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## **IHEEM 2008**

**Energy Saving  
Using Variable Speed Drives  
&  
Energy Efficient Motors**

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# Project Overview

- Imperial College Healthcare NHS Trust

Including:-

- Charing Cross Hospital (42Motors)
- Hammersmith Hospital (27Motors)



- Project Initiated. 2006
- Implementation /Completion. 2007

# Air Movement & Fluid Control Methods

## ■ Traditionally Method

Throttling to regulate flows of air or fluid.

Throttling reduces the flow. However, the motor is still running at full speed and works even harder as it has to work against resistance.

## ■ Modern Method

Reduce the speed of the motor using Variable Speed Drive (VSD). Ensures no more energy than necessary is used to achieve the required flow.

# Motor Starting Techniques

- Direct On-Line.
- Star-Delta.
- Soft-Starter.
- Rotor Resistance.
- Variable Speed Drive (Frequency Control).

# Motor Relationship

## Speed and Energy Consumption

- Centrifugal Pump or Fan Running at Half Speed Consumes One-Eighth of the Energy Compared to Motor running at Full Speed.
- The Torque Needed to Run a Pump or Fan is the Square of the Volume.
- Example:- Reducing the pump speed to 80% only requires 64% of the torque.

# Energy Efficient Motors Classification and Labelling System

- Typical Squirrel Cage Motor      85% Approx
- EFFI Motor      93% Approx

- Note

Manufacturers offer motors manufactured to exceed EFF1 motors at higher costs.

# High Efficiency Motors How?

- Increased Copper: Reduces power losses.
- Precision Air Gap: Reduces stray load losses.
- Larger Rotor Bars: Reduces resistance.
- Improved Fan Operation: Lower noise level.
- Higher Grade Steel Laminations: Reduces magnetising  $\omega I_n \phi$
- V-Ring: Reduces mechanical losses.

# High Efficiency Motors

## • The Benefits

- High Efficiency
  - A) Superior Performance.
  - B) Lower Energy Consumption.
  - C) Longer Operating Life.
  - D) Low Losses.
  - E) Low Noise.
  - F) Reduced Pully and Belt Replacements.

# Variable Speed Drives Control Interfaces

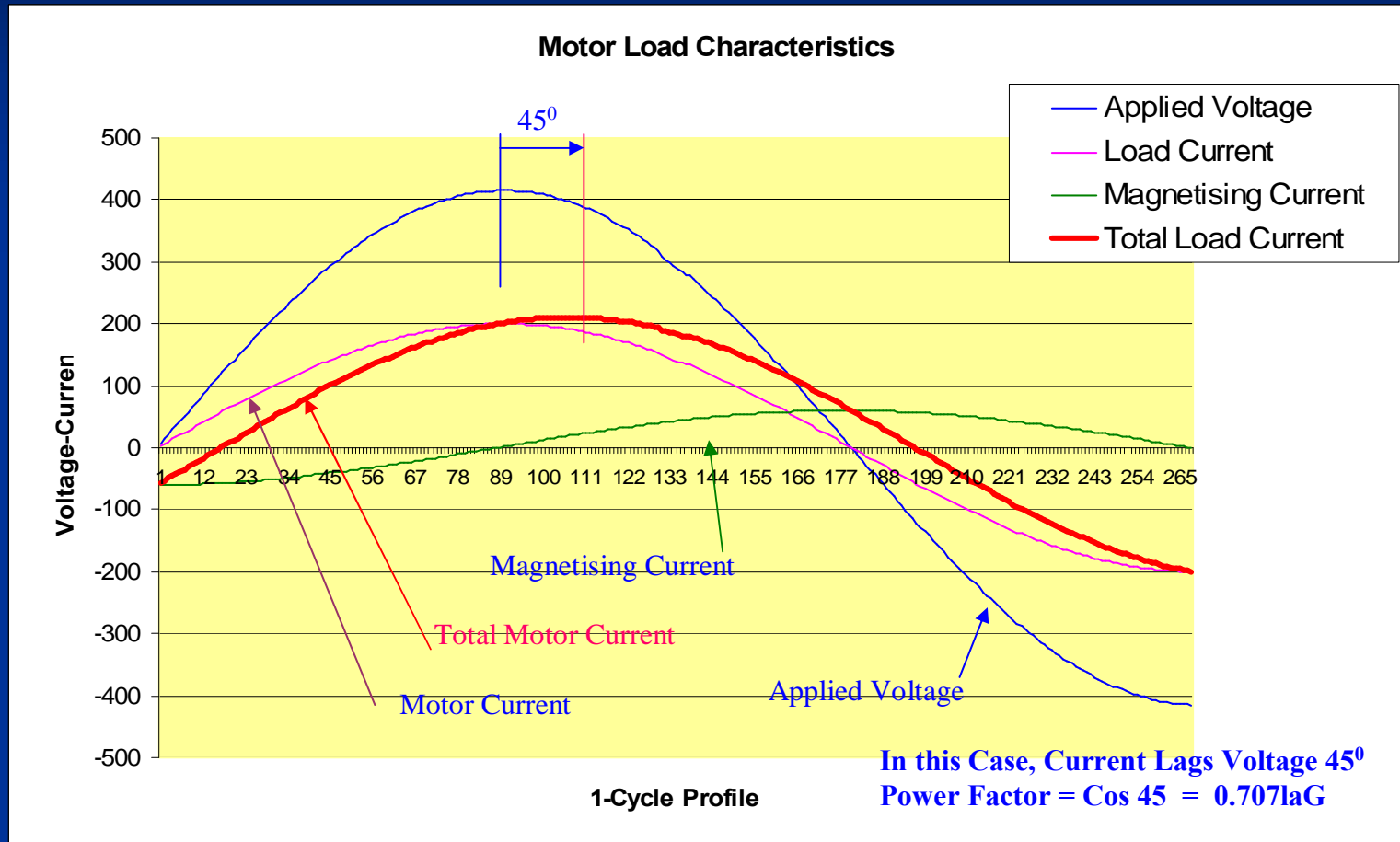
- BMS Interfaces (Typical Requirements)
  
- Standard four hard-wired I/O connections
  - a) Start/Stop signal.
  - b) Analogue 0-10V input for speed control.
  - c) Fault relay output.
  - d) Speed feedback.

