Welcome
to the
3rd Annual Northern Ohio Energy Management Conference

September 30, 2008

Recover Lost Dollars…

Demand Side Electrical Energy Savings…

By Improving Distribution System Efficiency, Capacity and Power Quality

Presented by
Benjamin Rosolowski

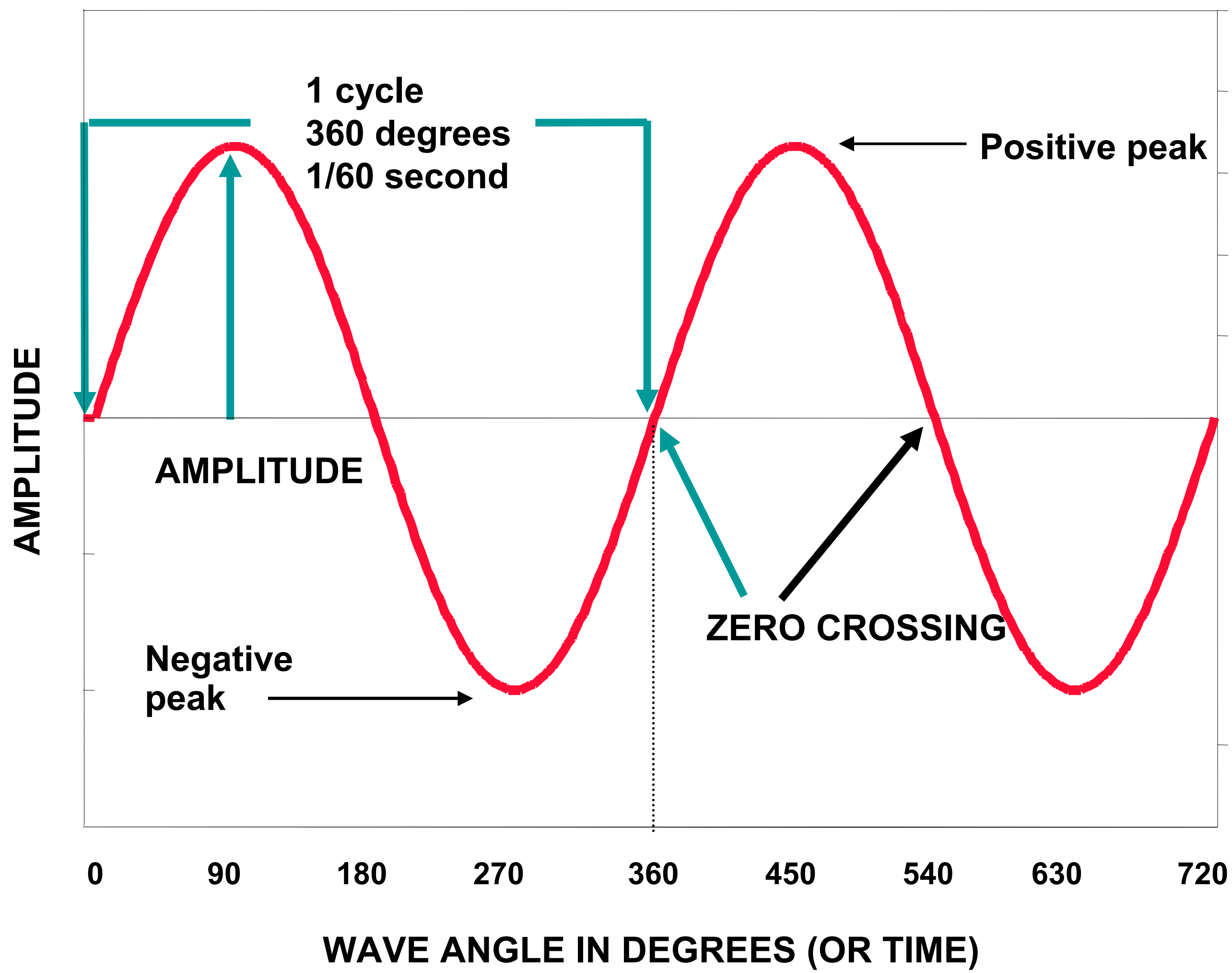
Basic Issues Related to Electrical Distribution

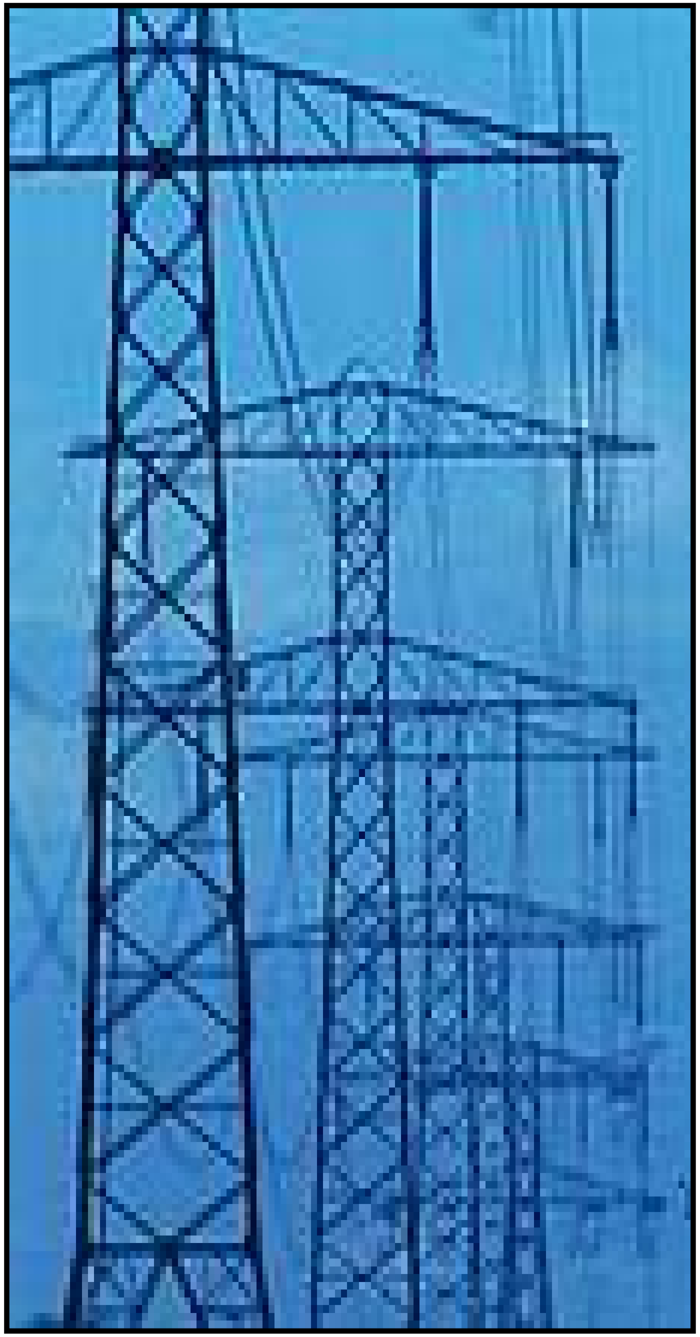
- Reliability
- Capacity
- Safety
- Operating Costs

Terms & Definitions

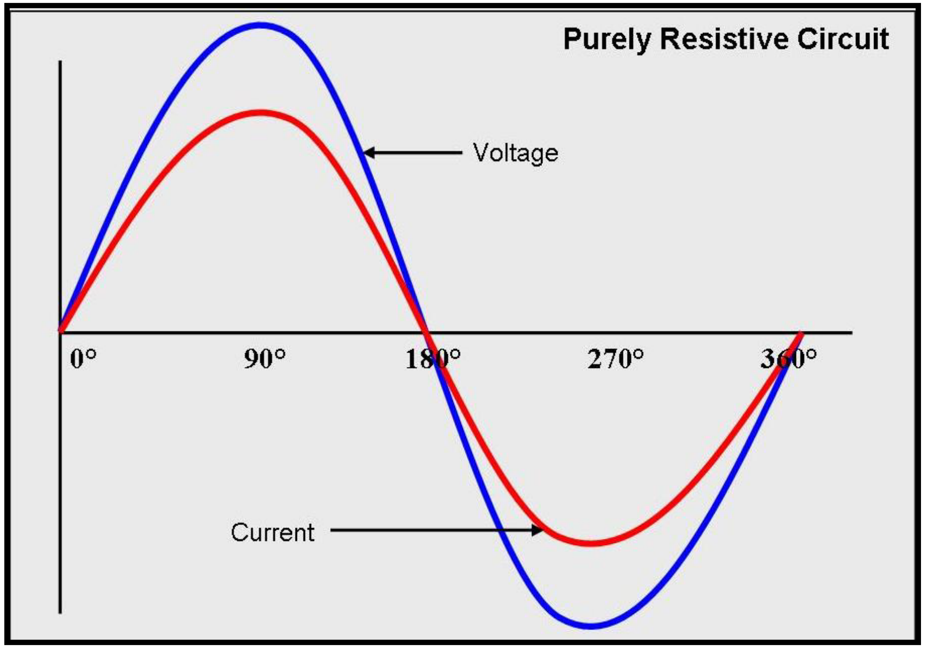
- **<u>Sinusoidal Wave Forms</u>**
- Power Quality
- Electrical Loads Types
- Harmonics
- RMS
- Power Factor

Nature of a Sine Wave





Utilities Typically Supply Pure Efficient Power



Terms & Definitions

- Sinusoidal Wave Forms
- <u>**Power Quality**</u>

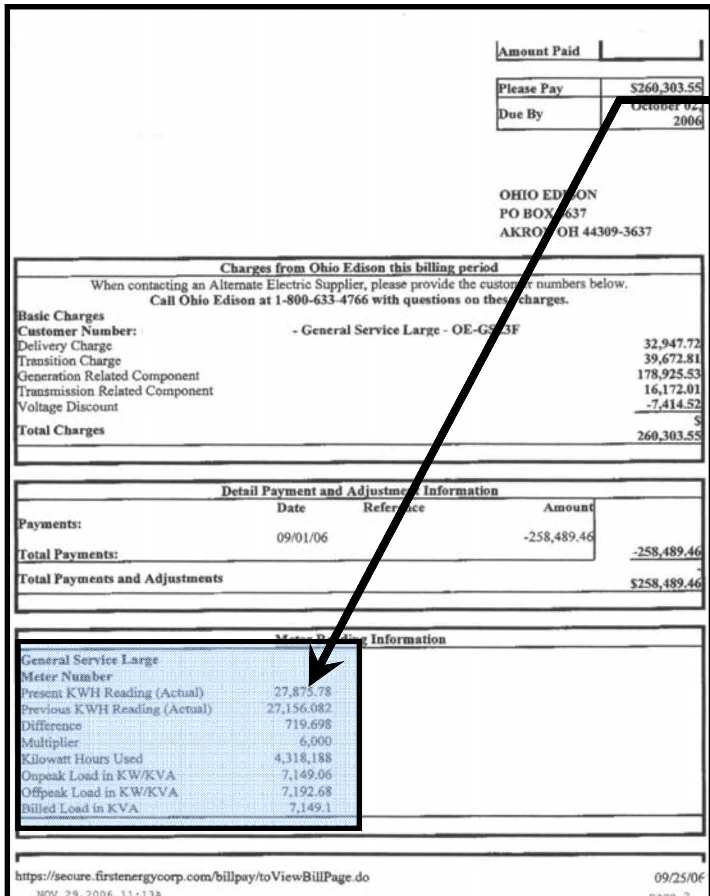
What is Power Quality?

- Power Quality is the quality of the electric power supplied to electrical equipment.
- There is no single way to completely quantify the quality of Power.
- Poor power quality can result in misoperation of the equipment and higher energy costs.

Most Common Power Quality Issues

- Voltage sags, dips & swells
- ***<u>Voltage & Current Distortion</u>***
- Transients
- ***<u>Harmonics</u>***
- <u>Voltage Unbalance & Regulation</u>
- Flicker
- Frequency variations
- Inrush
- ***<u>Poor Power Factor</u>***

Poor power quality is reflected in your monthly electric bill as increased kW/kVA (Demand) and kWH (Usage).


Amount Paid

Please Pay	$260,303.55
Due By	October 02, 2006

OHIO EDISON
PO BOX 3637
AKRON OH 44309-3637

Charges from Ohio Edison this billing period
When contacting an Alternate Electric Supplier, please provide the customer numbers below.
Call Ohio Edison at 1-800-633-4766 with questions on these charges.

Basic Charges		
Customer Number:	- General Service Large - OE-GS 3F	
Delivery Charge		32,947.72
Transition Charge		39,672.81
Generation Related Component		178,925.53
Transmission Related Component		16,172.01
Voltage Discount		-7,414.52
Total Charges		$ 260,303.55

Detail Payment and Adjustment Information

	Date	Reference	Amount	
Payments:	09/01/06		-258,489.46	
Total Payments:				-258,489.46
Total Payments and Adjustments				$258,489.46

Meter Reading Information

General Service Large	
Meter Number	
Present KWH Reading (Actual)	27,875.78
Previous KWH Reading (Actual)	27,156.082
Difference	719.698
Multiplier	6,000
Kilowatt Hours Used	4,318,188
Onpeak Load in KW/KVA	7,149.06
Offpeak Load in KW/KVA	7,192.68
Billed Load in KVA	7,149.1

https://secure.firstenergycorp.com/billpay/toViewBillPage.do 09/25/06
NOV 29,2006 11:13A page 2

