Looking at Your Power

Understanding Power Factor and Harmonics

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The Opportunity of House Bill 420

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Questions to Answer

- ✓ What is Power Factor?
- ✓ Why Should I Improve My Power Factor?
- ✓ How Do I Correct (Improve) My Power Factor?
- ✓ What Are the Benefits?
- ✓ What Are Harmonics?
- ✓ Where do Harmonics Come From?
- ✓ Do Harmonics Hurt the Operation?
- ✓ How Do We Fix Harmonic Issues?

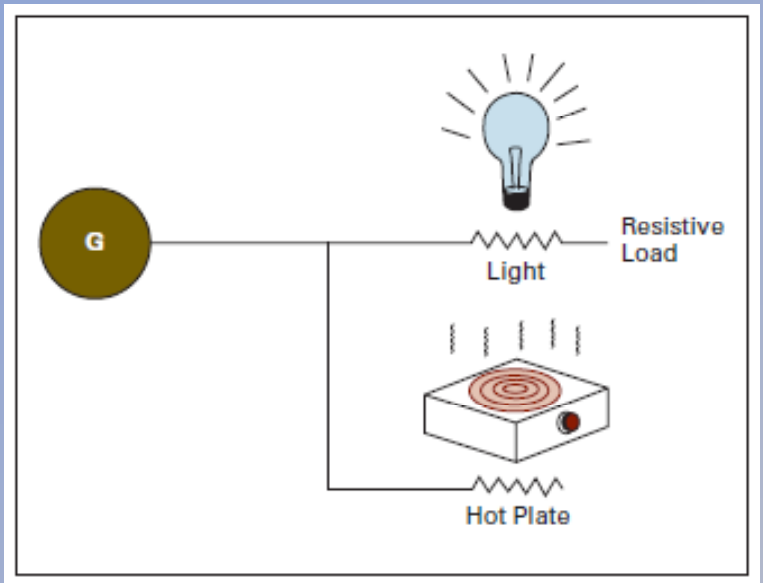
What Is Power Factor?

- ✓ Most loads in an electrical distribution system are inductive. (motors, transformers, lighting ballasts, induction furnaces)

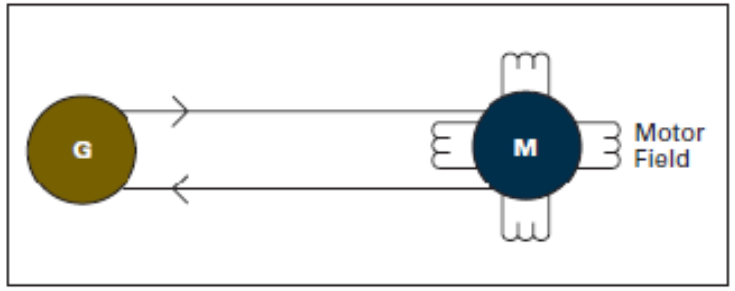
- ✓Inductive loads require two kinds of current:
  - ✓ Working power (kW) to perform the actual work of creating heat, light, motion, etc.
  - ✓ Reactive power (kvar) to sustain the magnetic field. This magnetic field is what makes motors spin.
  - ✓ Together the current generated by the working power (kW) and the current generated by the reactive power (kVAR) add together inside the motor to make the total current delivered to the motor.

- ✓ Working power and reactive power together make up “apparent power”.
  - ✓ This is seen as kilovolt – amperes (kVA).