# Motors & Power Factor

- **Power Factor**  
**Power.** Defined as the ratio of the Active (True or Real) Power to Apparent.
- **Active (Real or True) Power** Measured in watts (W)  
Power drawn by the electrical system that does useful work.
- **Apparent Power** Measured in Volt-Amperes  
Voltage multiplied by all current flows in the Circuit.
- **Reactive Power:-** Measured in Volt-Amperes Reactive (VAR). Reactive Power is the power stored in and discharged by inductive motors.

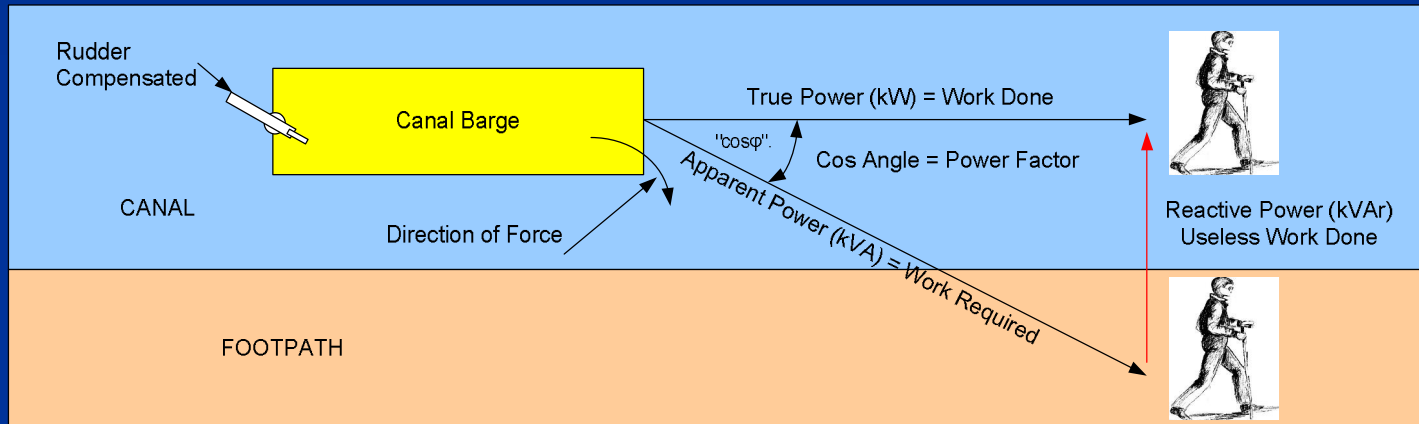
# Motor Load

## Voltage & Current Characteristics



# Power Factor

## A Layman's Analogy

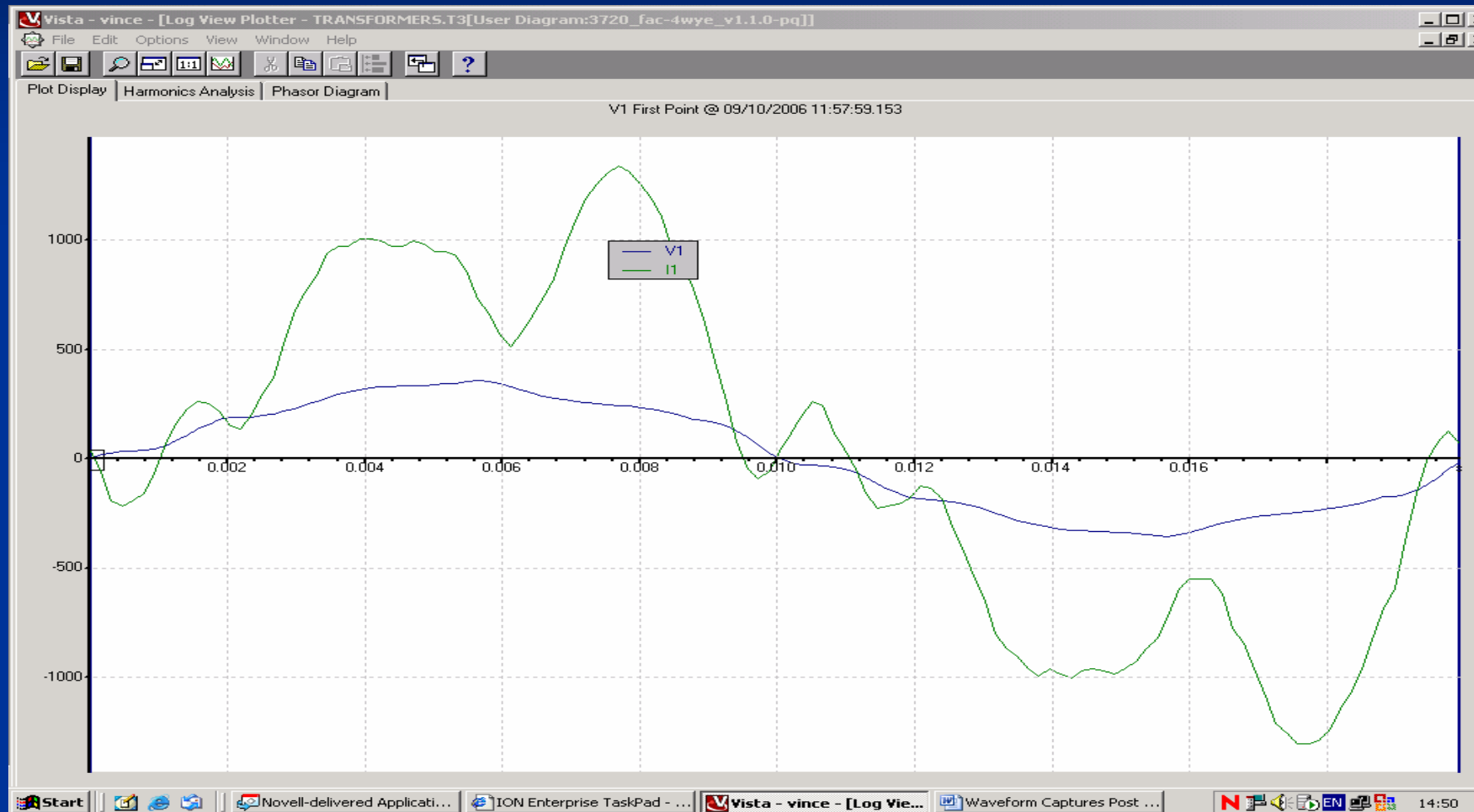


$$\text{Power Factor} = \frac{\text{True Power (kW)}}{\text{Apparent Power (kVA)}}$$