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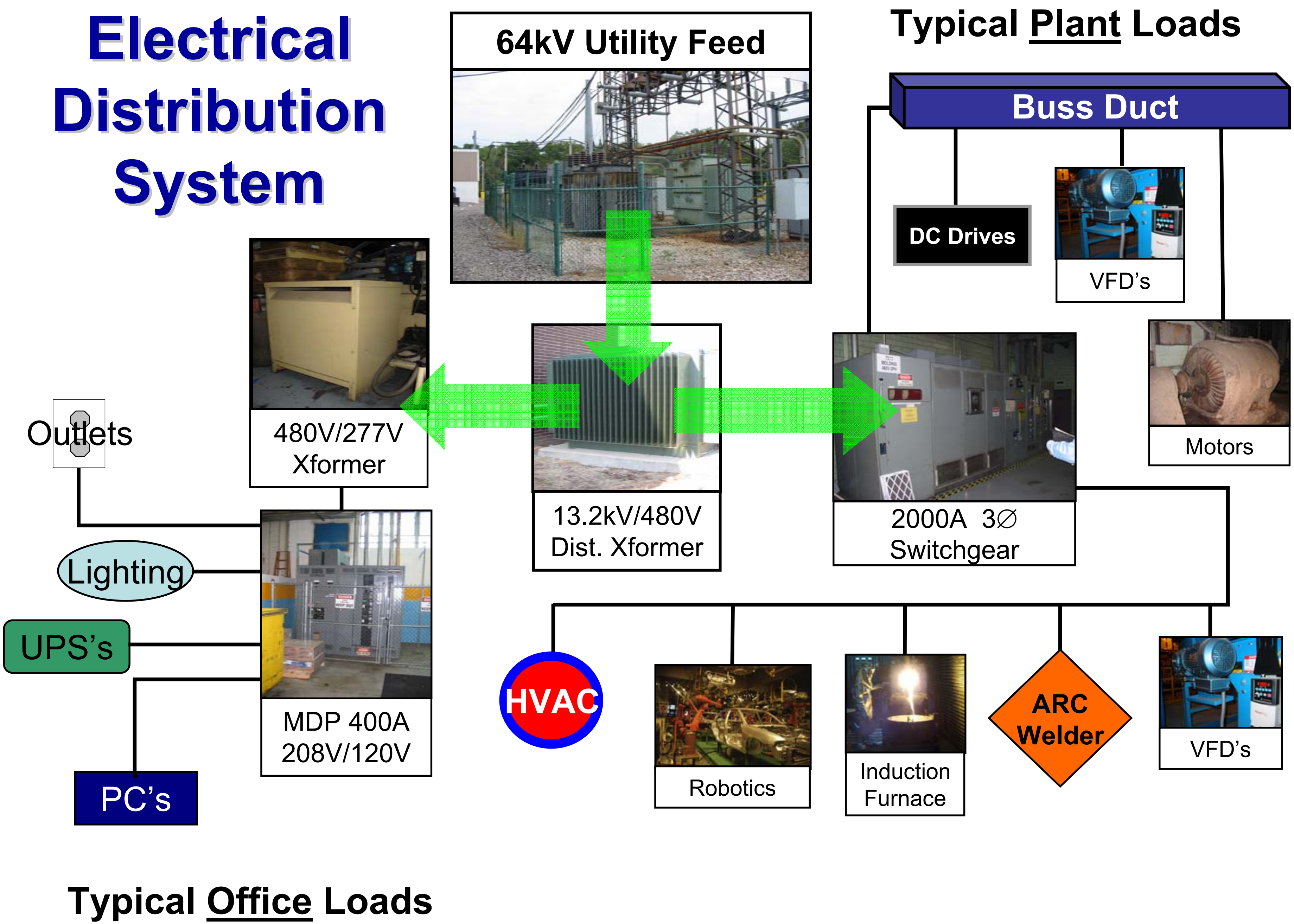
Symptoms of power quality problems can be categorized into two main areas:

- Equipment failure and misoperation
- Economic considerations

Terms & Definitions

- Sinusoidal Wave Forms
- Power Quality
- **Electrical Load Types**
  - Resistive, Inductive
  - Linear vs. Non Linear

Electrical Distribution System



Examples of Resistive Loads

- Incandescent Light Bulb
- Hot Plate
- Electric Hot Water Tank

Examples of Inductive Loads

- Transformers
- Motors
- Lighting Ballasts
- Induction Furnaces

Linear & Non-Linear

- Linear Load - The current waveform looks like the voltage waveform
- Non-linear Load – The current waveform does not look like the voltage waveform
- The more the current looks like the voltage, the more linear the load

What do Non-Linear Loads have in common?

- Convert AC into DC
- Contain some kind of rectifier
- Induce harmonic currents
- React with the source to produce harmonic voltage distortion

Linear & Non-Linear Loads

What is important ?

Linear Loads

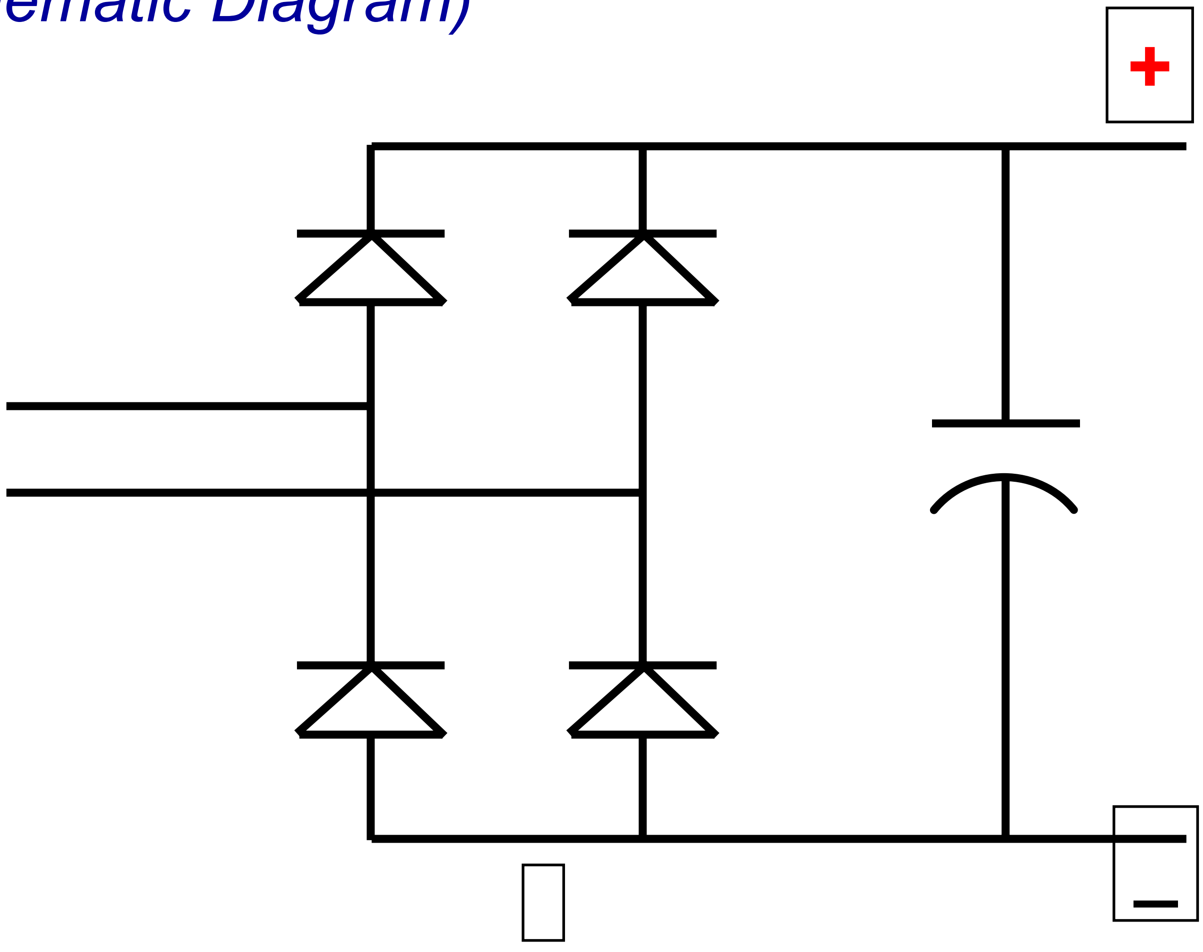
Draw their power at 60 Hz

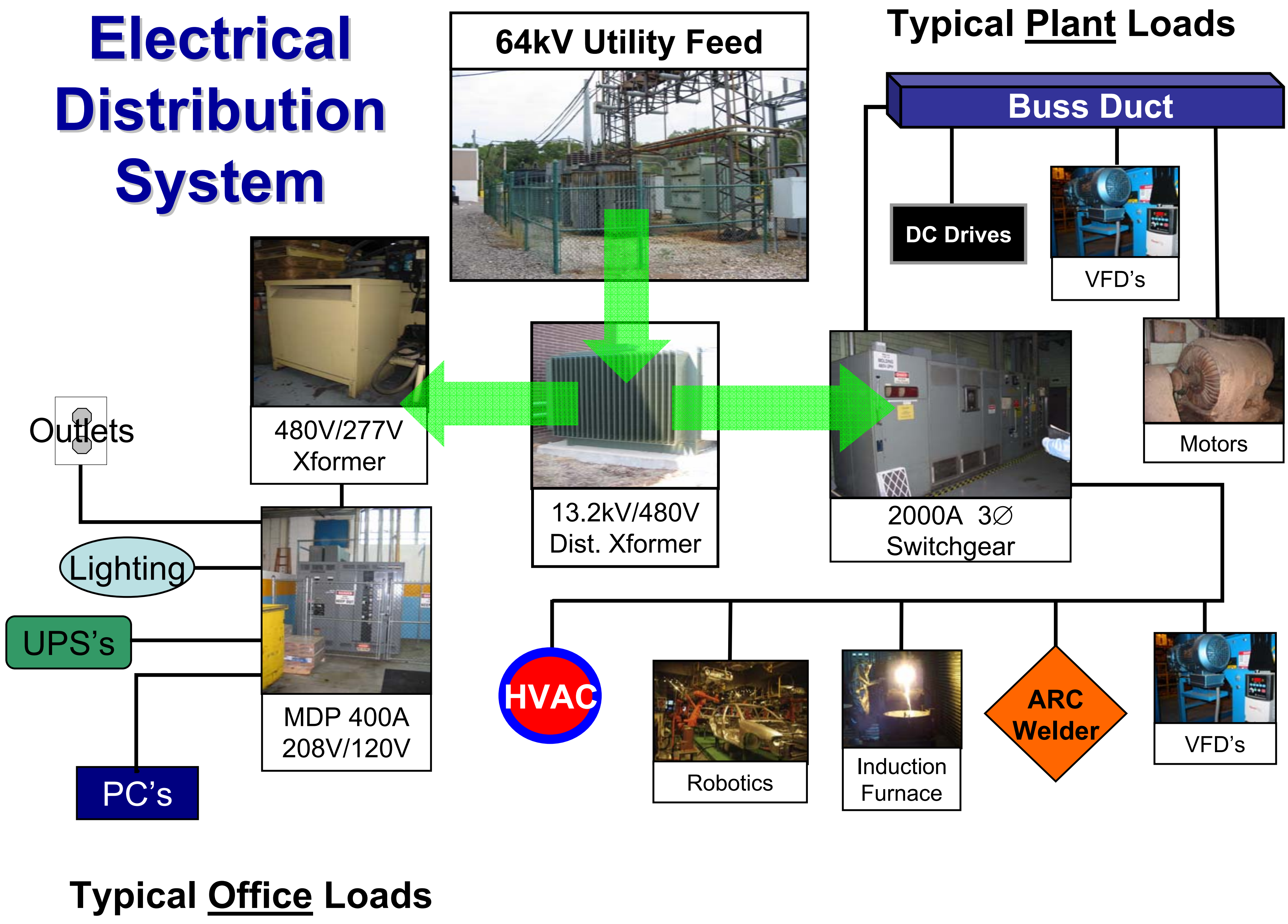
Non-linear Loads

Draw their power from 60 Hz ; however, they reflect large amounts of harmonic current back into the distribution system

Single-Phase 2-pulse Diode Bridge

(Schematic Diagram)

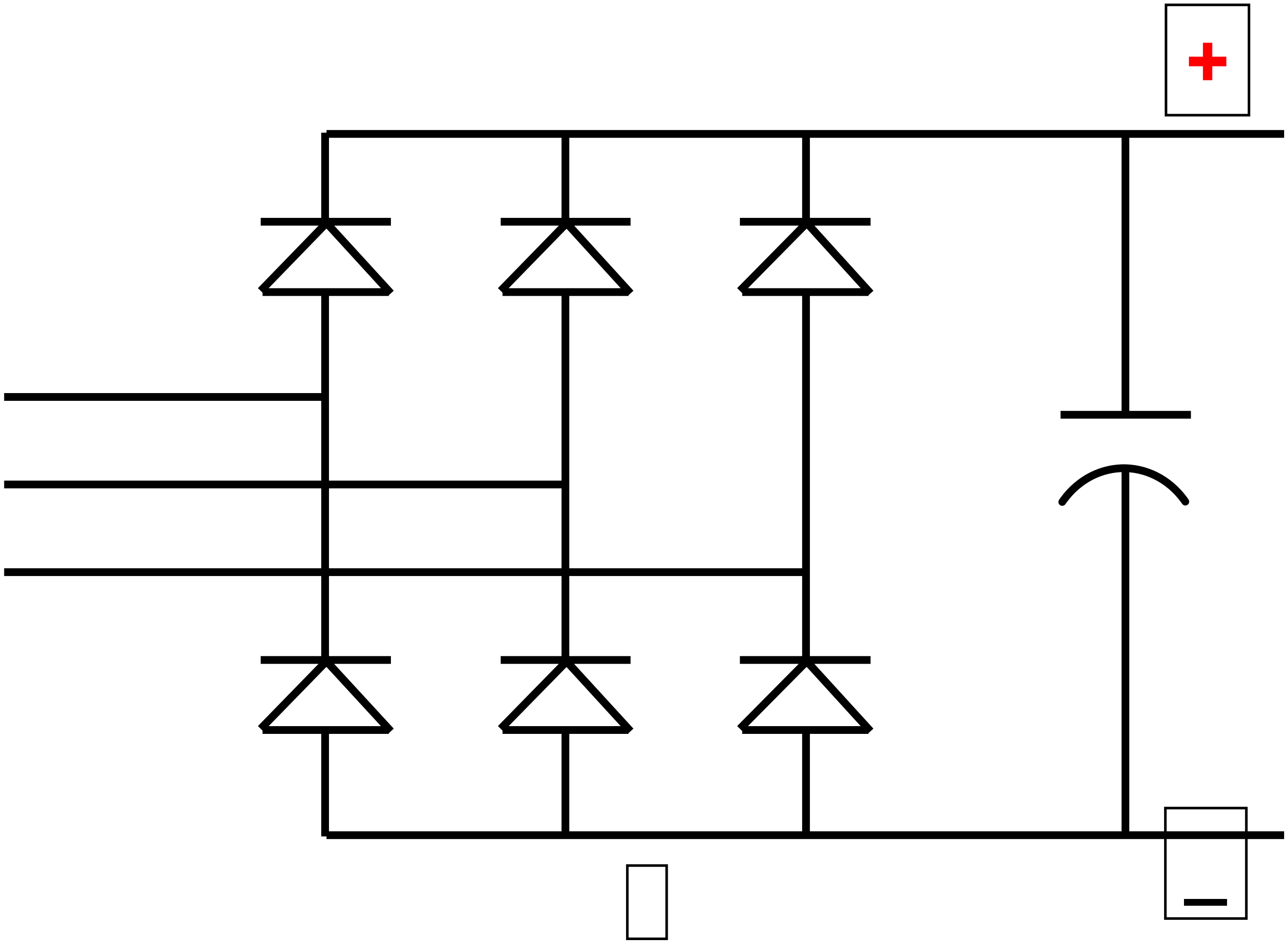




Electrical Distribution System
64kV Utility Feed
Typical Plant Loads
Buss Duct
DC Drives
VFD's
Motors
480V/277V Xformer
13.2kV/480V Dist. Xformer
2000A 3∅ Switchgear
Outlets
Lighting
UPS's
PC's
MDP 400A 208V/120V
HVAC
Robotics
Induction Furnace
ARC Welder
VFD's
Typical Office Loads

Three-Phase 6-Pulse Diode Bridge

(Schematic Diagram)



Typical Non-Linear Loads

(Two Pulse and Six Pulse Rectifiers)

- Computers
- Copy & Fax Machines
- Solid-State Lighting Ballasts
- Programmable Controllers
- DC Drive Systems
- VFD's
- Electroplating Processes
- Solid State UPS's
- Induction Furnace

Terms & Definitions

- Sinusoidal Wave Forms
- Power Quality
- Electrical Loads Types
- **Harmonics**

What are Harmonics?