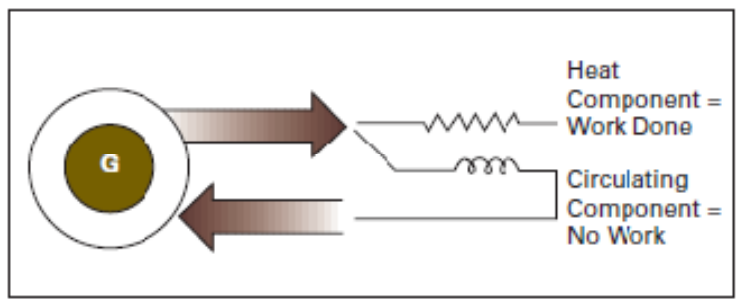
Examples of kW, kVAR, and kVA



kW Power – Figure 1

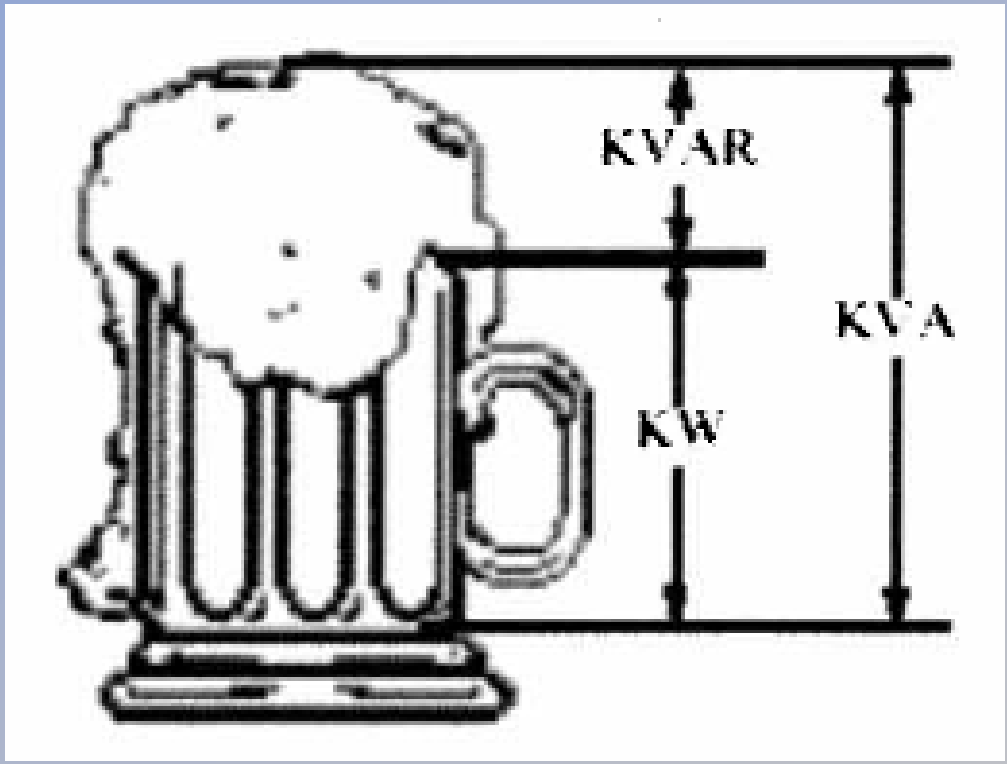


kVAR Power – Figure 2



kVA Power – Figure 3

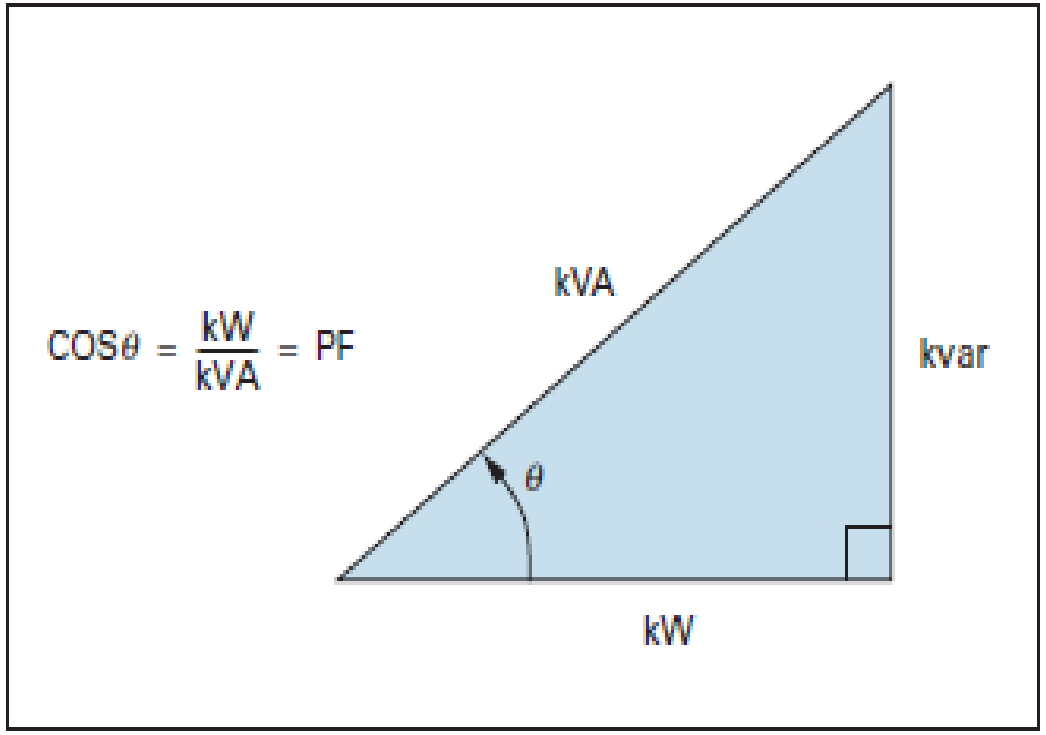
The Beer Analogy



The Beer Analogy – Figure 4

The Power Triangle

Power Factor - The ratio of the working power (kW) to the apparent power



The Power Triangle – Figure 5

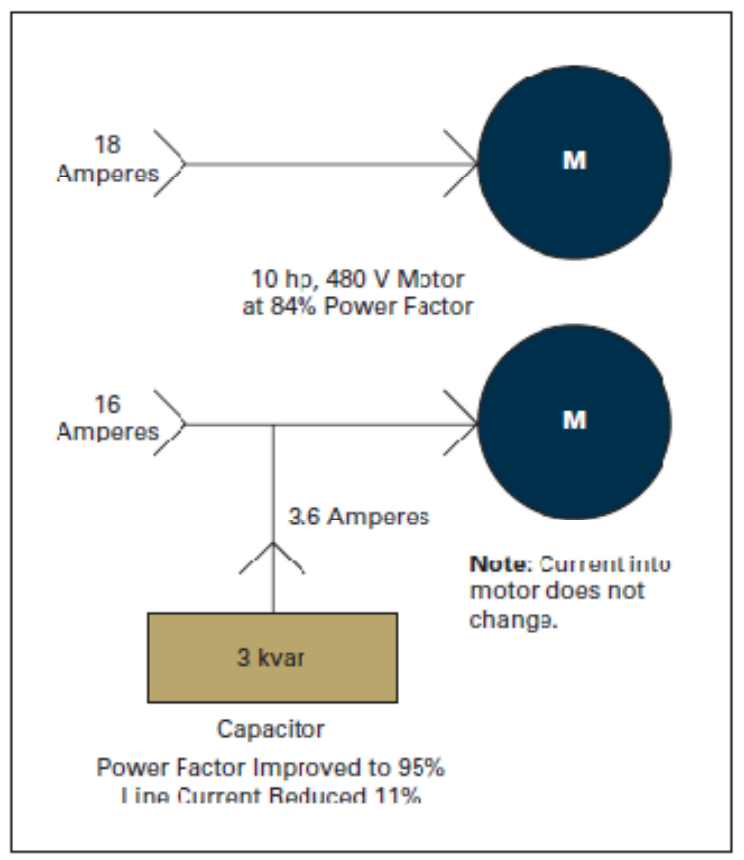
Why Should I Improve Power Factor?

- ✓ When apparent power (kVA) is greater than working power (kW) the utility must supply the excess reactive current plus the working current.
- ✓ The power company charges your facility for the kVA (demand) or power factor penalties.
- ✓ Your plant loses power capabilities because of the excess current needed.