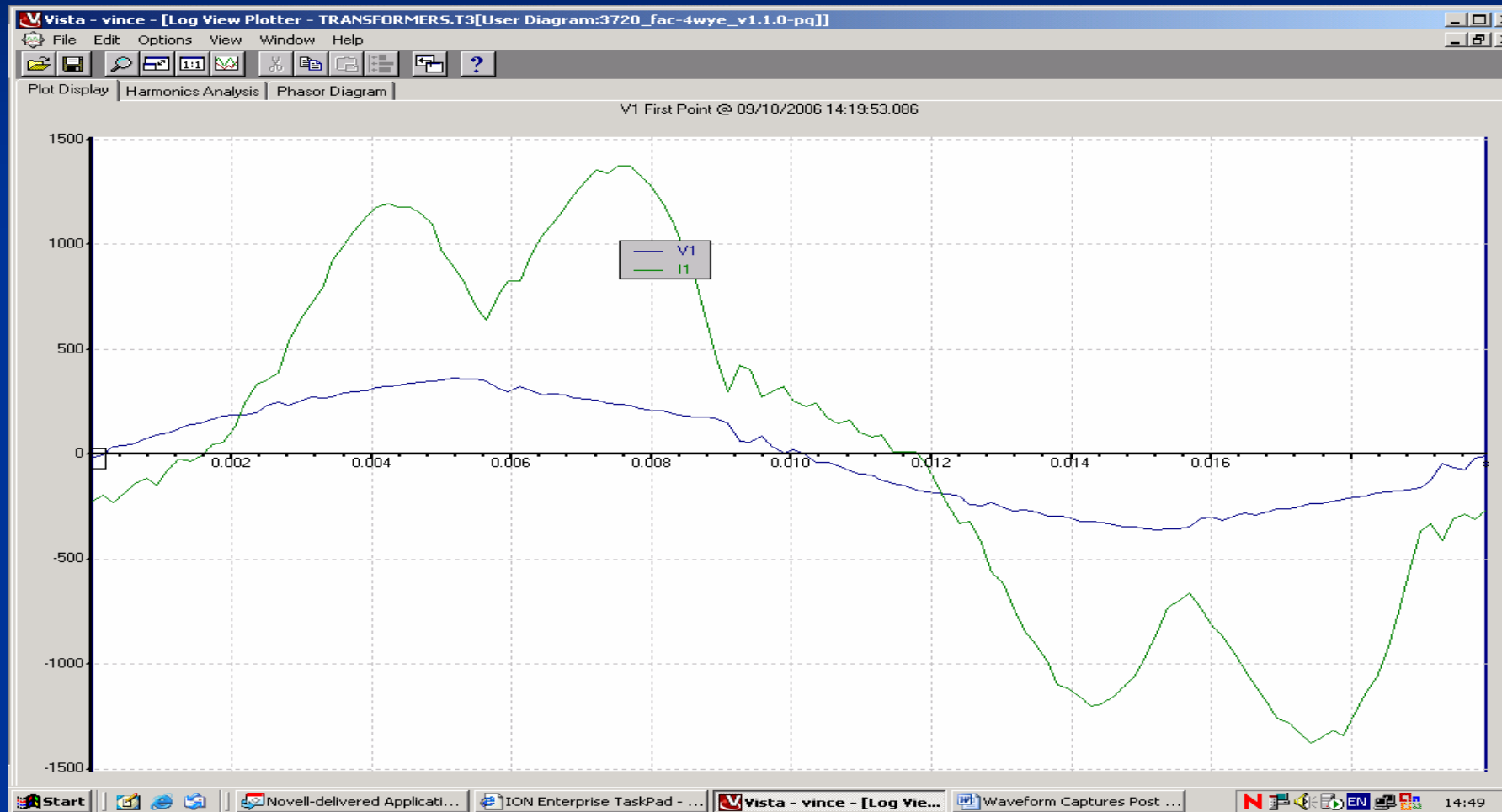
# Variable Speed Drives + PF =Leading Power Factor

- Variable speed drives operate @ 0.95 Power Factor.
- Presence of Power Factor will over compensate.
- Resonance on Capacitor Banks may occur.
- Over-voltages may occur and capacitor banks fail.
- Capacitor Banks Should be De-Commissioned.