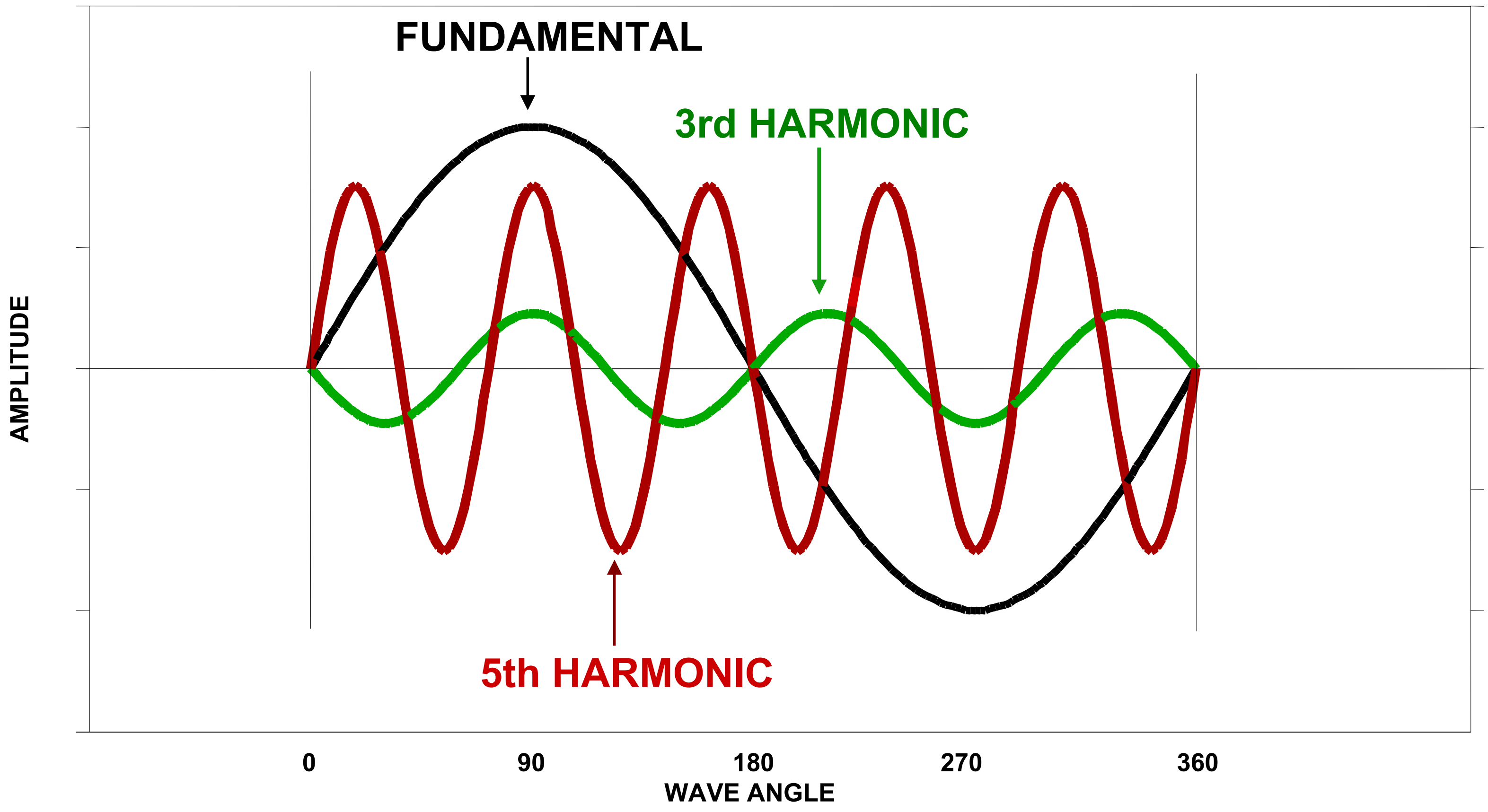
- Integer multiples of the fundamental frequency (Voltage or Current at 60 hertz)

Table of Harmonics

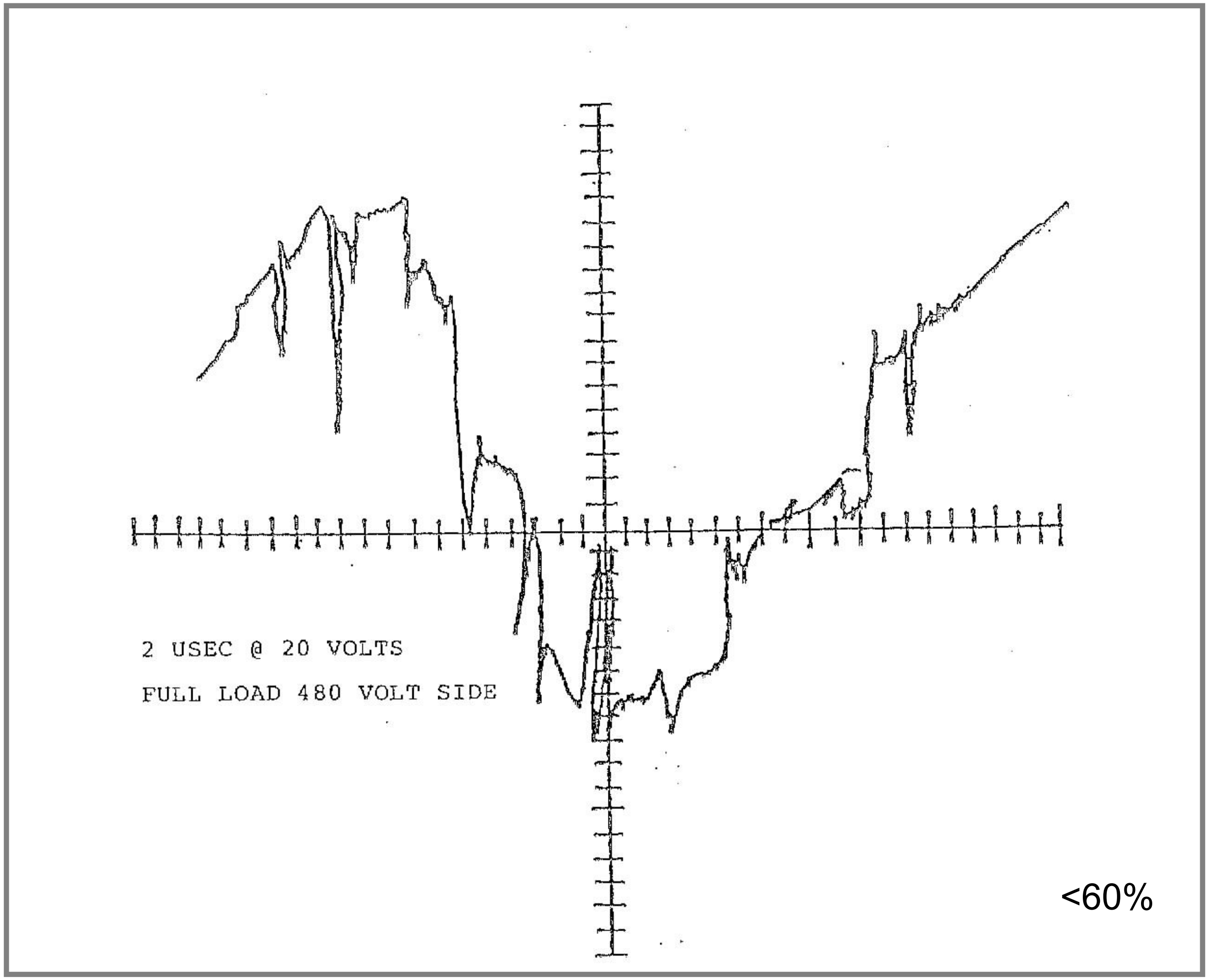
HARMONIC	FREQUENCY	
	U.S. POWER	AIRCRAFT
1	60	400
2	120	800
3	180	1200
5	300	2000
7	420	2800
9	540	3600
11	660	4400
…	…	…
49	2940	19600

Harmonic Waveforms

Algebraically add and subtract to distort the fundamental waveform

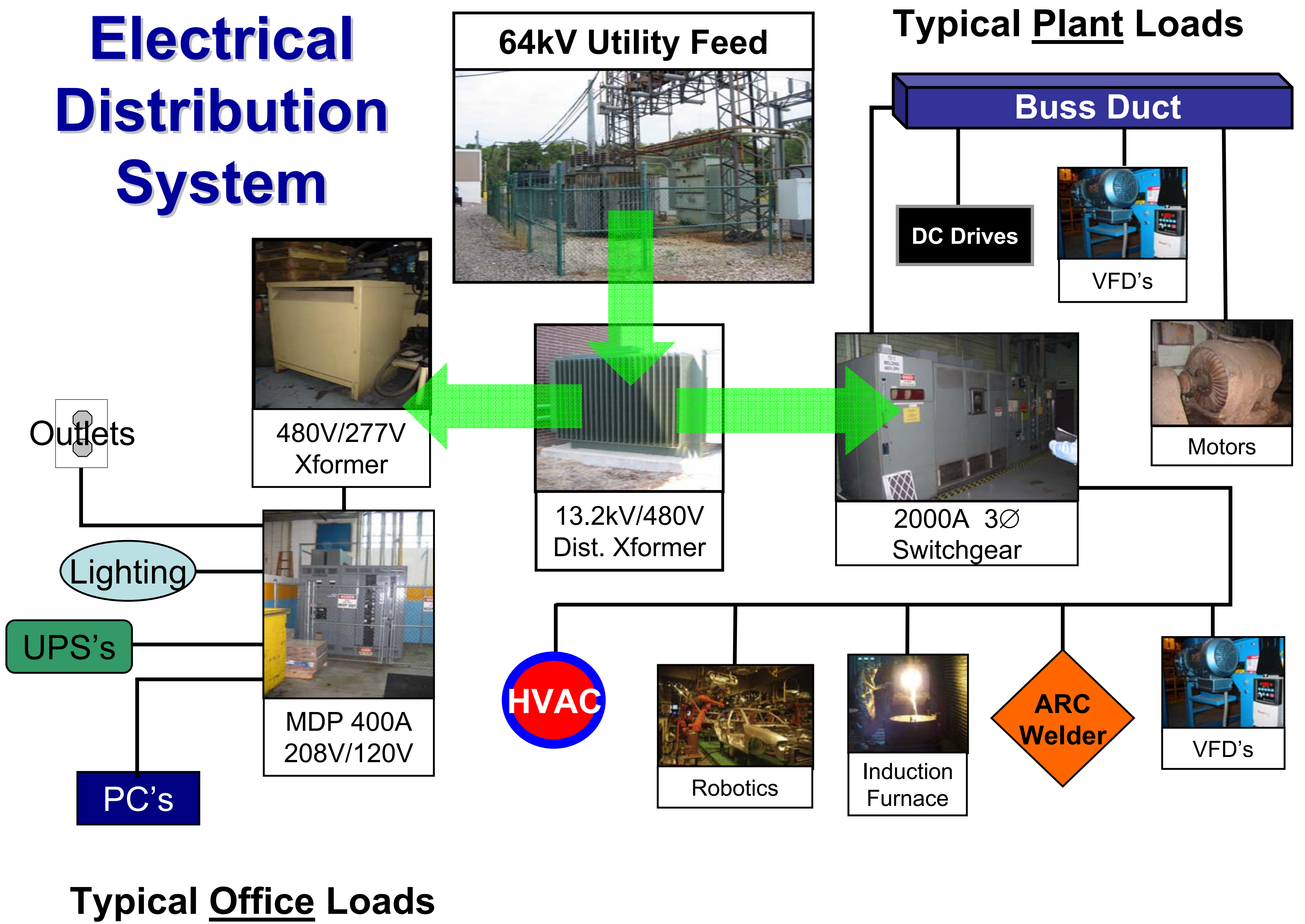


Poor Power Quality ("Dirty")



Symptoms of Harmonic Problems

- Overheated phase conductors, panels, and transformers
- Random tripping of circuit breakers
- Premature failure of transformers and UPS systems
- Reduced system capacity
- Very high neutral currents
- Low Power Factor



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Typical Office Loads

Terms & Definitions

- Sinusoidal Wave Forms
- Power Quality
- Electrical Loads Types
- Harmonics
- **RMS**

What is RMS?

(Root Mean Square)

&

Why is it Important?