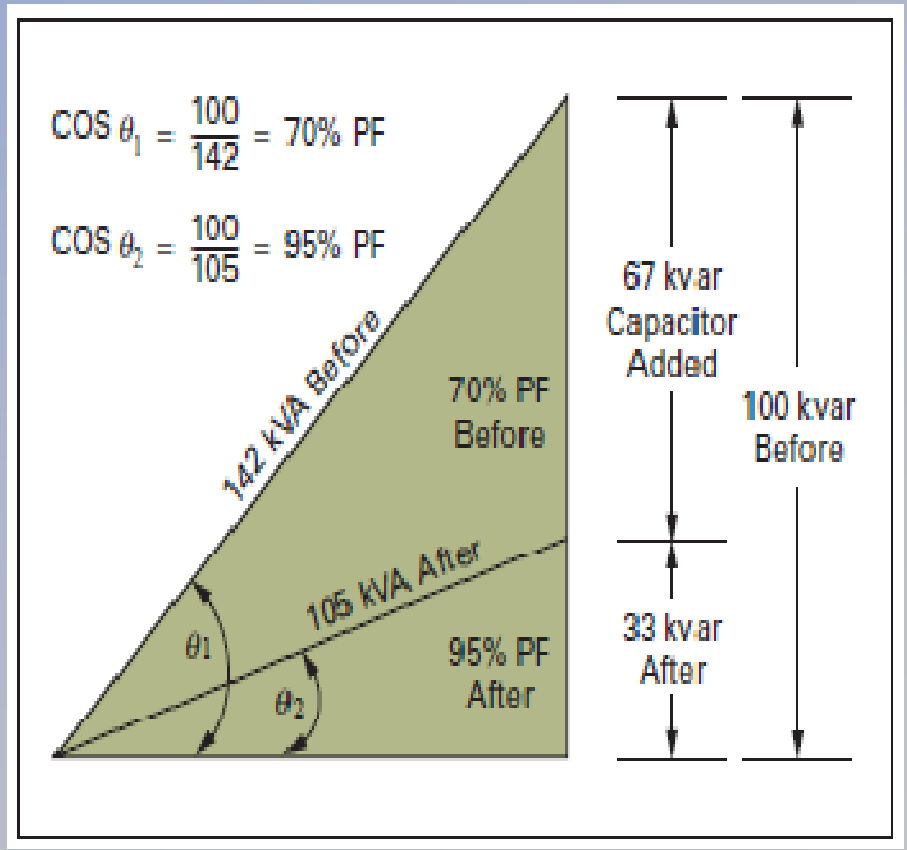
How Can I Improve Power Factor?

- ✓ Measure and monitor your motor's power. A data logger would typically measure and store voltage, amperage, kW, kVA, PF and kVAR.
- ✓ Utilizing the results from the data logger, size and install a "reactive current generator". This device is commonly referred to as a capacitor.
- ✓ Re-measure your motor's power data and see the results.
- ✓ Calculate the savings over the long-term based on average usage and utility rates.