# VSD Load With Power Factor



# VSD Load Without Power Factor



# Waveform Characteristics

- **Theoretical Waveform = Sinusoidal.**
- **Non- Sinusoidal = Complex.**

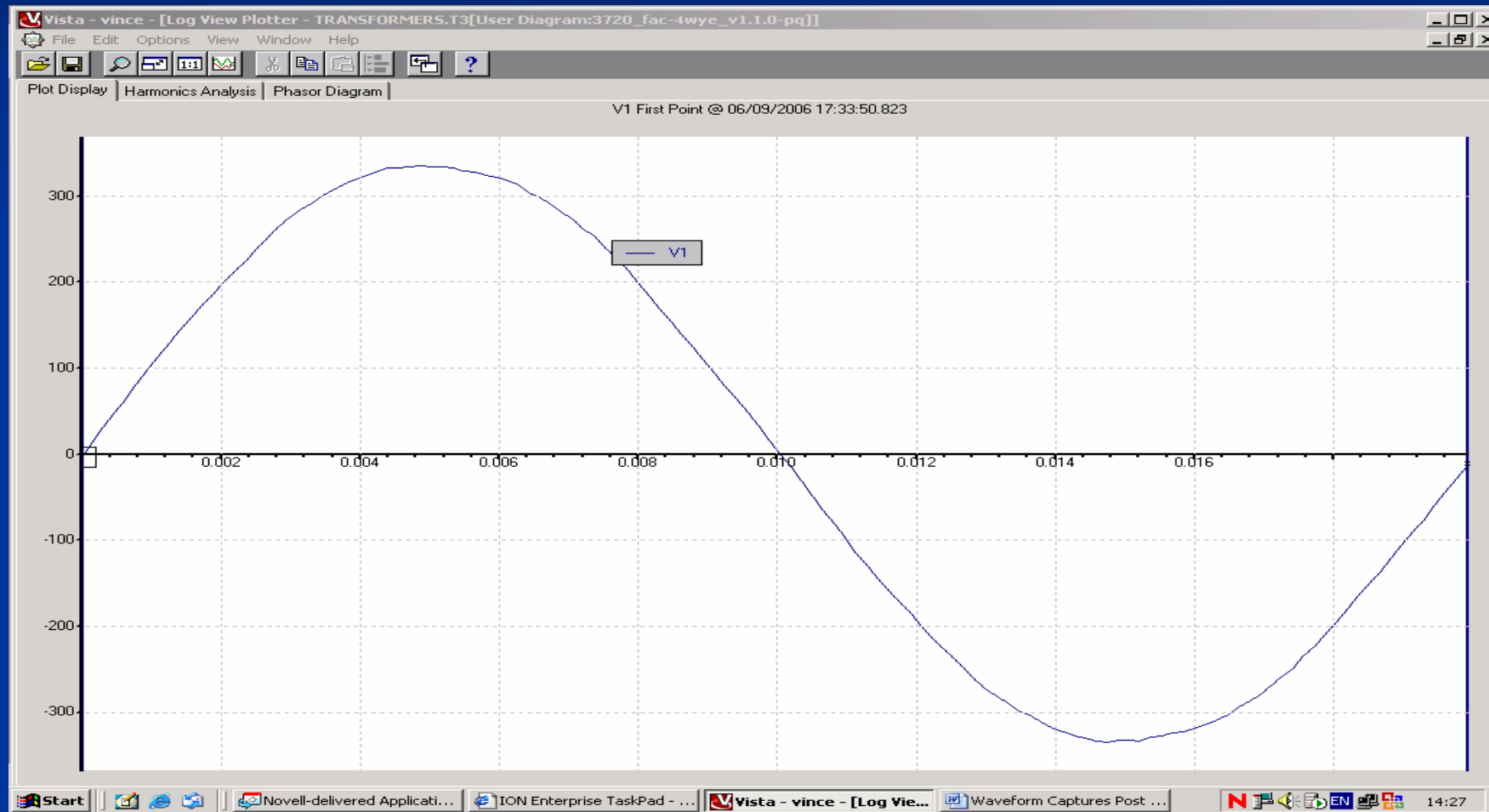
## Harmonics?

**Series of Different Frequencies which are  
Exact Multiples of 50Hz Fundamental.**

# Site Factors Considerations

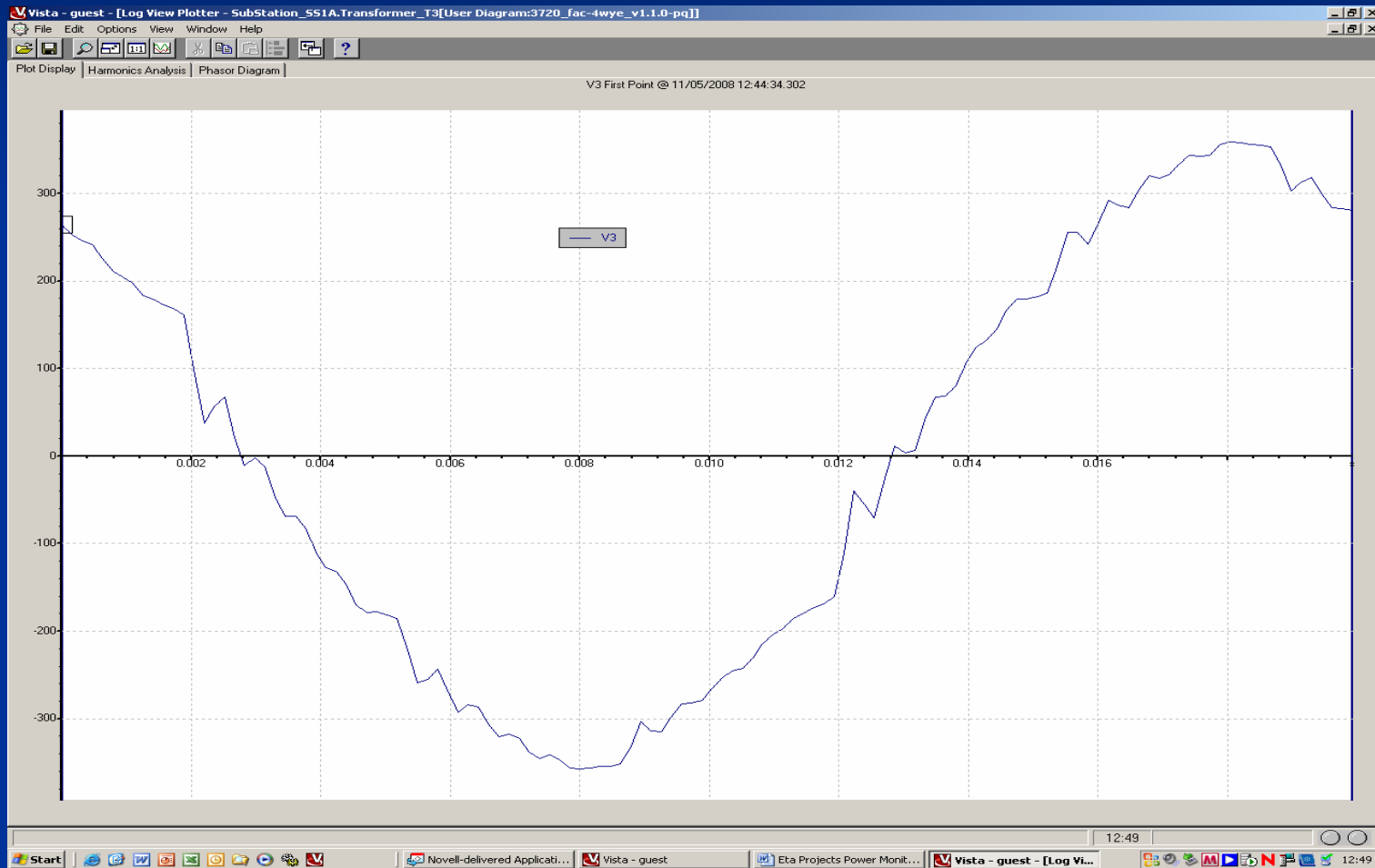
- Factors That Increase Harmonic Currents:
  - a) Large motor compared to the supply transformer.
  - b) Higher motor load.
  