Definition of RMS Values

(rms means root mean square)

$$I_{(rms)} = \sqrt{70^2 + 50^2 + 30^2 + 20^2}$$

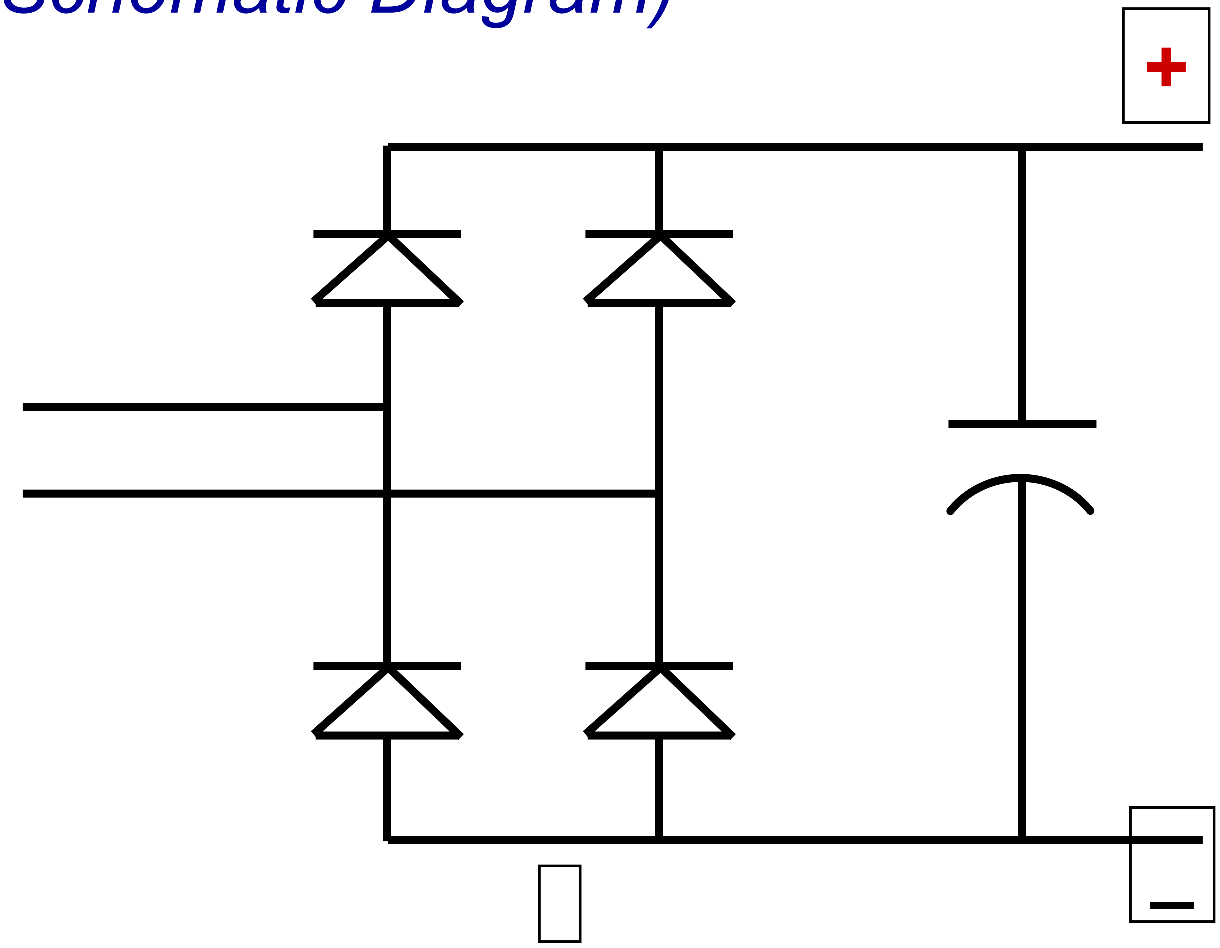
$$= 93\ amps$$

Why is RMS Important?

The importance of RMS voltage and current are that they can be directly used to calculate the total or true power.

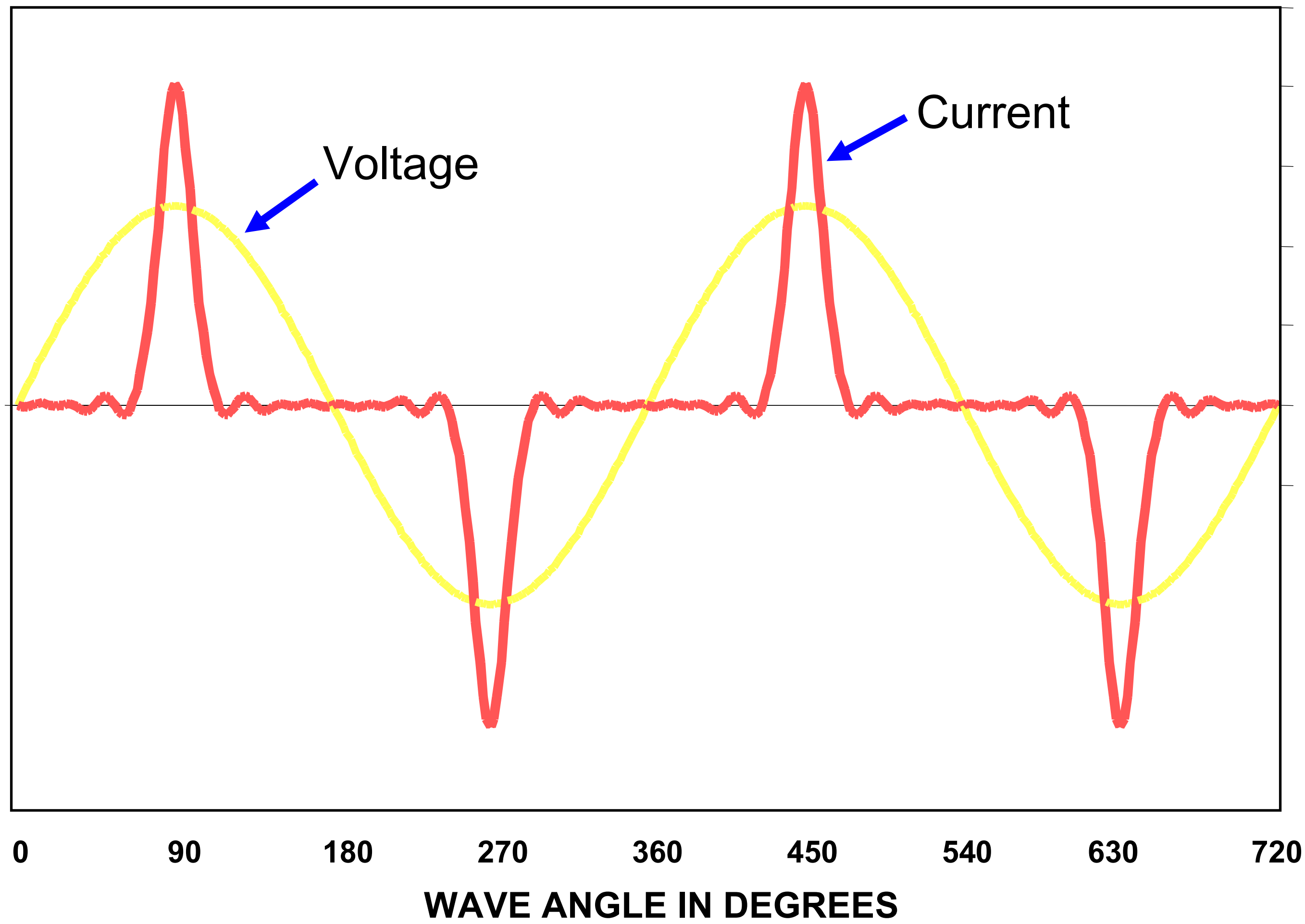
Single-Phase 2-pulse Diode Bridge

(Schematic Diagram)

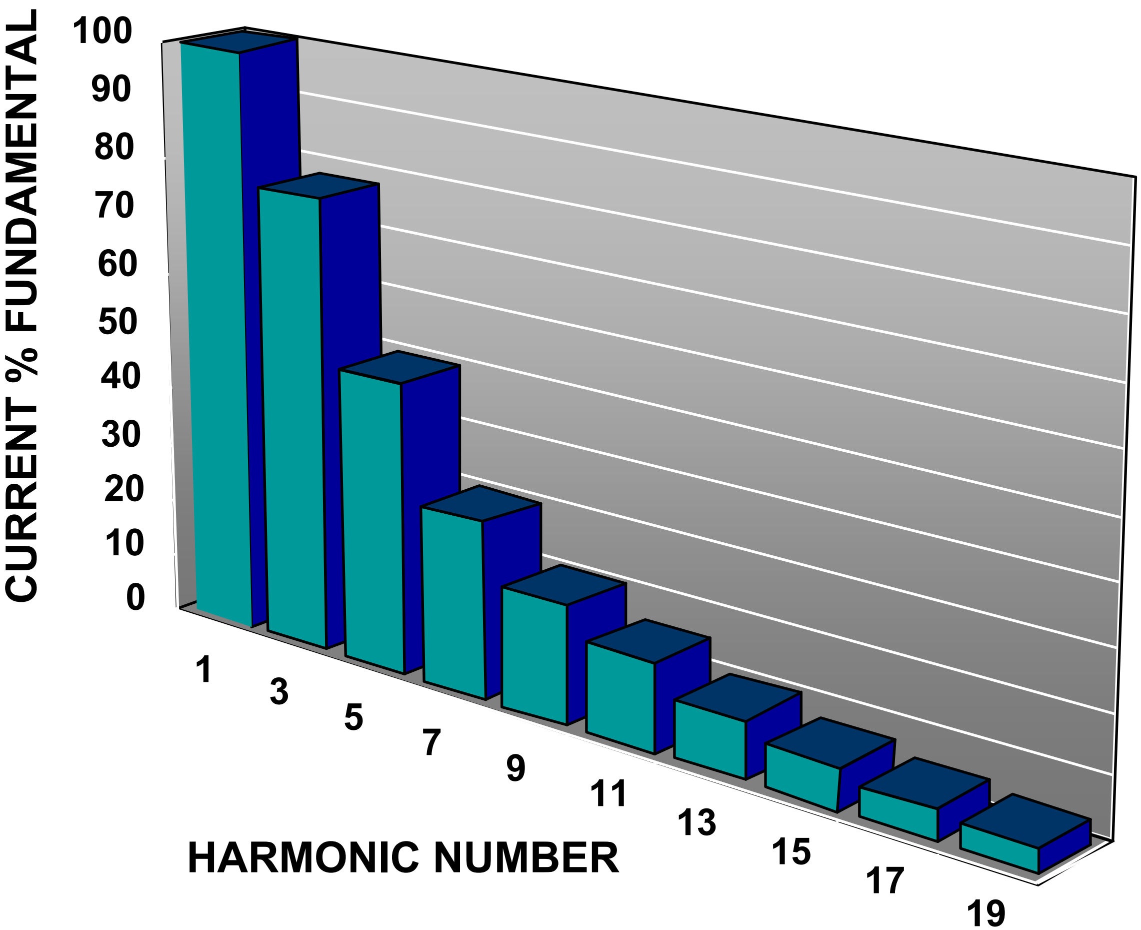


Single-Phase 2-Pulse Diode Bridge

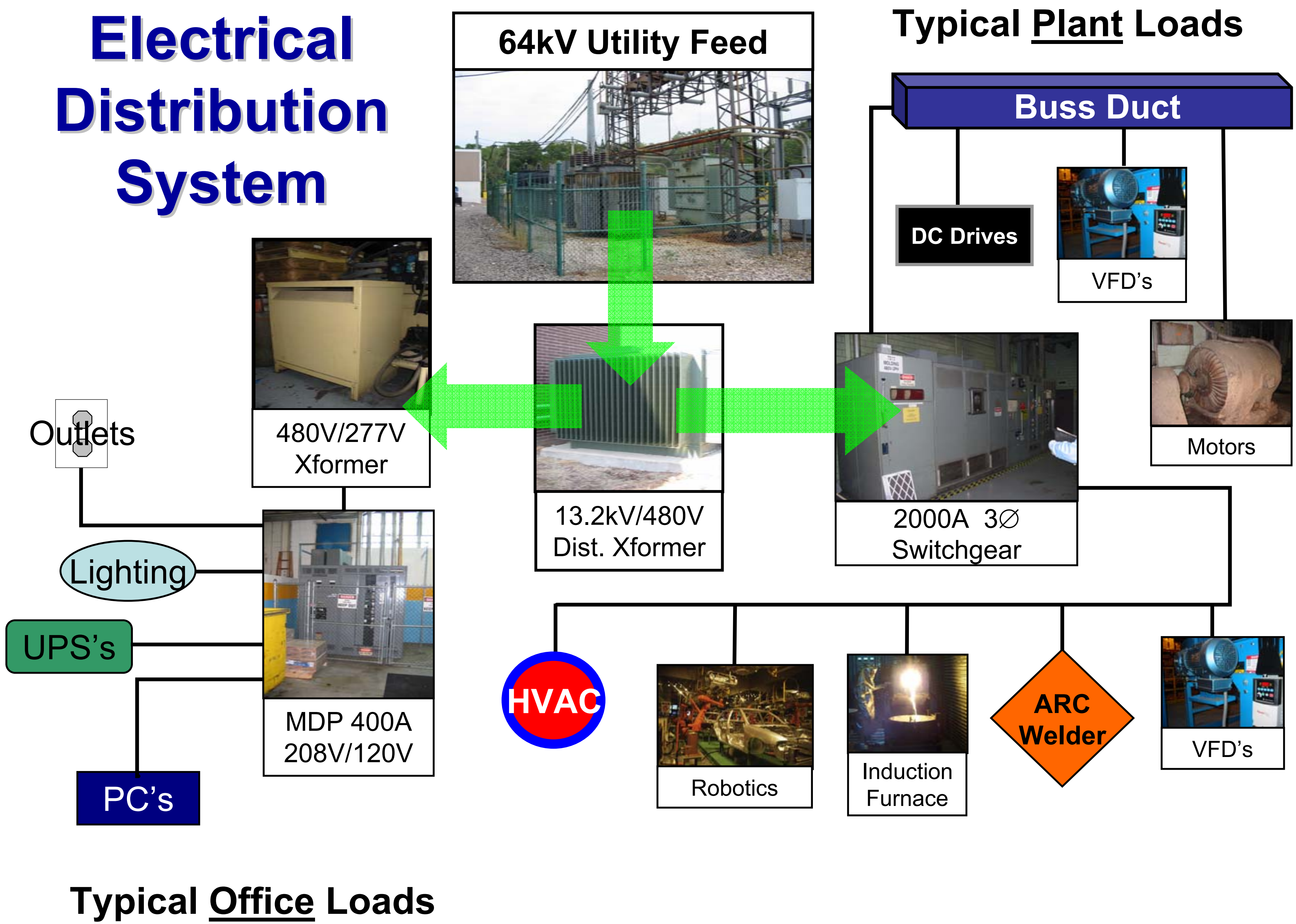
(Waveform)



Single-Phase 2-Pulse Rectifier
(Typical for Personal Computers)