Capacitor Systems Improve Power Factor

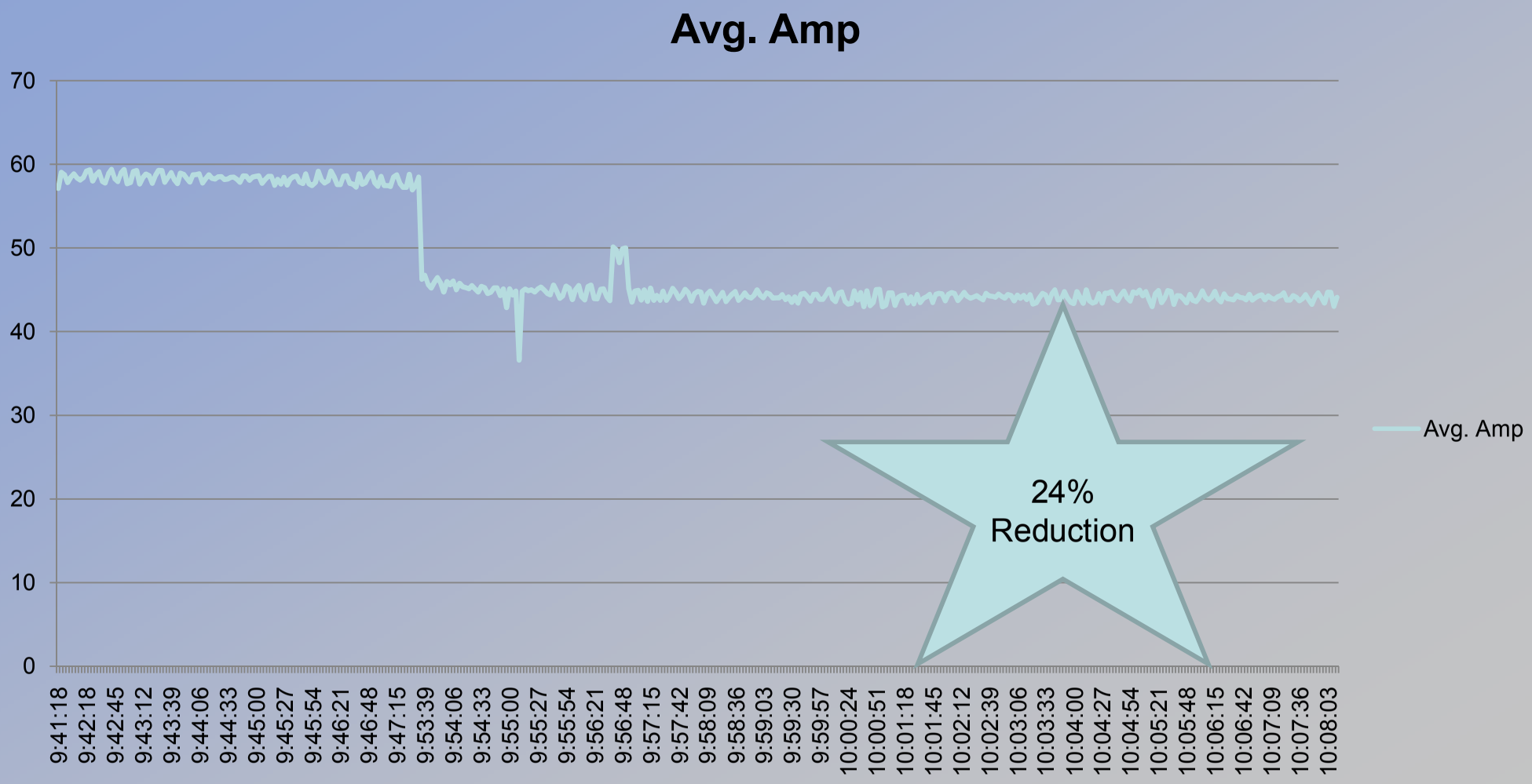


Capacitors as kVAR generators - Figure 9

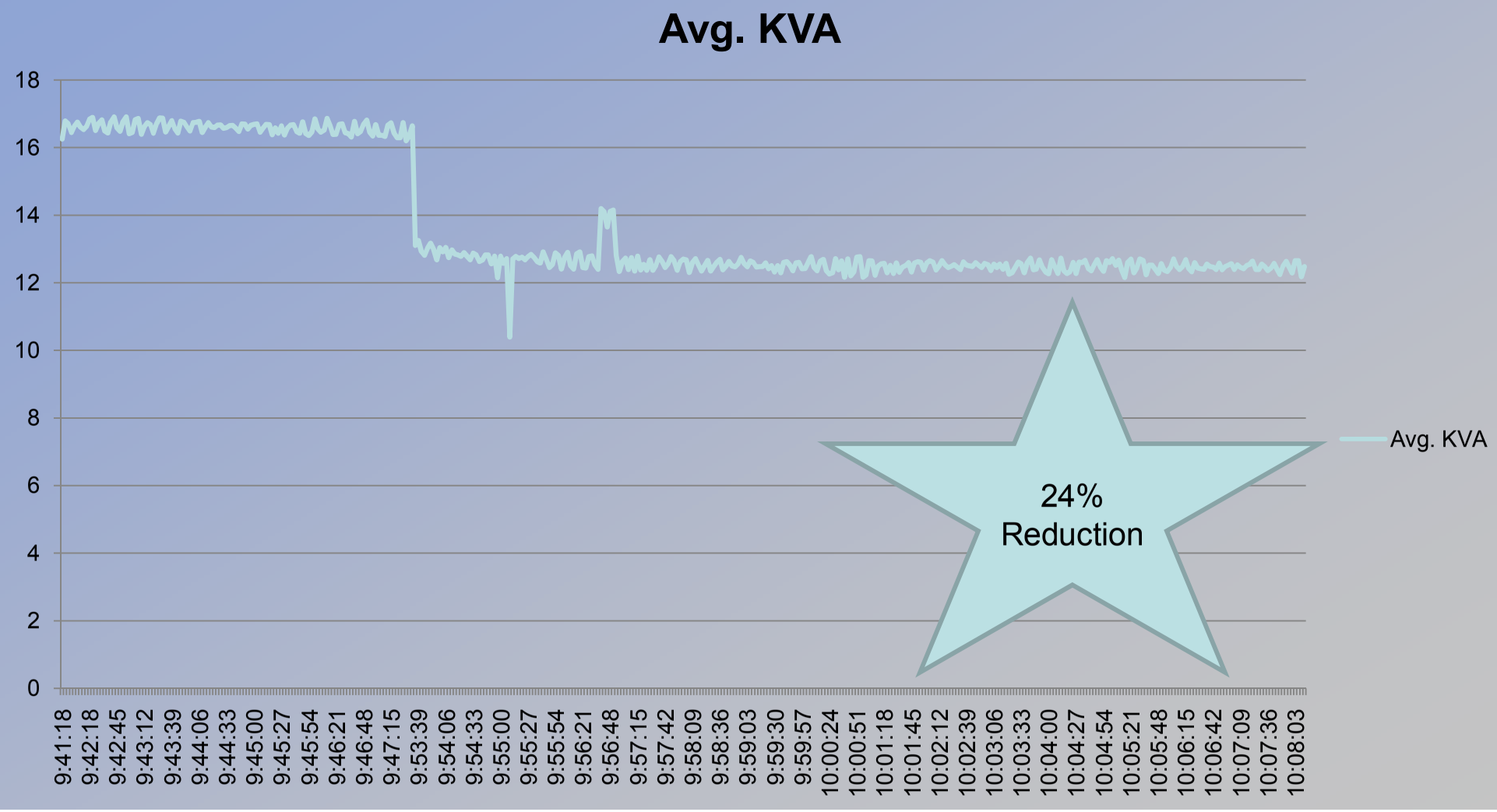


Required kVA before and after adding capacitors - Figure 10

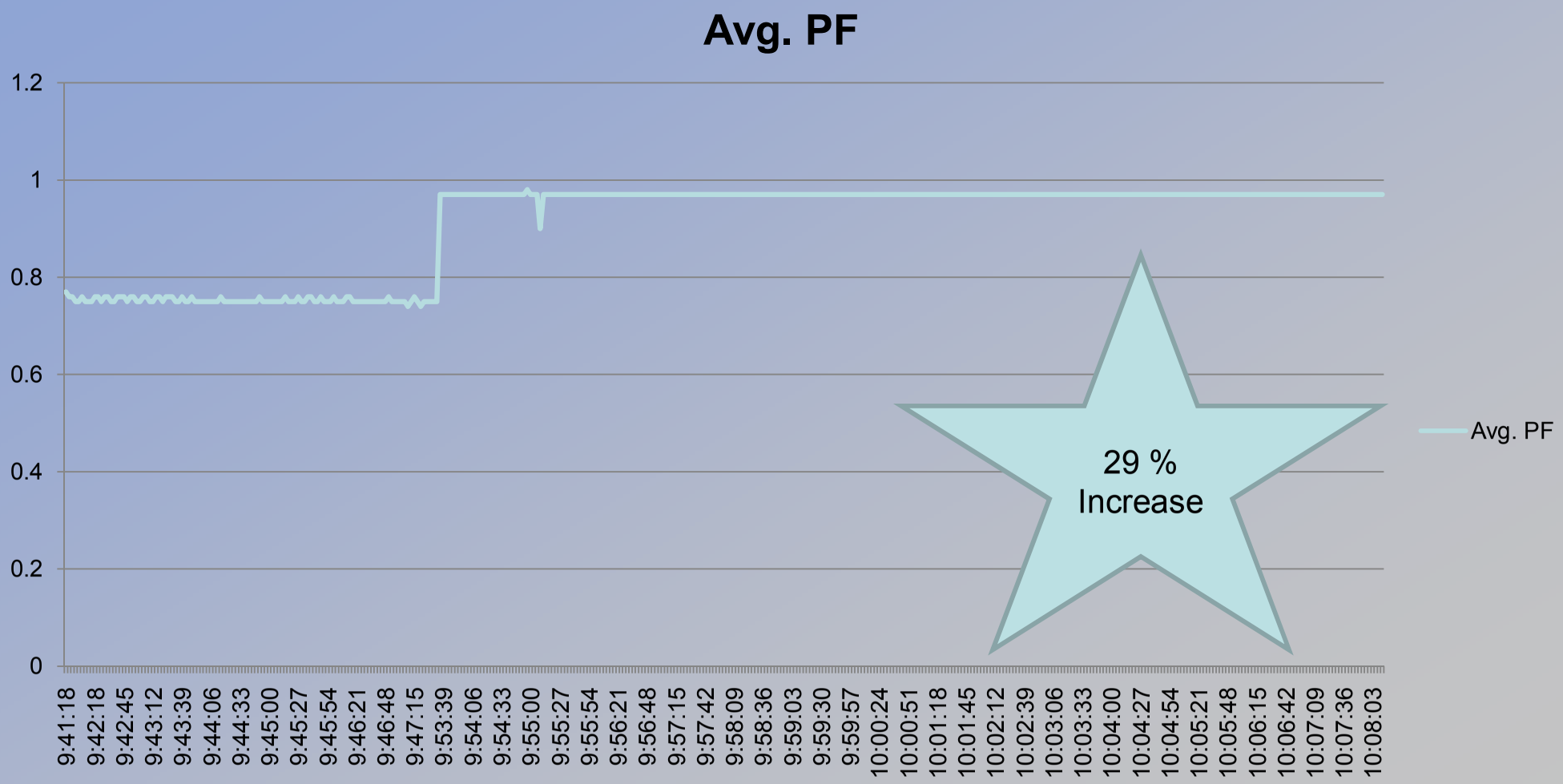
Example of Amperage Reduction – 20 HP



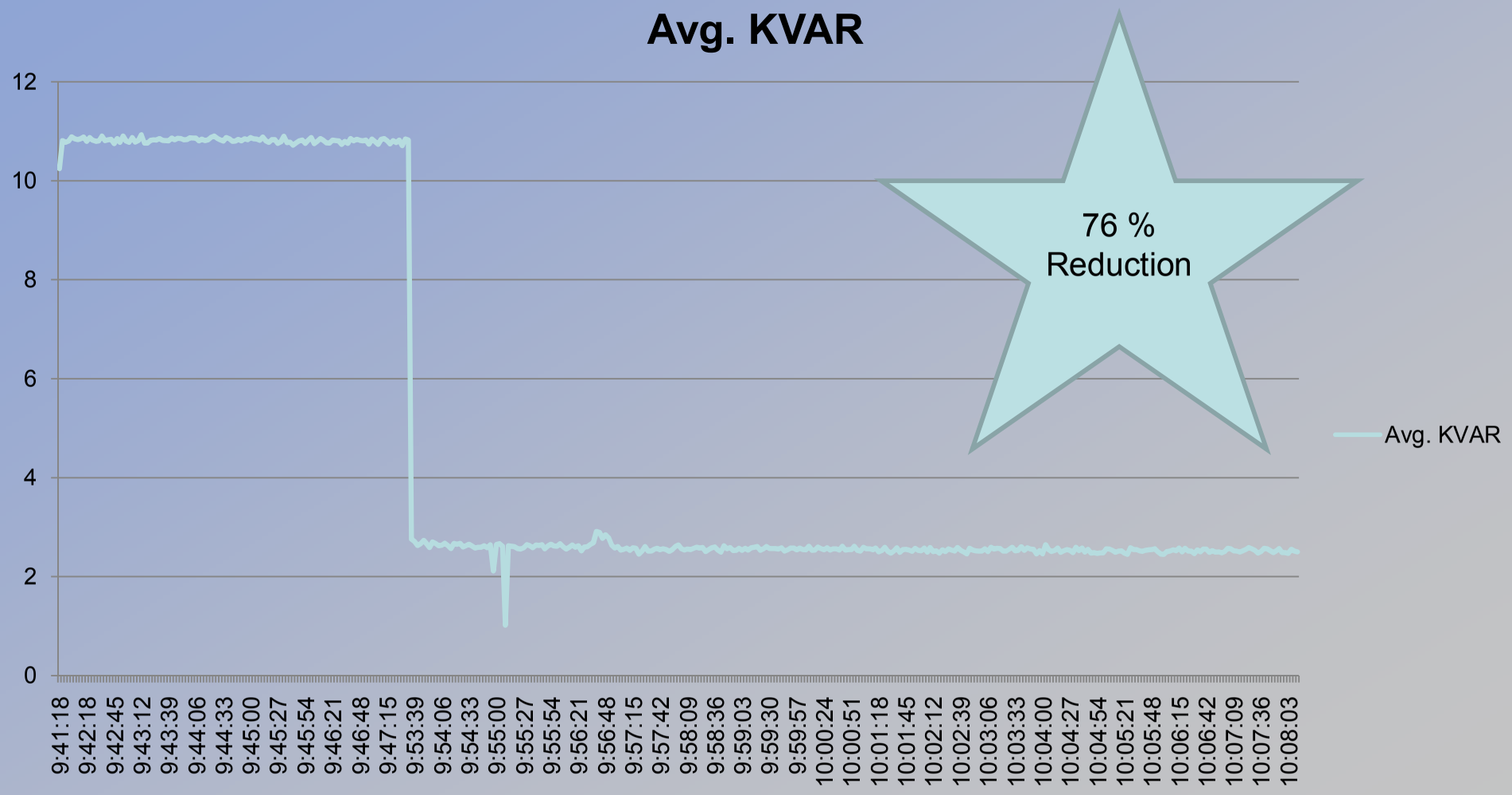
Example of KVA Reduction - 20 HP



Example of PF Increase – 20 HP



Example of kVAR Decrease – 20 HP



What Are the Benefits?

- ✓ Possible improvement in voltage drop in plant
- ✓ Cables and transformers in the facility are "less stressed".
- ✓ Real Cost Savings. The power company's charge to you will be reduced because you are reducing the reactive demand charge.