- Factors that Decrease Harmonic Currents.
  - a) Greater DC or AC inductance.
  - b) Higher number of pulses in the rectifier.
  - c) Larger transformer.
  - d) Lower transformer impedance.
  - e) Higher short circuit capacity of supply.

# Voltage Waveform Pre-Variable Speed Drives



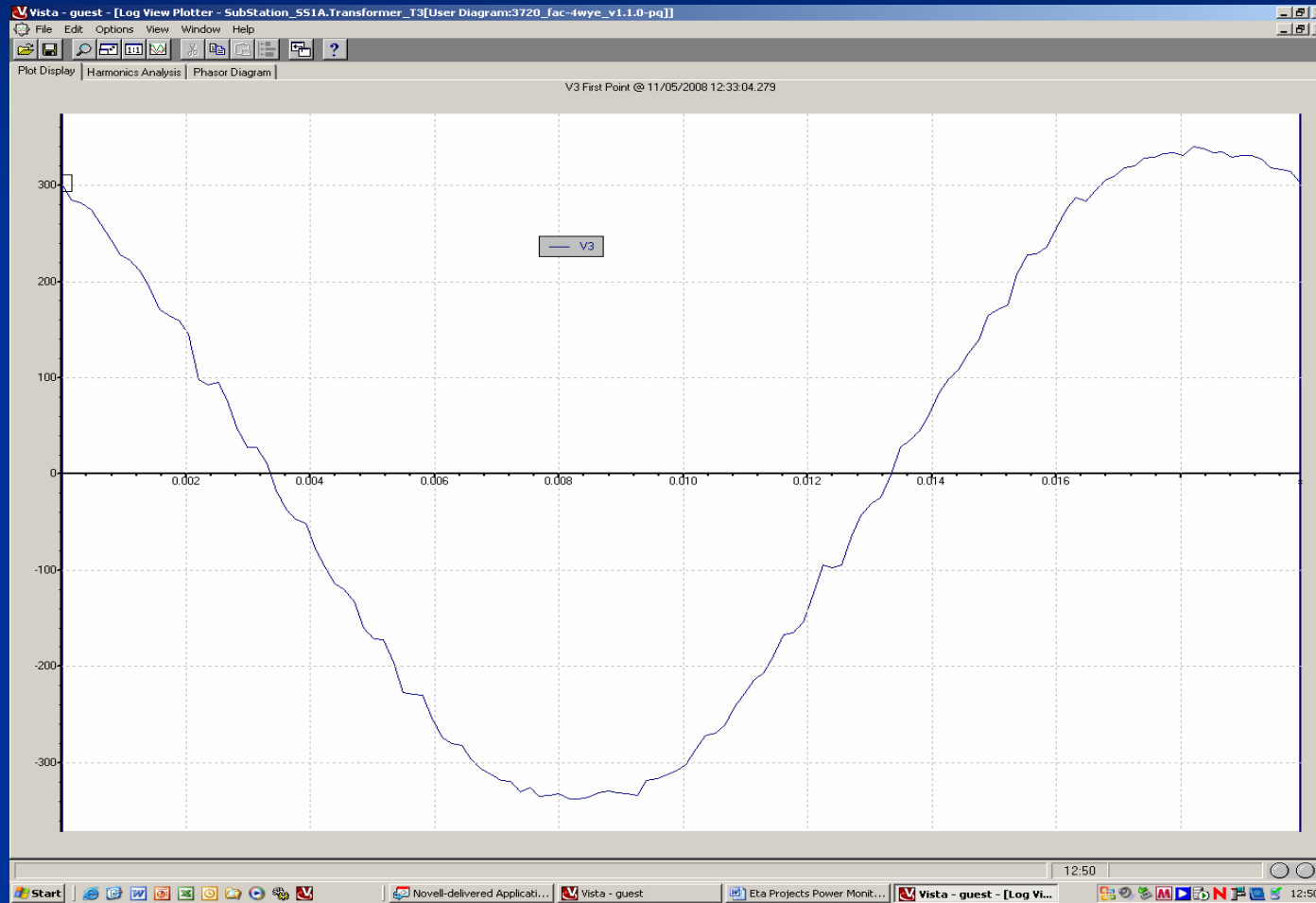
# Voltage Waveform

## VSD Added $\omega$ Harmonic Filter Off

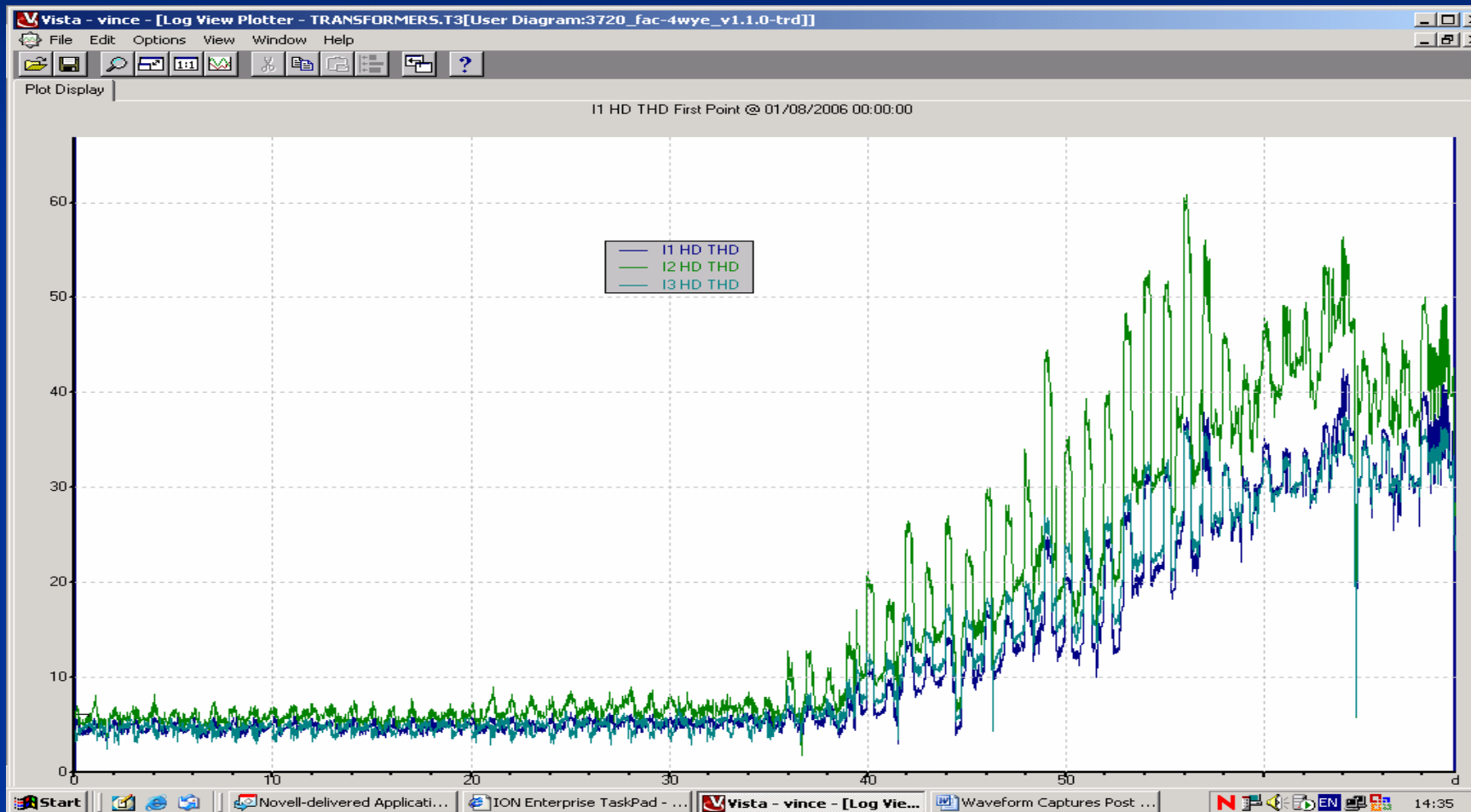