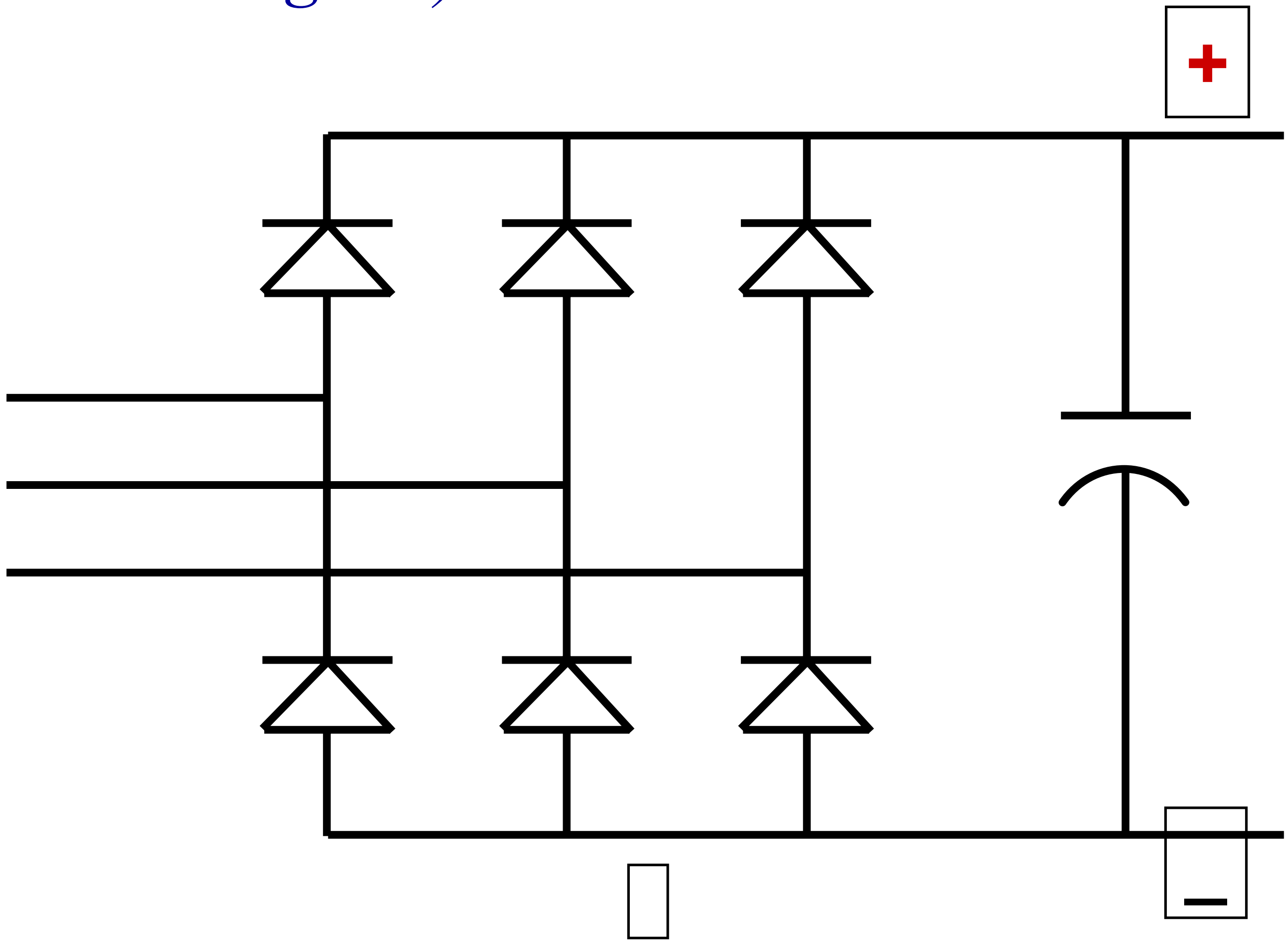
Electrical Distribution System

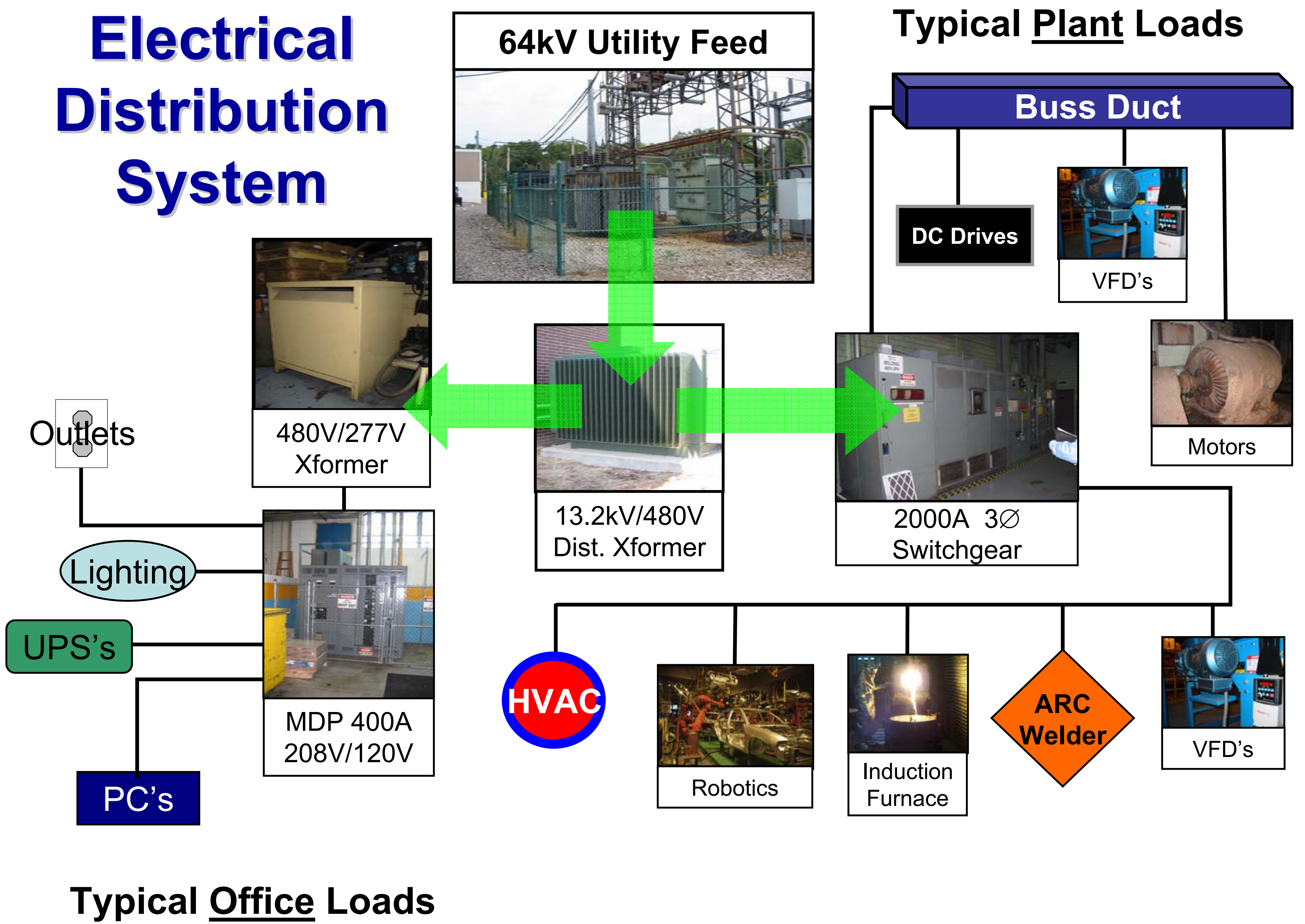


Three Phase Variable Frequency Drive (VFD)

Three-Phase 6-Pulse Diode Bridge

(Schematic Diagram)





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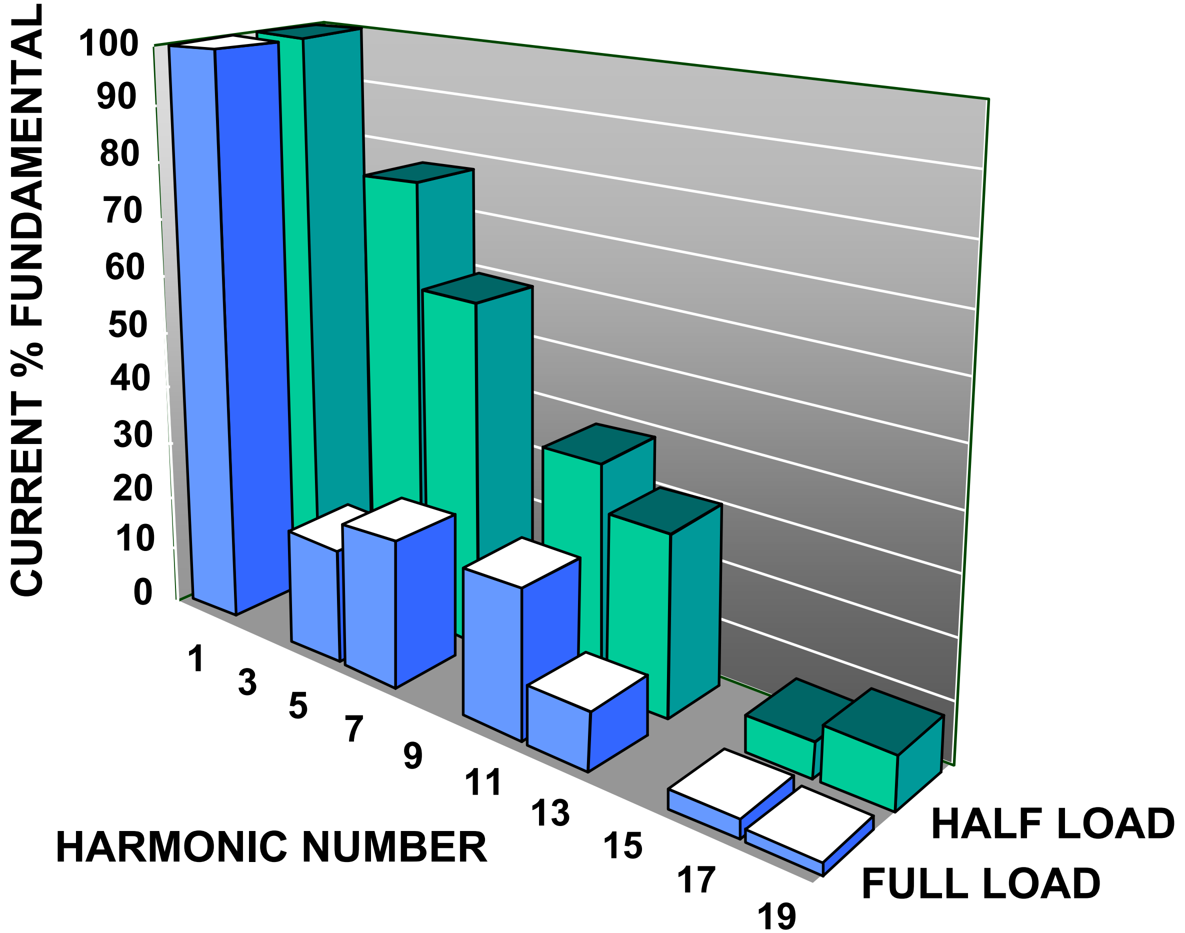
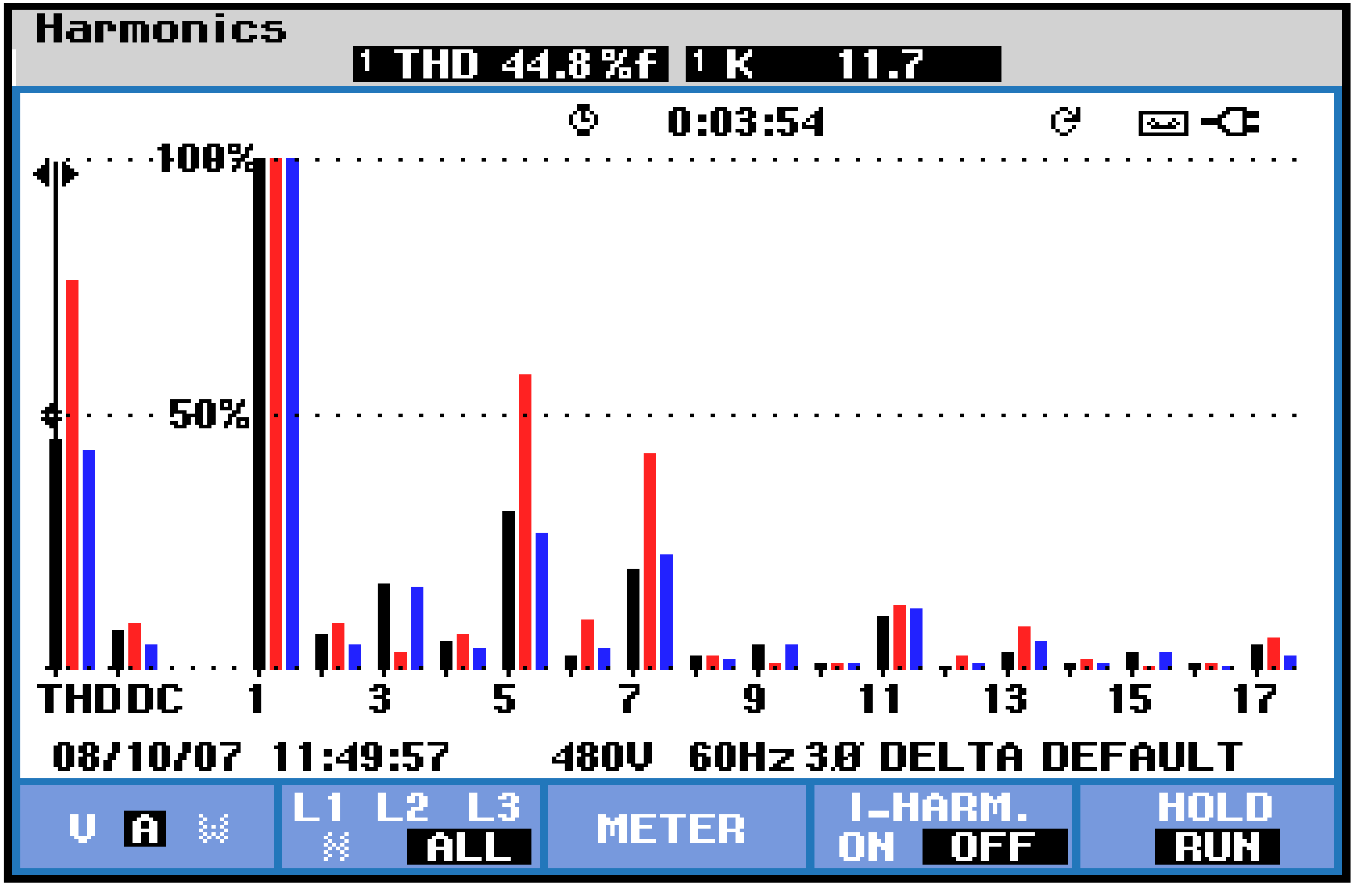
6-Pulse Diode Bridge Rectifier Harmonic Current Spectrum

(Half & Full Speed Operation)

