	33%	42%	137	175	154	55	153	3
B2, 150	40%	79%	168	327	191	52	187	4
B3, 150	45%	46%	186	192	201	50	197	3
C2, 150	44%	56%	183	234	252	81	243	4
C3, 150	67%	58%	277	244	325	77	319	4
C1, 150	58%	56%	240	234	286	55	280	3
D1, 150	42%	33%	175	138	197	45	190	3
D2, 150	29%	28%	121	117	148	51	135	3
D3, 150	37%	35%	153	146	178	43	174	3
				Totals	2135	537	2067	33
	rms Neutral Current Reduction		75%		3rd harmonic Neutral Current Reduction		98%	

Conclusions

- **Every electrical distribution system powering multiple single-phase non-linear loads, is susceptible to harmonic neutral current problems**
- **Installing a Harmonic Suppression System increases electrical system reliability**
- **Installing a Harmonic Suppression System reduces heat and wasted energy system-wide**
- **Using the HSS saves you energy and money**

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