Savings and ROI Calculation – 20 HP

Before (Combined Phase Average)

	Volts	Amps	kW	kVA	PF	KVAR
Average	284	58.2	12.4	16.5	.75	10.8

Monthly Demand*	$249
Monthly Consumption**	$1104

After (Combined Phase Average)

	Volts	Amps	kW	kVA	PF	KVAR
Average	282	44.3	12.1	12.5	.97	2.5

Monthly Demand*	$189
Monthly Consumption**	$1077
Annual Demand Savings	$720
Annual Consumption Savings	$322
Annual Net Savings	$1042

*Assumes 100% uptime under constant load - $15.02/kVA Demand Charge

*Assumes 100% uptime under constant load - $0.07/kWh Consumption Charge
Calculated using (V*A*PF*1.73/1000*24 hours*30.41 days per month*kWh Rate)

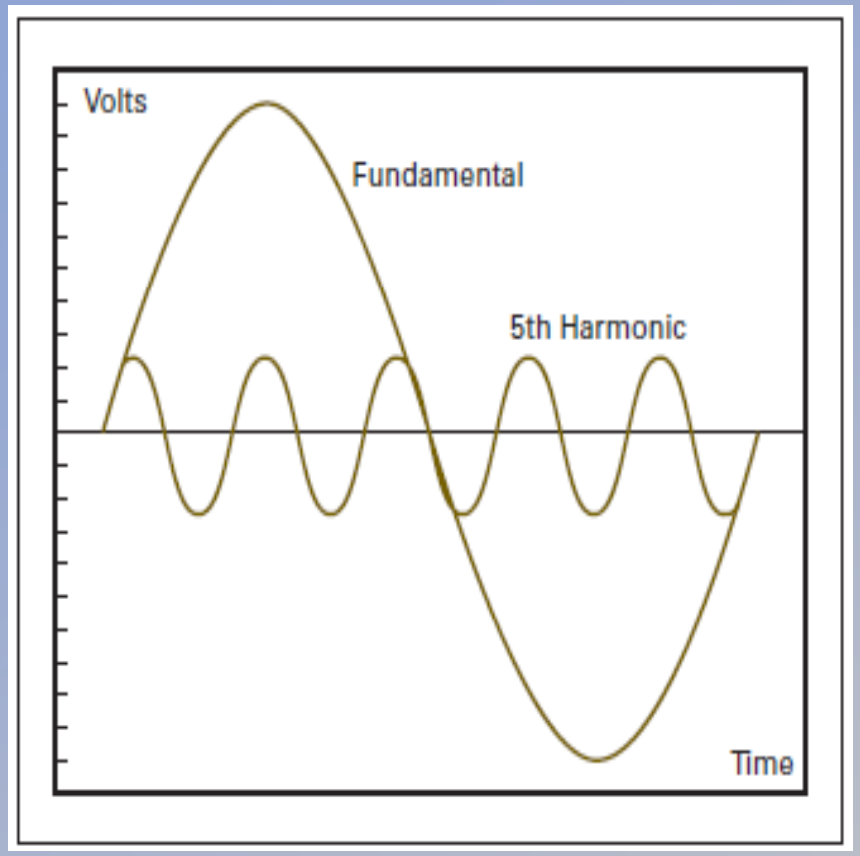
Estimated Installation Cost	Yearly Savings	ROI
$2395	$1042	27 months

What Are Harmonics?

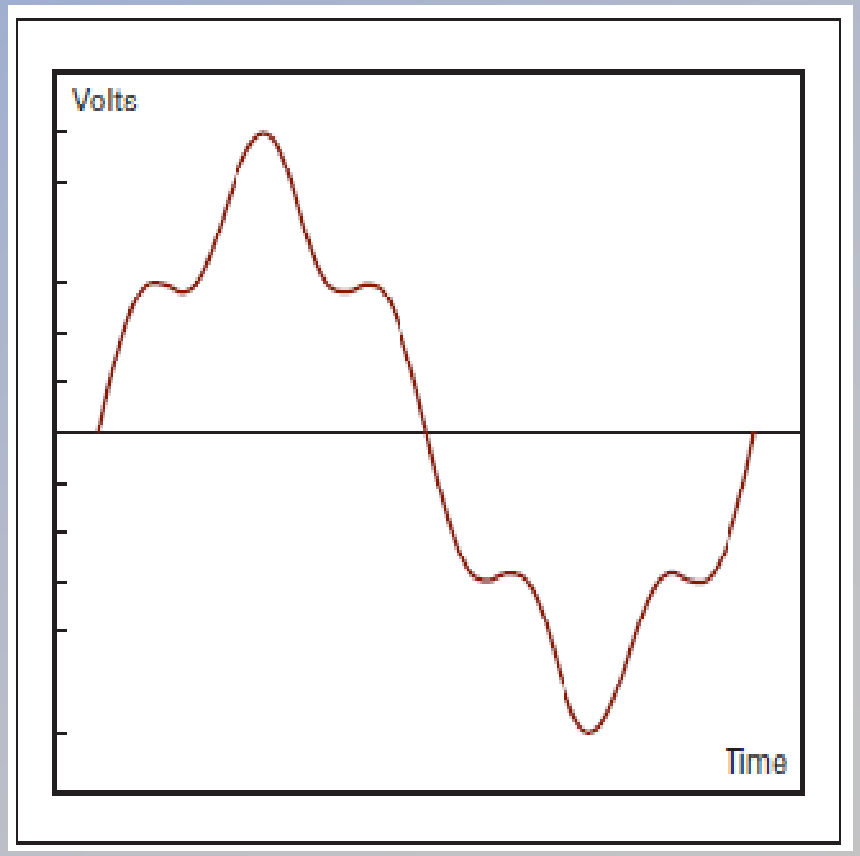
- ✓ A harmonic is a component of a periodic wave having a frequency that is an integral multiple of the fundamental power line frequency (60 Hz or cycles/sec).

The Effects of Harmonic Distortion

Figure 17 shows the resultant harmonic distortion of the waveform.



Fundamental and 5th harmonic – Figure 16



Fundamental and 5th harmonic combined – Figure 17

Where Do Harmonics Come From?