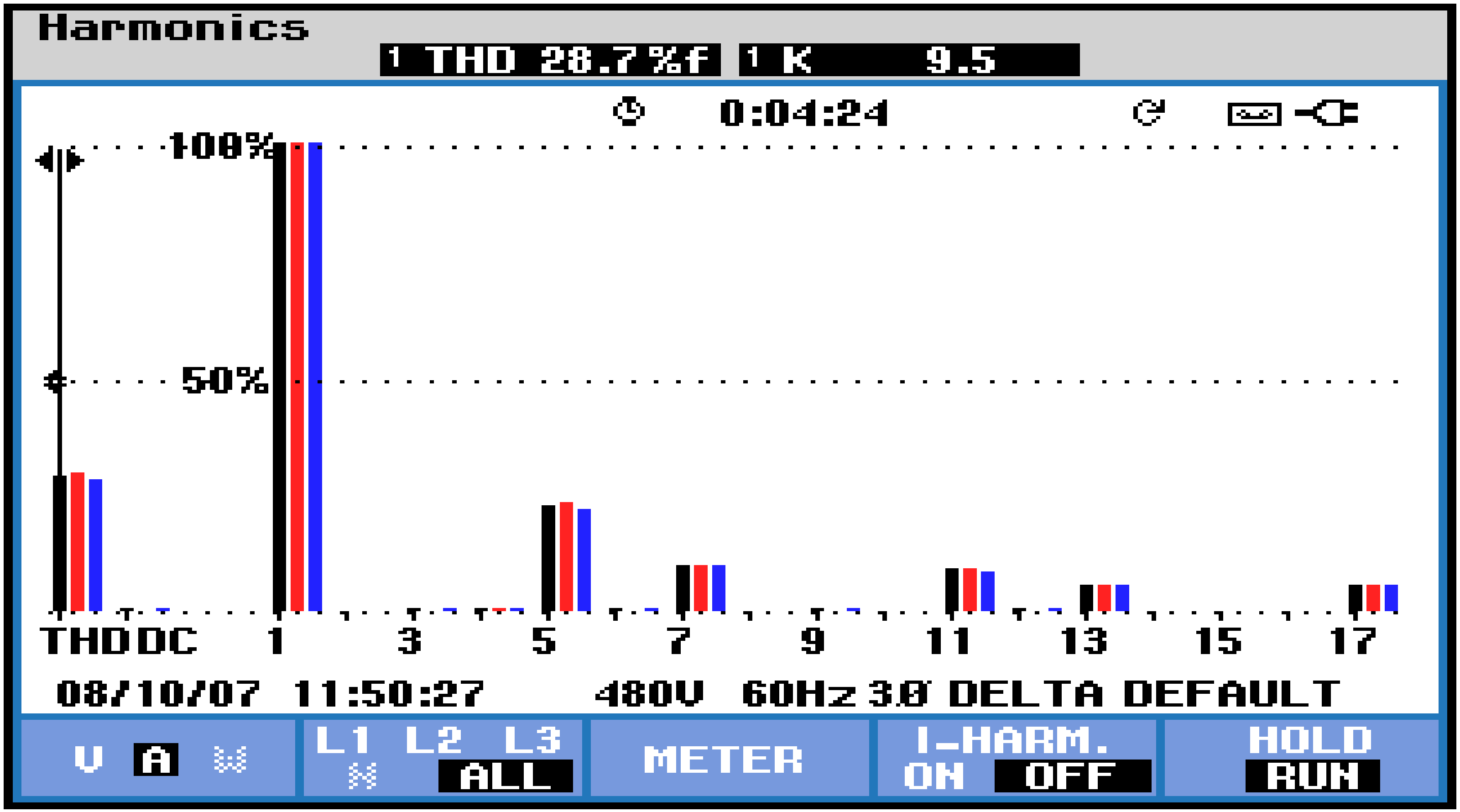


Unloaded

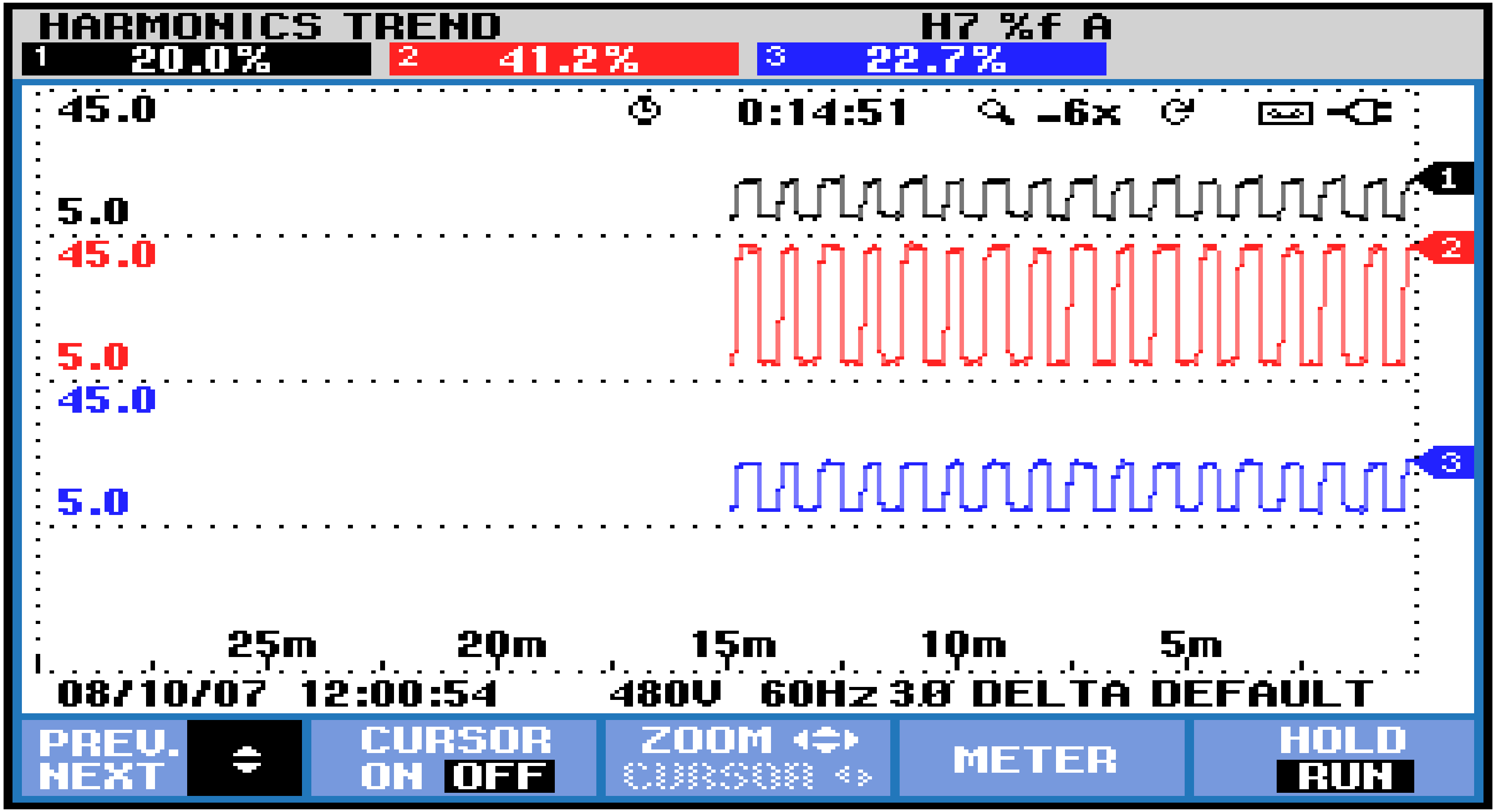


Harmonics
1 THD 44.8 %f
1 K 11.7
0:03:54
100%
50%
THD DC 1 3 5 7 9 11 13 15 17
08/10/07 11:49:57 480V 60Hz 3.0 DELTA DEFAULT
V A
L1 L2 L3
ALL
METER
I-HARM.
ON OFF
HOLD
RUN

Fully Loaded



7th Harmonic Current Distortion (420Hz)



Terms & Definitions

- Sinusoidal Wave Forms
- Power Quality
- Electrical Loads Types
- Harmonics
- RMS
- **Power Factor**

Utility Billing Parameters

- kW Thousand Watts
- kWh Thousand Watt hours
- kVA Thousand Volt Amps
- kVAR Thousand Volt Amps Reactive
- kVARH Thousand Volt Amps Reactive Hours*
- PF Power Factor

* No unit cost typically associated with this parameter. Used by utility to calculate PF.

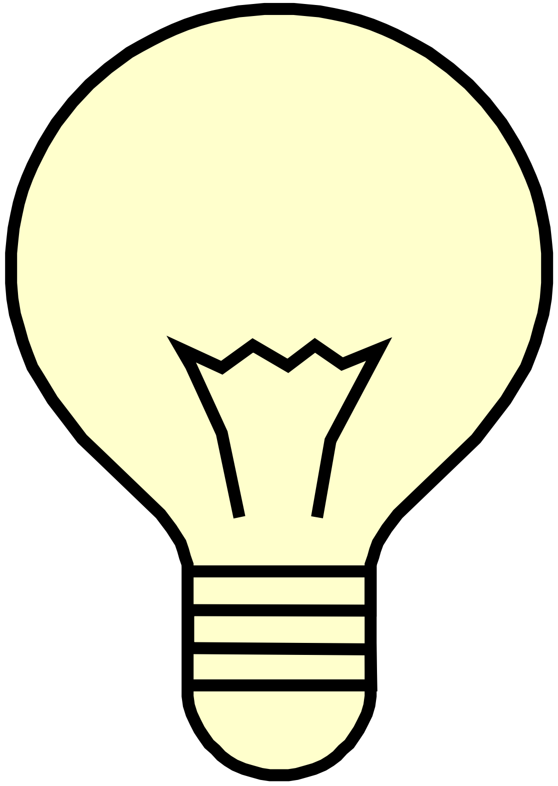
kW Kilowatts

- Working power (kW) to perform the actual work of creating light, heat, torque, etc.
- Measured on a wattmeter in kilowatts.

kW (Watts)
Working power

kWh Kilowatt-Hour

- Number of actual watts times the hours they do work



kVAR
Kilo-Volt Amperes Reactive

- Power required to sustain the magnetic field of an inductive load.
- Performs no useful work
- Circulates between the power supply and the load
- Measured by the utility as kVAR demand