# Voltage Waveform

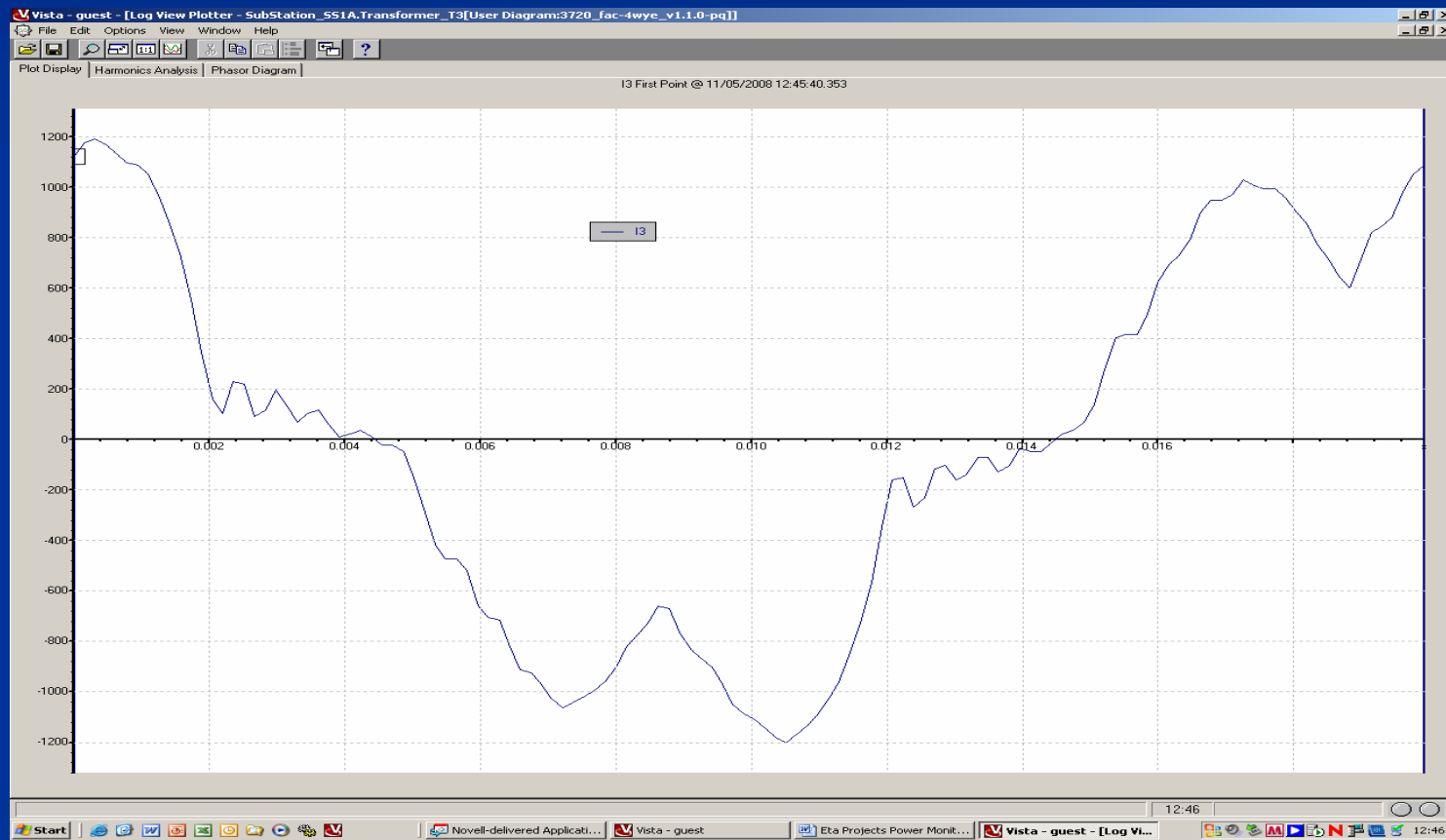
## VSD Added Harmonic Filter On



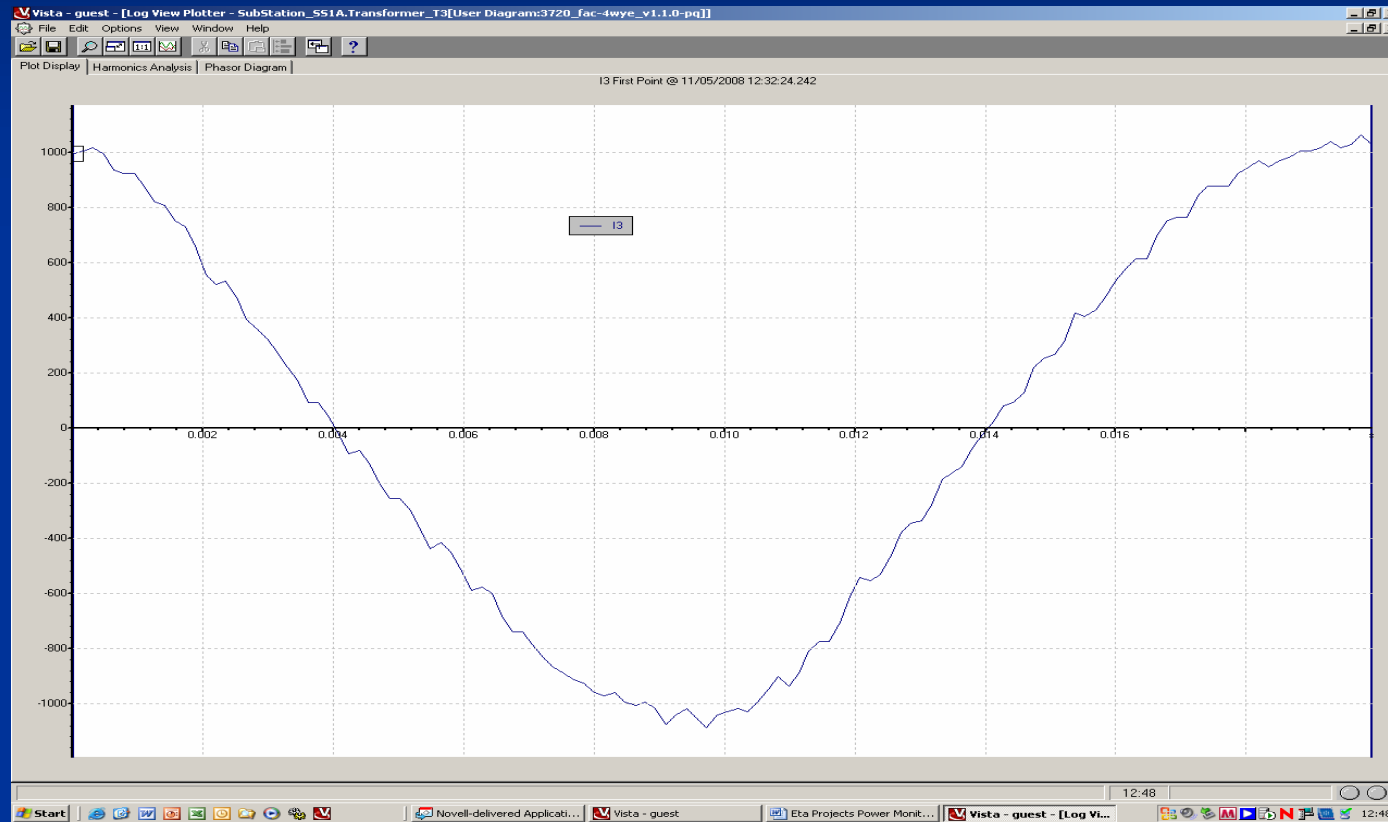
# Current Harmonic Distortion Drive Implementation Programme