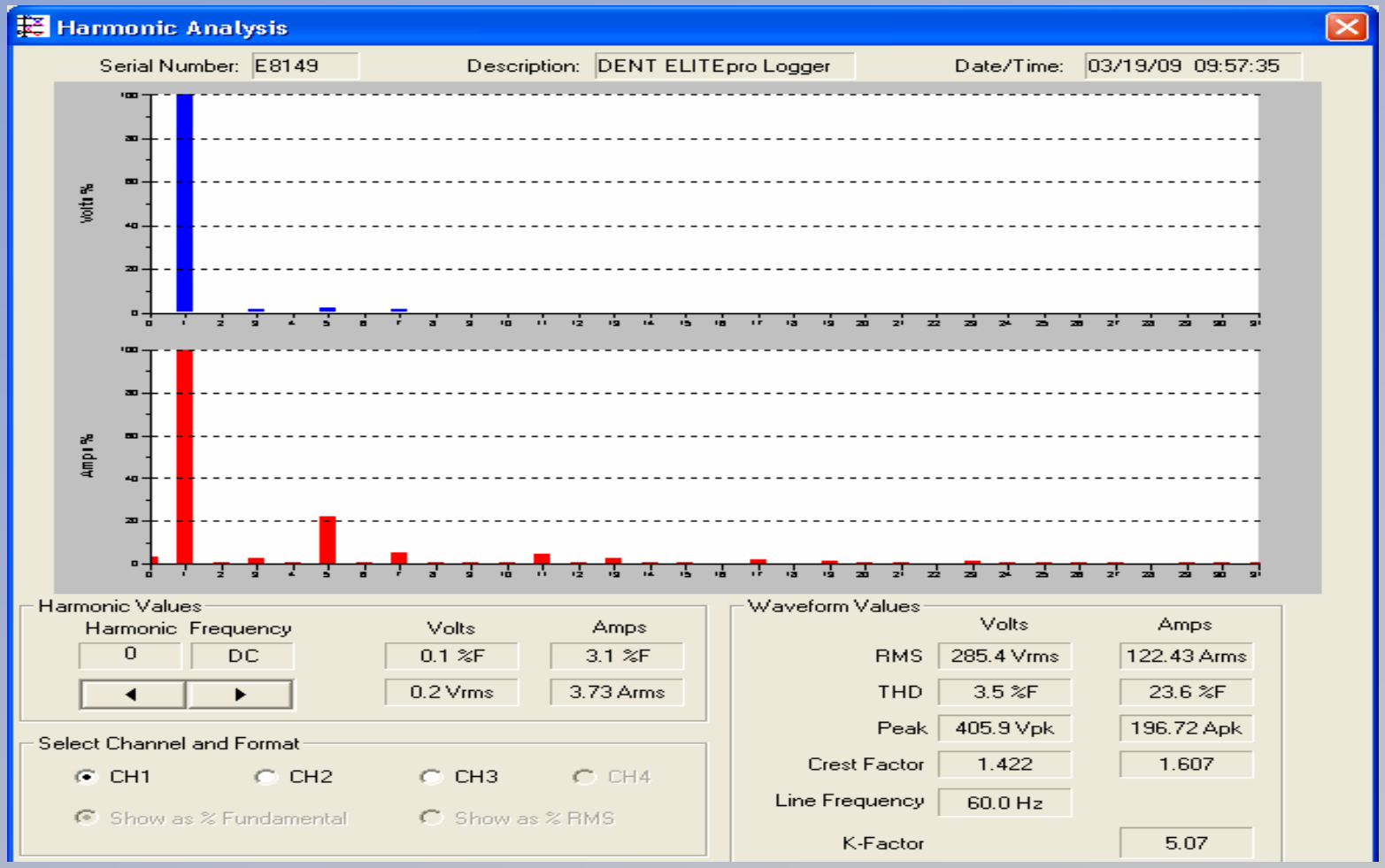
- ✓Harmonics can be generated by any of a variety of non-linear electrical devices.
  - ✓Examples are VFD's, other adjustable speed drives, power supplies and other devices using solid state switching, rectifiers, converters.
- ✓Arc furnaces and arc welders can also cause harmonics.

How Do Harmonics Impact Operations?

Equipment	Consequences
Current Harmonic Distortion Problems	
Capacitors	Blown fuses, reduced capacitor life
Motors	Reduced motor life, inability to fully load motor
Fuses/Breakers	False/spurious operation, damaged components
Transformers	Increased copper losses, reduced capacity
Voltage Harmonic Distortion Problems	
Transformers	Increased noise, possible insulation failure
Motors	Mechanical fatigue
Electronic Loads	Misoperation