Reactive Power

Power Factor Triangle

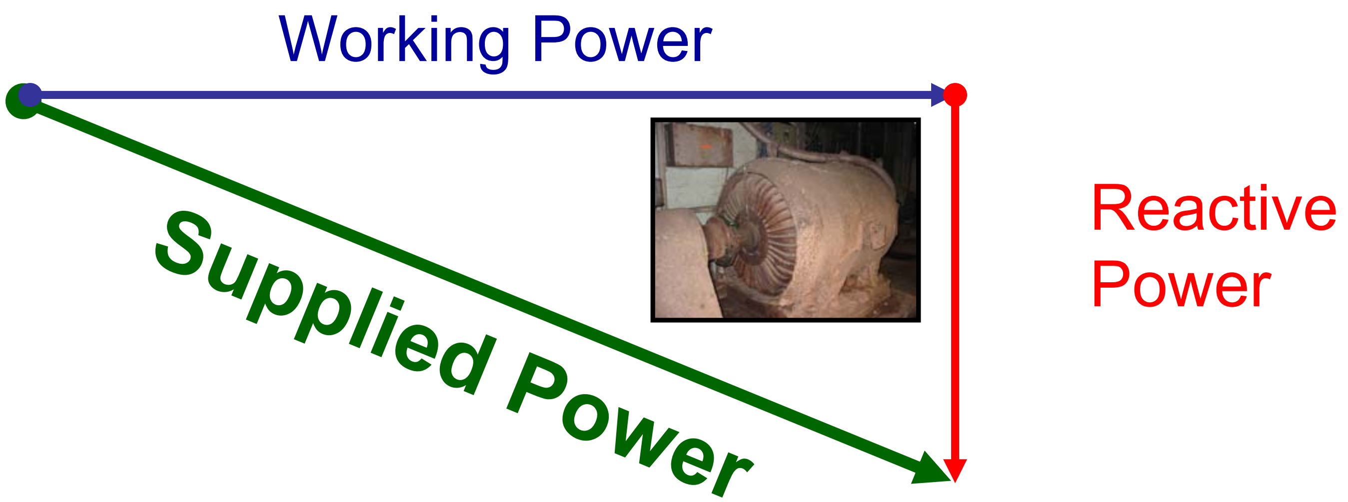
Working Power in *watts*

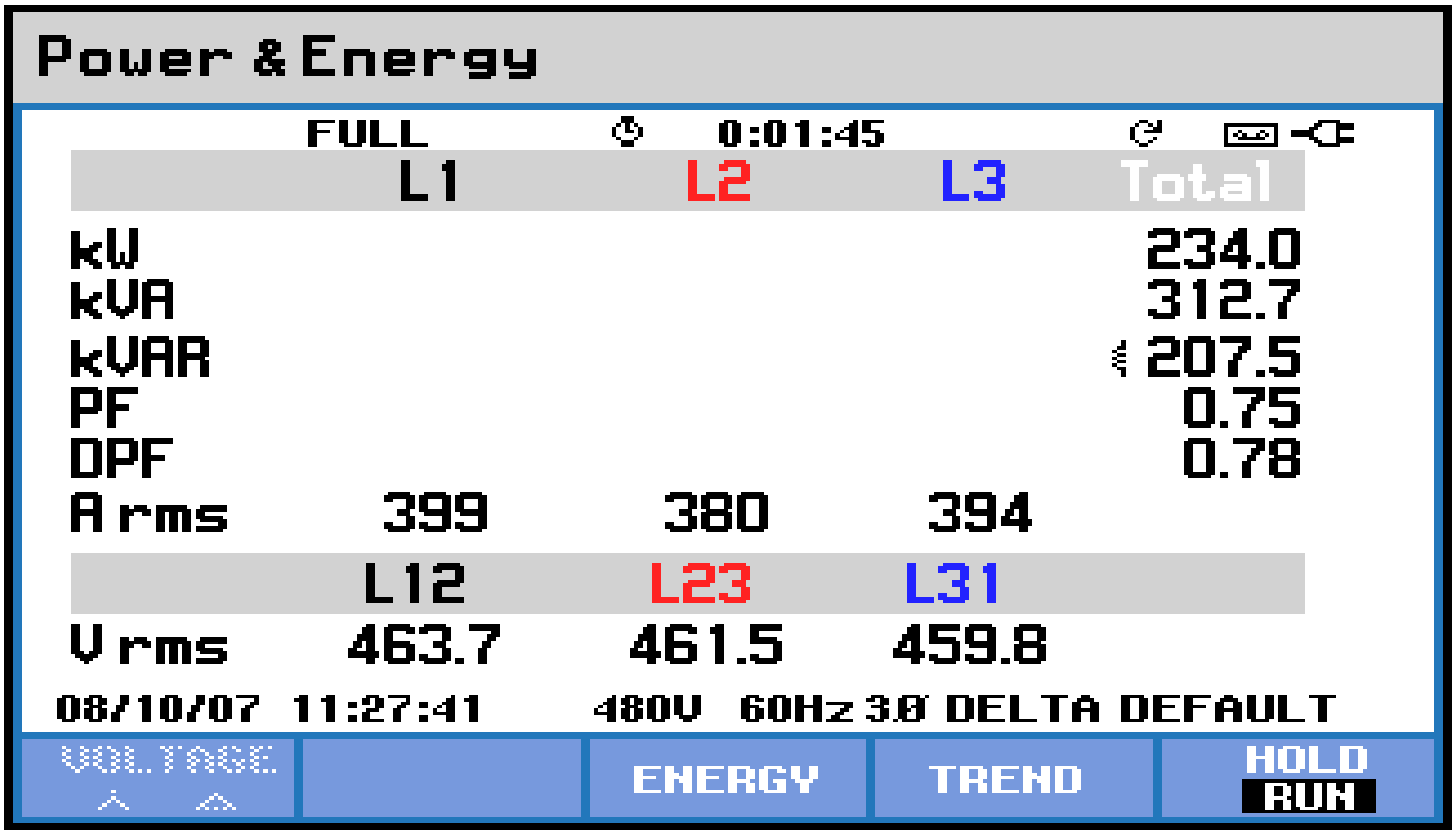
Reactive
Power in kVAR

kVA Kilovolt-Amperes

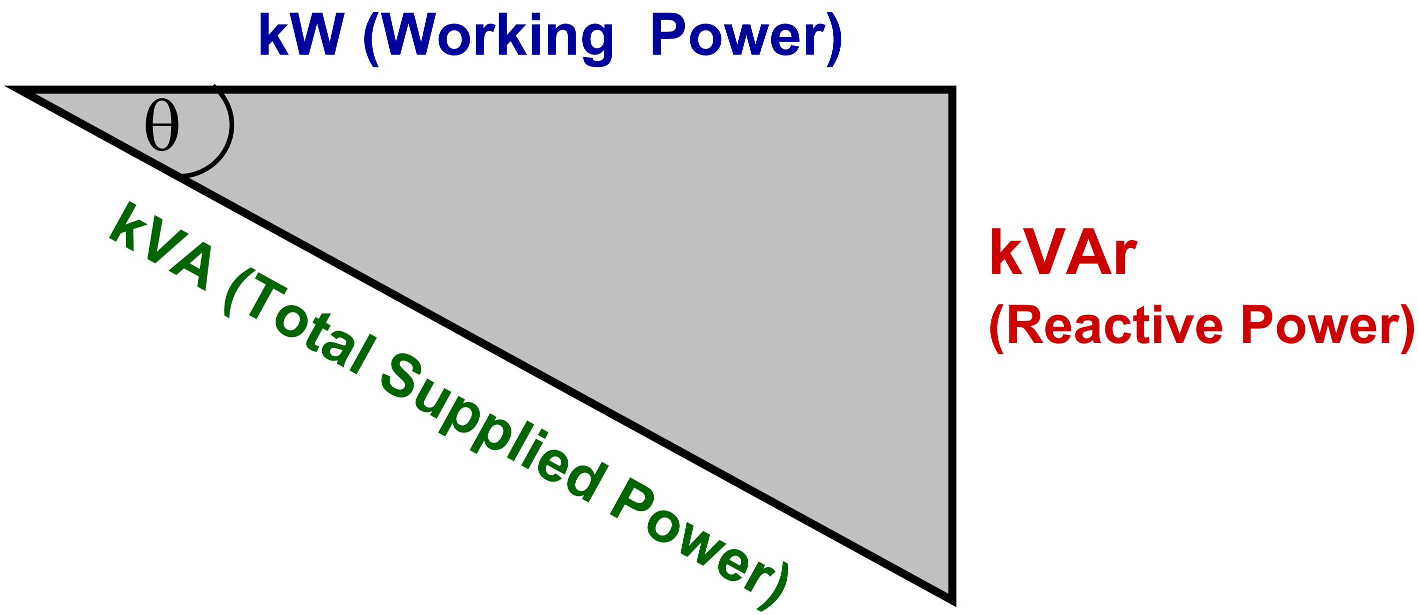
(Supplied Power)

- **Supplied Power (kVa)** is made up of working power (kW) and reactive power (kVAR).
- Measured in kilovolt-amperes (kVA)



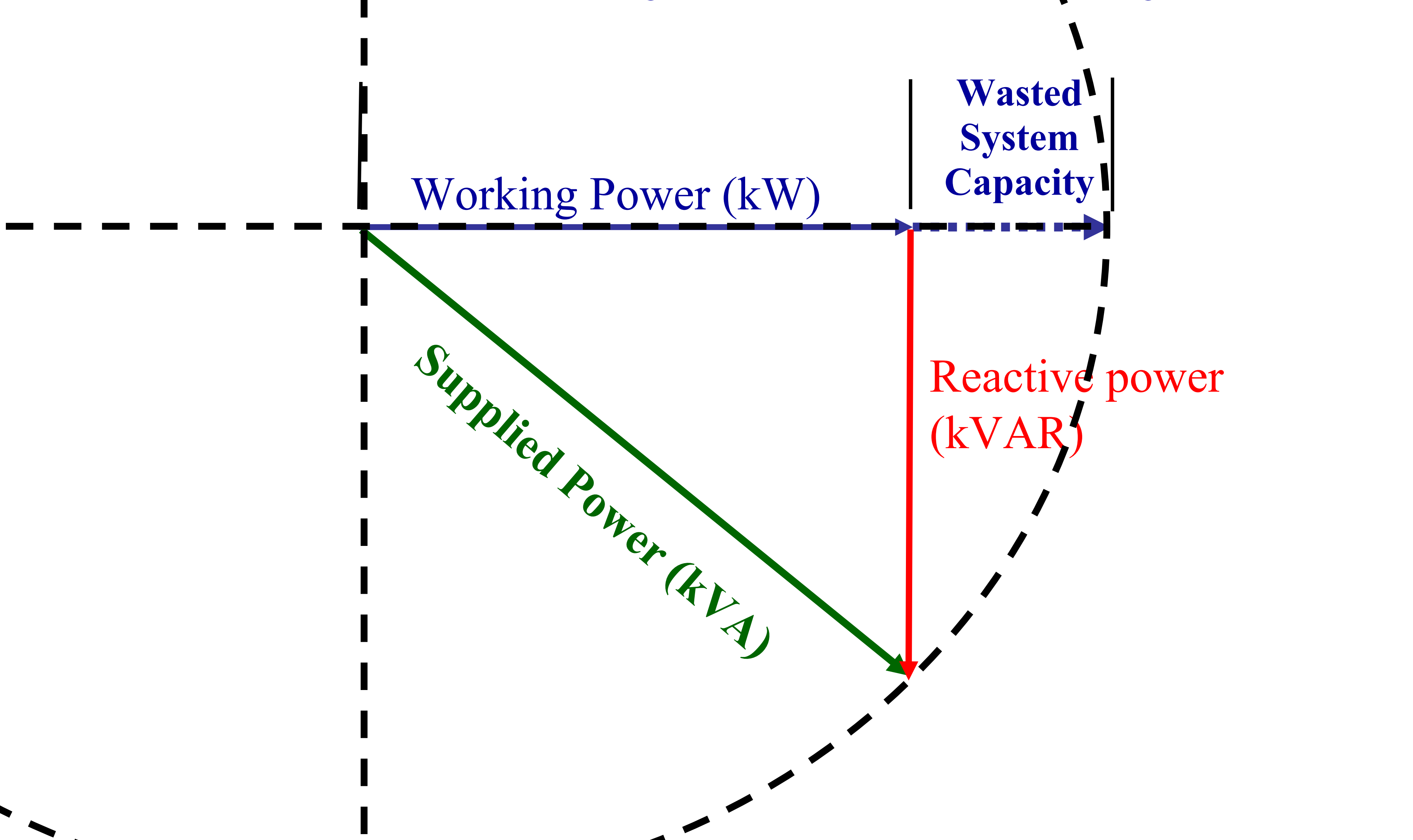

Power & Energy
FULL 0:01:45
L1 L2 L3 Total
kW 234.0
kVA 312.7
kVAR 207.5
PF 0.75
DPF 0.78
A rms 399 380 394
L12 L23 L31
V rms 463.7 461.5 459.8
08/10/07 11:27:41 480V 60Hz 3.Ø DELTA DEFAULT
VOLTAGE
ENERGY
TREND
HOLD
RUN

POWER FACTOR



$$\text{Power Factor} = \frac{\text{kW (working power)}}{\text{kVA (total supplied power)}}$$

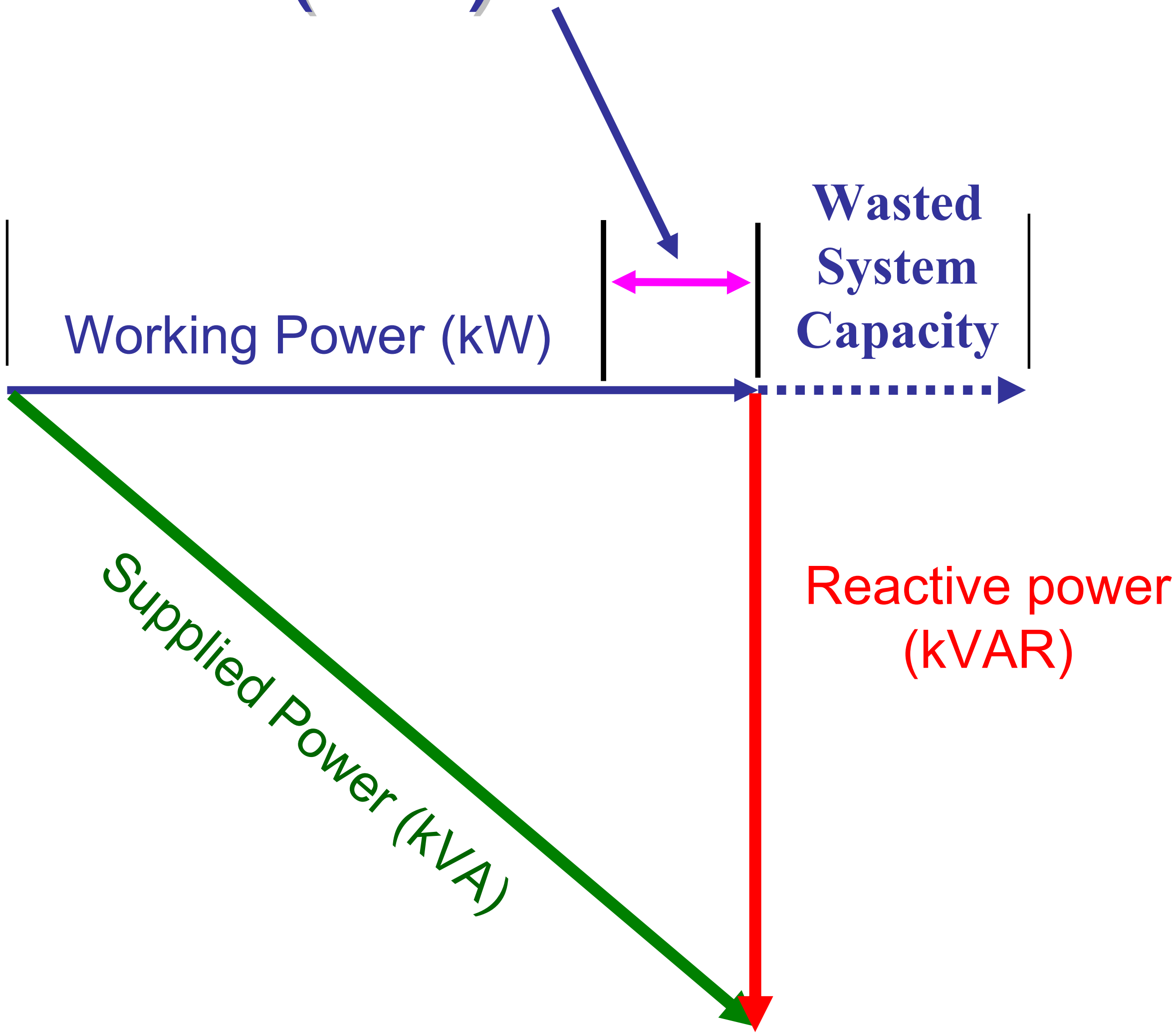
How Poor Power Factor Relates to Wasted System Capacity



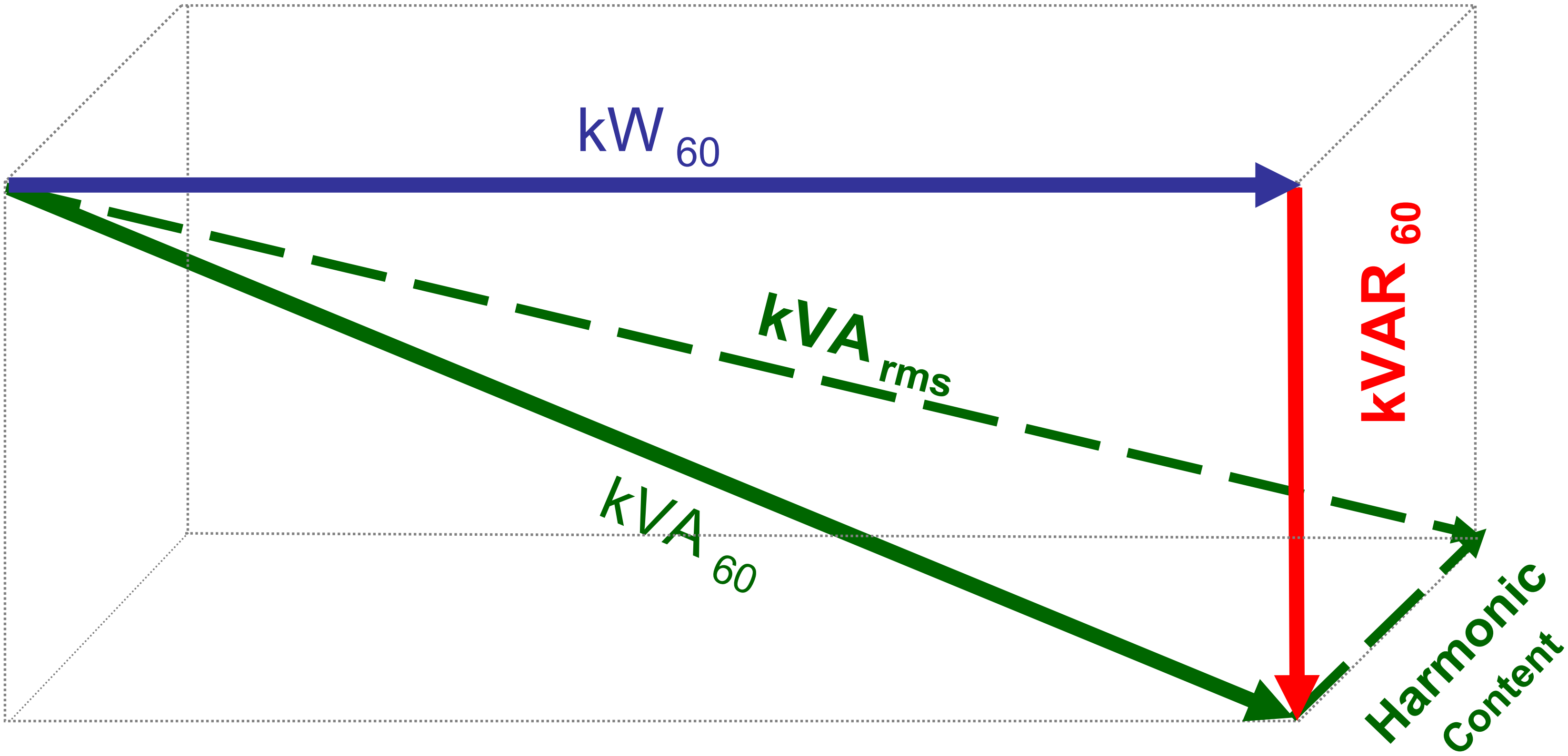
Simply Put !