# Current Waveform “Harmonic Filters Off”

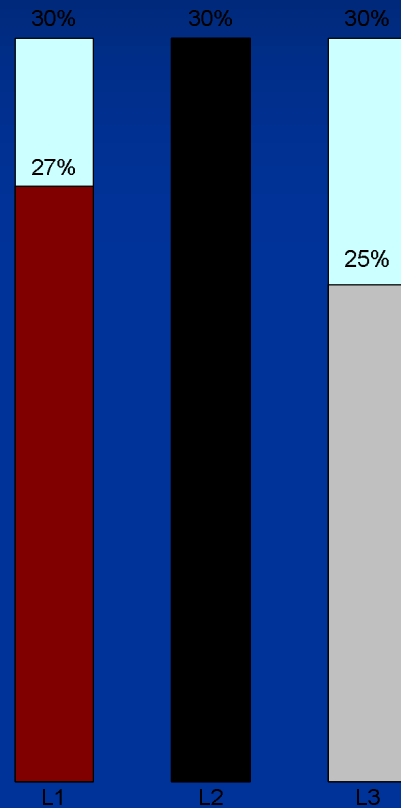


# Current Waveform Harmonic Filter On

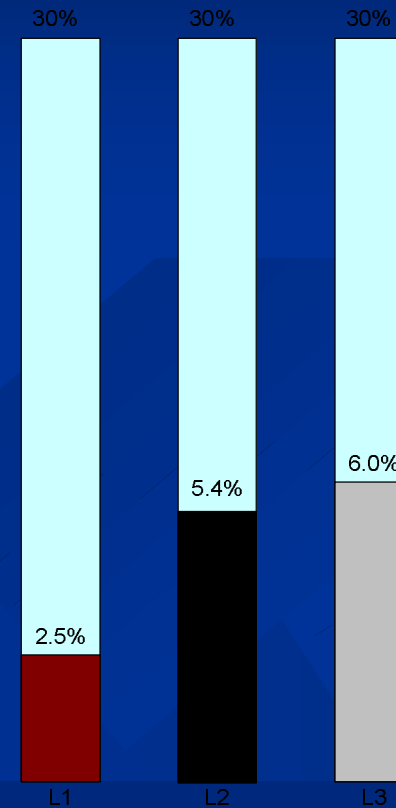


# Current Harmonic Distortion

## Pre-HD Filter and Post HD Filter



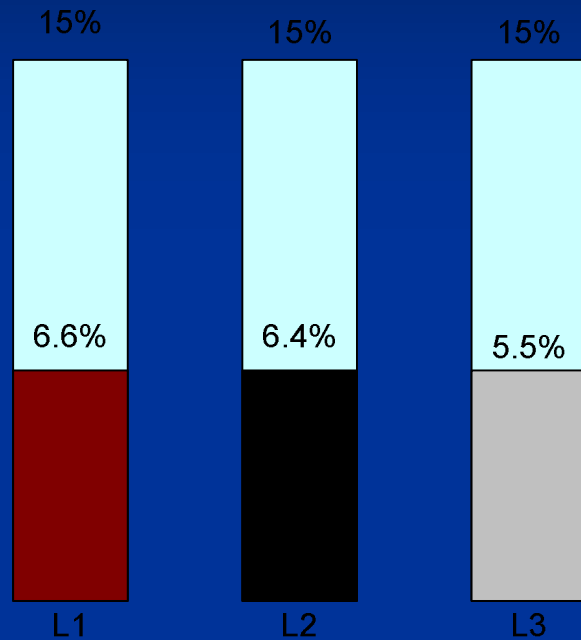
Harmonic Distortion  
on Current  
(Pre-Harmonic Filters)



Harmonic Distortion  
On Current  
(Post-Harmonic Filters)

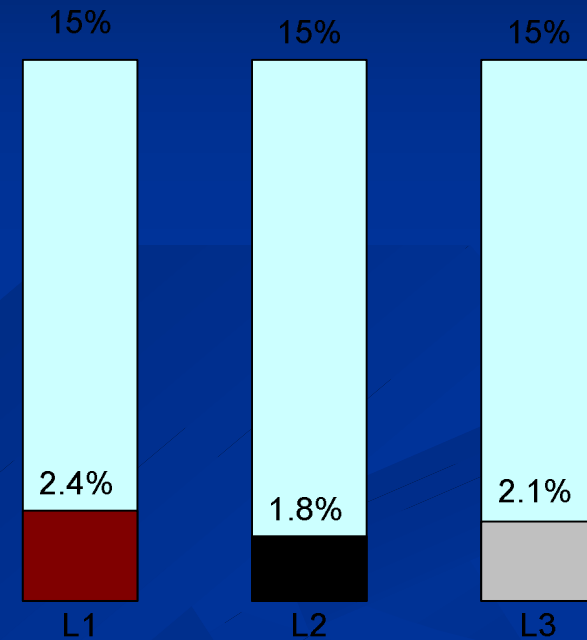
# “Voltage” Harmonic Distortion

## “Pre- HD Filter and Post HD Filter”



Harmonic Distortion  
on Voltage

(Pre-Harmonic Filters)



Harmonic Distortion  
On Voltage

(Post-Harmonic Filters)

# Typical Energy Saving One 18.5kW Motor c/w VSD Drive

- Motor Rating 18.5kW.
- Motor Power (Measured) 15.7kW.
- Motor Power (Eff1+VSD) 13.4kW.
- Immediate Saving 2.3kW.
  
- Costs for Motor+VSD £4,937.
- Payback (100% Operation) 4-Years.
- Further Saving (Vary Speed).

# Supply & Installation Costs

## Based on 18.5kW (2007 Prices)

■ EFF1 Motor 18.5kW	£ 467.00.
■ Motor Implementation Works	£ 600.00.
■ New VSD	£1,186.00.
■ VSD Implementation Works	£ 600.00.
■ Sensors	£ 173.00.
■ BMS Works	£ 169.00.
■ Electrical Works	£ 1,000.00.
■ Commissioning	£ 600.00.
■ O&M Manuals	<u>£ 142.00.</u>
■ <b>Total Installation Costs</b>	<b>£4,937.00</b>

# Energy Savings “Achieved”

- Charing Cross Hospital

Nameplate Rating Total	942kW.
Measured Power Pre-Works	804kW.
Measured Power Post Works	619kW.
<b>Energy Saving (Measured )</b>	<b>185kW.</b>

- Hammersmith Hospital

Nameplate Rating Total	383kW.
Measured Power Pre-Works	381kW.
Measured Power Post Works	289kW.
<b>Energy Saving (Measured</b>	<b>92kW.</b>

# Financial Savings

## Achieved Savings (Year 2007-2008)

### Achieved Savings Based on 2007 Figures @ 6pence/kWh

Annual Consumption (kWh)	Annual Operating Costs	No of VSDø/Eff1 Motors	Capital Investment	Annual Consumption Saving (kWh) (20-50%)	Annual CO2 Emissions Savings (Tonnes)	Annual Costs Saving Based on 6p/Kwh	Payback Period VSD/EFF1 (Months)
5,893,685kWh	£353,621	69 = 1325kW	£486,249.00	1,940,340kWh	834Tonnes	£116,420.00	50-Months

### Achieved Savings Based on 2008 Figures @ 7.75 pence/kWh

Annual Consumption (kWh)	Annual Operating Costs	No of VSDø/Eff1 Motors	Capital Investment	Annual Consumption Saving (kWh) (20-50%)	Annual CO2 Emissions Savings (Tonnes)	Annual Costs Saving Based on 7.75p/Kwh	Payback Period VSD/EFF1 (Months)
5,893,685kWh	£456,760	69 = 1325kW	£486,249.00	1,940,340kWh	834Tonnes	£150,376	38-Months

# Variable Speed Drives Typical Specification

- **IP Rating** IP54 rating allows drive to be sited next to the motor in dusty or wet conditions.
- **Software** Lon Works, Profibus, Modbus and Compatibility Trend IQ Compatible to suit protocol of local BMS system.
- **Harmonic** Internal harmonic chokes to produce less Filtration Harmonic Current To comply with G5/4.
- **EMC filter** To meet EEC Standards.
- **Motor** Class F. If the motor is old with Class B Insulation upgrading should be considered Class F.
- **Power Factor** De-commission existing power factor banks.



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**Reduce Your Hospital  
Energy Bill  
(Carefully)  
Energy Saving  
Using Variable Speed Drives  
and  
Energy Efficient Motors  
Questions?**



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