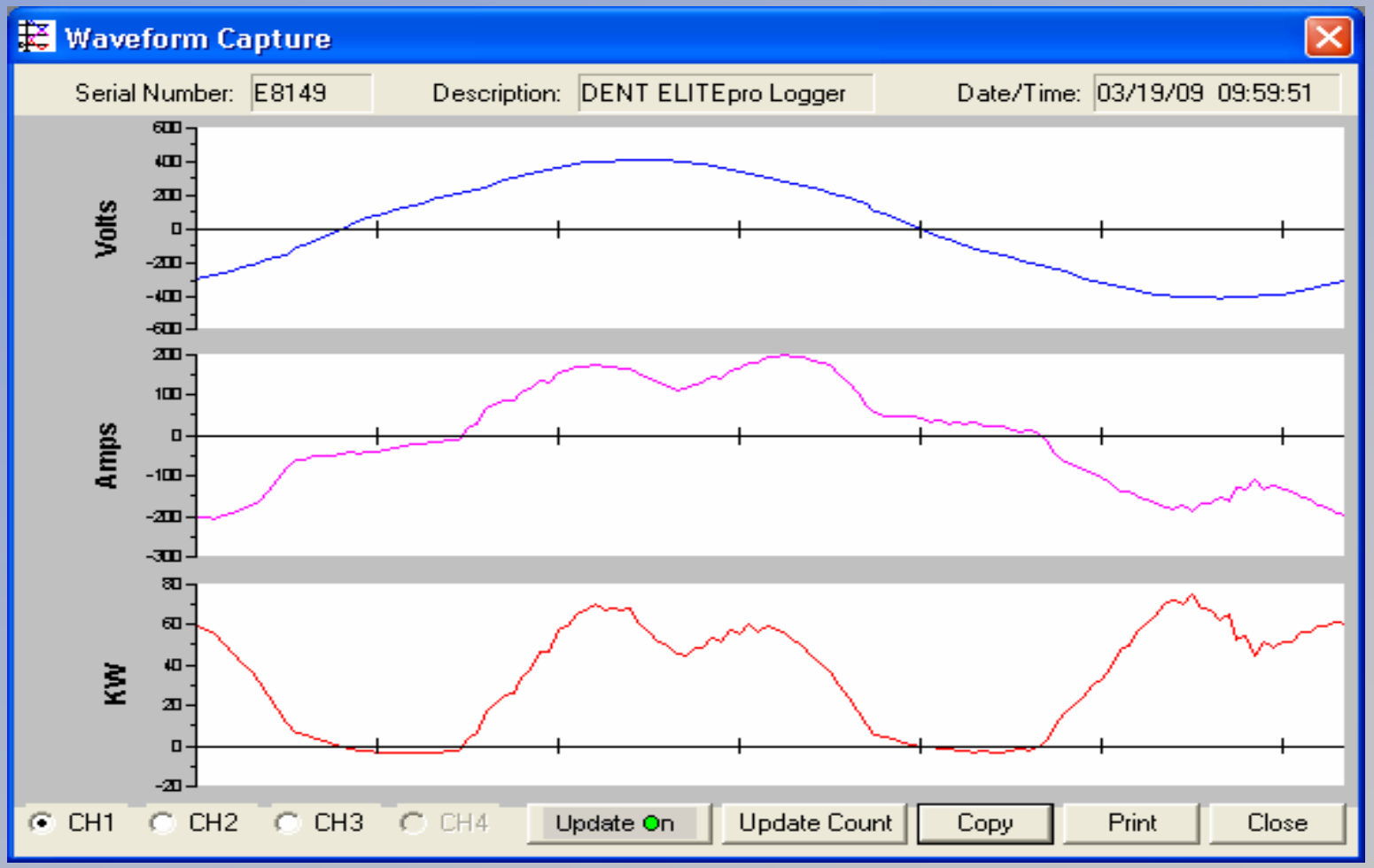
Negative consequence of Harmonics on plant equipment – Figure 18

Example - Harmonics in Power System



Example of a waste water treatment plant with harmonics in power system – Figure 19

Example - Harmonics in Power System



Example of waste water treatment plant with harmonics in power system – Figure 20

How Do You Fix Harmonics?

- ✓ Most good data logging devices have the capabilities to determine harmonics. The first step is to gather that data.

- ✓If harmonics are detected, you should retain an expert in the field to observe the operation, gather operating information and design a “tuned” filter or choke to correct the issue.

Questions?

Technical sources used:

- ✓Power System Engineering - Power Factor – The Basics
- ✓Open Book Project - Chapter 11 – Power Factor
- ✓Eaton – Power Factor Correction, A guide For the Plant Engineer
- ✓US Dept. of Energy – Energy Management for Motor Driven Systems

The Opportunity of House Bill 420

Patrick Smith – Vice President, Operations

What is House Bill 420?

- ✓ Amendment to Ohio Revised Code 717.02 to allow infrastructure construction related to energy savings for municipalities, as well as other publicly-funded institutions.

- ✓ Publicly-funded agencies can now finance energy retrofit projects through the issuance of bonds based on the projected savings over a specified period of time

What is an Energy Retrofit?

- ✓ "The construction of, installation or modification of an installation in, or remodeling of, a new or existing building or infrastructure, to reduce energy consumption."

Why Was it Passed?

- ✓ Energy conservation has become a top issue
  - ✓ Stimulus Bill allotted significant funds to energy sector
- ✓ Funding for these programs are often cost-prohibitive for publicly-funded agencies
- ✓ HB 420 creates a vehicle to finance energy conservation programs through the savings generated

Who Qualifies?

- ✓ Municipalities
- ✓ Counties
- ✓ Townships
- ✓ School Systems
- ✓ Universities
- ✓ Local Government Agencies
- ✓ State Government Agencies

What are the Requirements?

- ✓ Program is initiated through an architect, PE, energy services company, or contractor experienced in the design and implementation of energy conservation measures
- ✓ Competitive bidding can be avoided if owner asks for 3 proposals after appropriate advertisement (once per week for two weeks)
- ✓ Owner can then select “the most qualified vendor” for the project offering the “lowest and best bid or bid most likely to result in greatest energy savings”
- ✓ Program must be certified by a PE that the energy conservation report used reasonable methods and analysis and estimation
- ✓ Municipality may then issue tax-exempt bonds to finance the retrofit
- ✓ Amortization is extended up to 30 YEARS

What Types of Programs Qualify?

- ✓ ANY initiative that can demonstrate sustainable and quantifiable energy savings over a period of time.
  - ✓ HVAC – high-efficiency heating/cooling systems, heat recovery
  - ✓ Electric conservation technology –PF correction (e.g., capacitors), induction / CF lighting, occupancy sensors
  - ✓ LED parking lot lighting
  - ✓ Smart metering technology
  - ✓ Building efficiency – Replacement of exterior doors, roof, insulation, weather-stripping and caulking
  - ✓ Cogeneration systems producing heat or electricity
  - ✓ Water conservation systems – low flow faucets, toilets, etc.

How Does This Benefit My Operations?

- ✓ Converts a capital expense to a long-term debt
- ✓ Significantly reduces upfront cash outlays and/or interest costs of financing
- ✓ “Pay Only for Performance” – energy savings offset monthly payments
- ✓ Enables owners to package several energy initiatives into one financial program

How Can I Get Started?

- ✓ Determine if HB420 will benefit your facility
- ✓ Create a team and get buy-in internally
- ✓ Identify key areas for savings – electric, water, gas, facilities
- ✓ Quantify the costs and related savings through energy retrofit programs, get certification of savings estimates through a PE
- ✓ Help is available – independent energy audit firms take a holistic approach to a facility