- Poor Power Factor means more current is flowing through the electrical distribution system than is necessary to do the required work.

Line Loss (I^2R) = Watt Loss



Total Power Factor with Harmonics



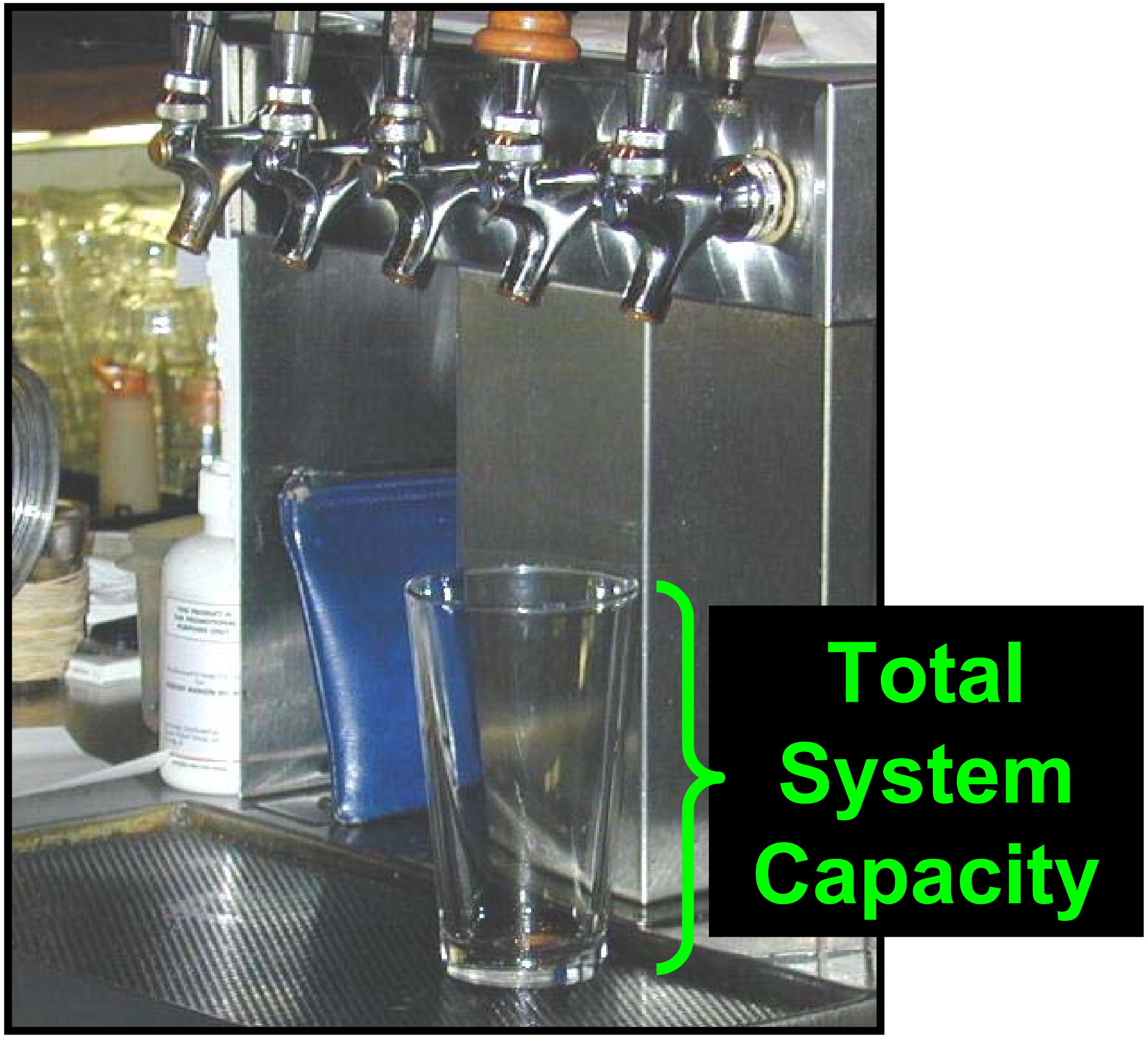
DISPLACEMENT PF = $kW_{60} \div kVA_{60} = 0.87$

TOTAL PF = $kW_{60} \div kVA_{rms} = 0.77$

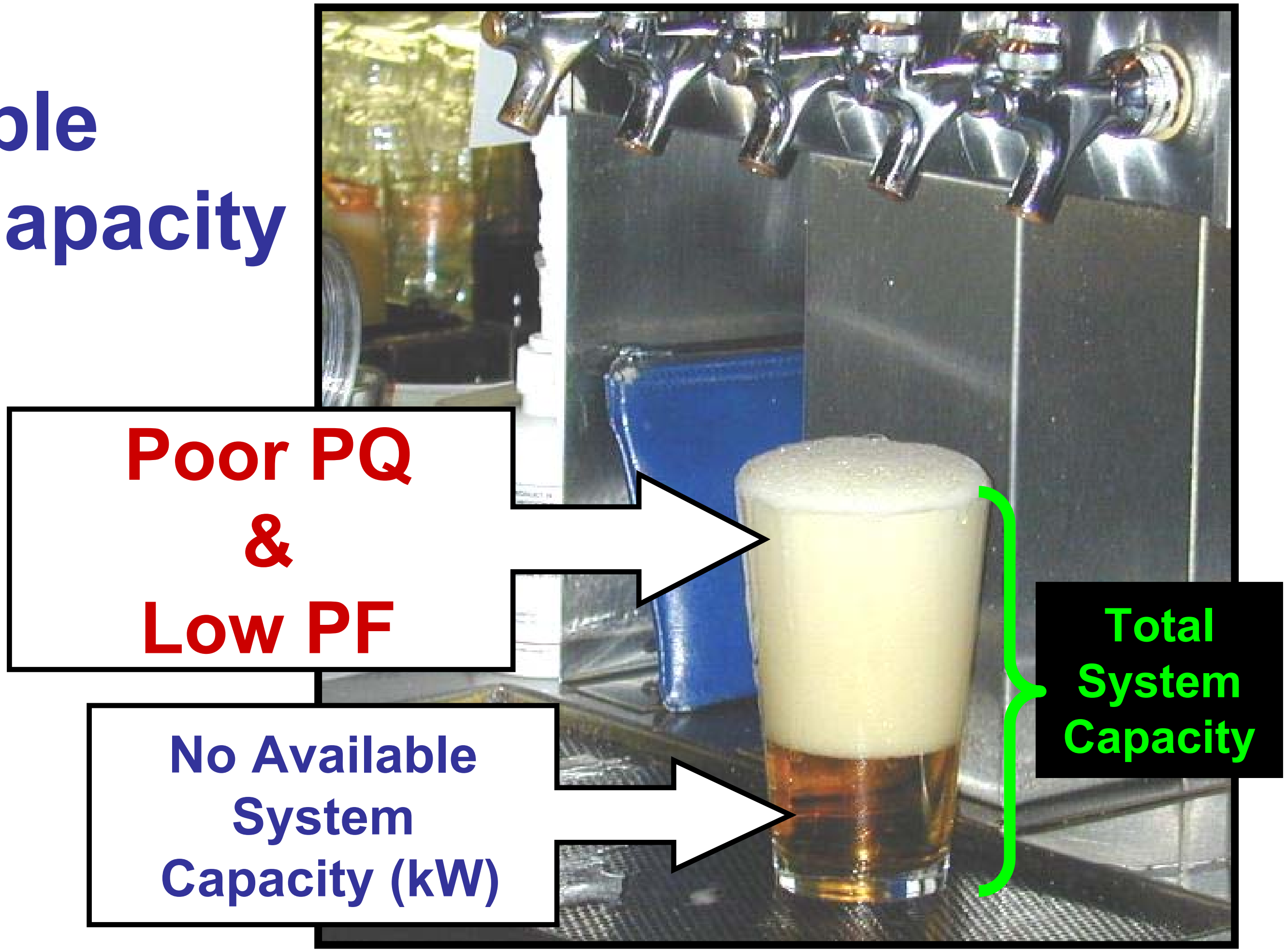
Poor Power Quality & Poor Power Factor

Putting it all together

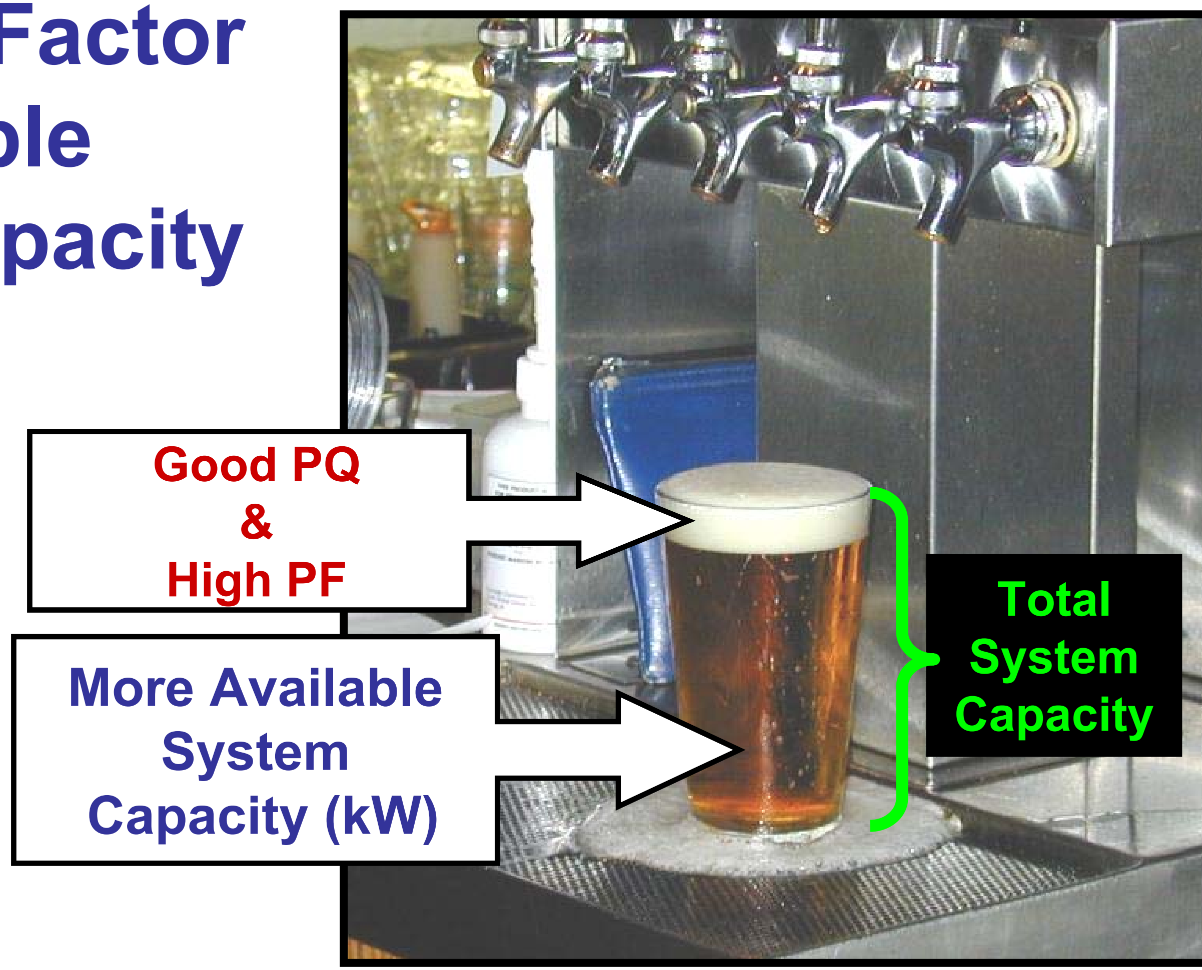
Unloaded Electrical System, Perhaps Your Transformer Capacity 1000 kVA



Poor Power Quality
Low PF
No Available System Capacity



Good Power Quality
High Power Factor
More Available System Capacity



How efficient is your system?

You can't control what you don't measure!

You can't capture ($ s) if you don't invest in expertise and equipment that pays you back!

CPI GROUP™
CONCISE POWER INTEGRATION GROUP
LIMITED

Applied Technologies

TMaG System™
Integrated Power Correction

PureMonics™
A DIVISION OF CPI GROUP LIMITED

Pure60™
Harmonic Mitigating Technology
Made in USA

Basic Steps Toward Improving Electrical Efficiency

- 12 Months Billing History
- Power & Energy Study
- Determine Load Ratio
- Power Quality Assessment
- Evaluate Data & Information
- Design a Comprehensive Strategy
- Select Appropriate Technology/Operational Adj.
- Life Cycle Cost Analysis
- Submit a Project Appropriation Request

Thank You!

CPI GROUP™
CONCISE POWER INTEGRATION GROUP
L I M I T E D

Phone : 216-525-0046

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Email: br@cpigroupltd.com

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