Photovoltaic Overview

Demand Side Management and Power Quality

City of Brisbane
Baylands Specific Plan

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SUNPOWER NEXTENERGY

Photovoltaics : Techologies

Crystalline Silicon – ~99% of market

Single and polycrystalline Si

n– Boron p- Phosphorous

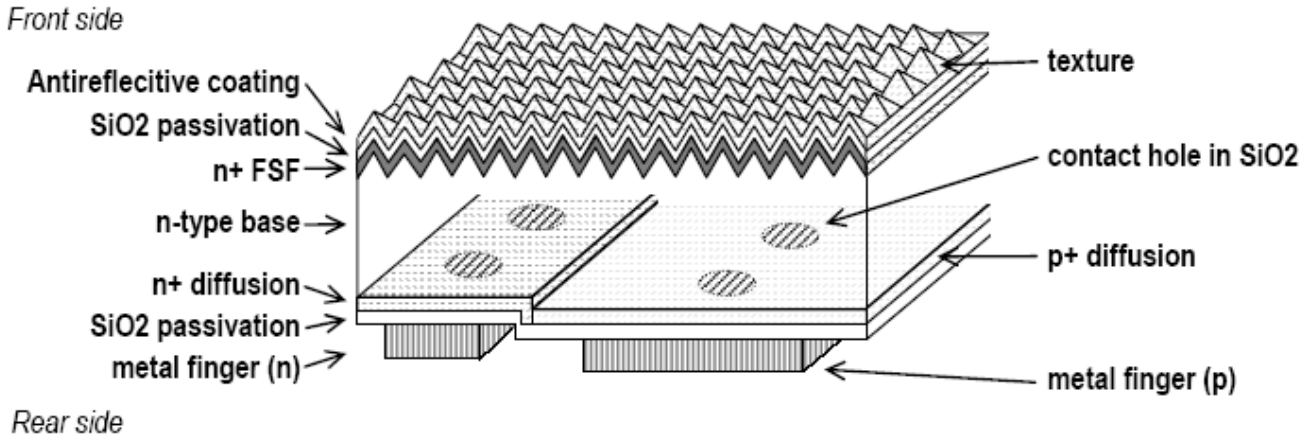


Figure 1: Schematic diagram of SunPower's A-300 solar cell (not to scale).

Alternate PV technologies

Amorphous Silicon

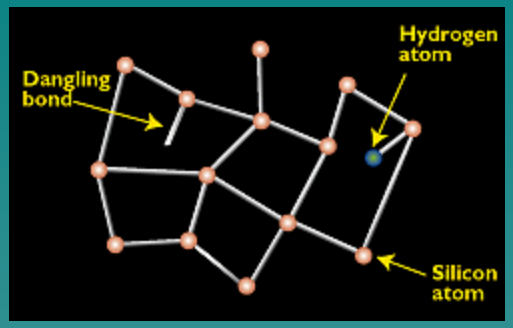


Figure 1. - Amorphous silicon's random structural characteristics result in deviations like "dangling bonds. " Dangling bonds provide places for electrons to recombine with holes, but this may be neutralized somewhat with hydroge

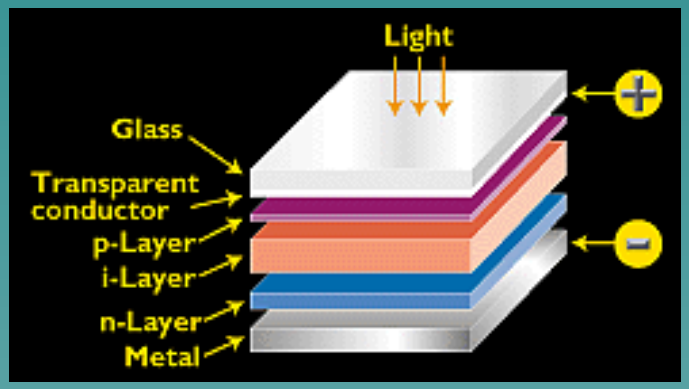


Figure 2. - The typical amorphous silicon cell employs a p-i-n design, in which an intrinsic layer is sandwiched between a p layer and an n layer.

Other PV technologies

Ga-As Gallium Arsenide - 28 % efficient!

n- Germanium p Indium Gallium Phosphide

Cd-Te Cadmium-Telluride

Potentially cheaper but toxic, less efficient (11%)

Nano- tech - *the jury is still out*

Science and engineering in PV, other technologies

Current Standard (Crystalline Si)

99+ % of PV market

Sunpower, Sharp, Sanyo, BP Solar etc

PV Market standard to match:

4$ / DC watt wholesale price

Stable cost regardless of growth (!)

14-21% cell efficiency;10-12% system

No degradation - 25 year *warranty*

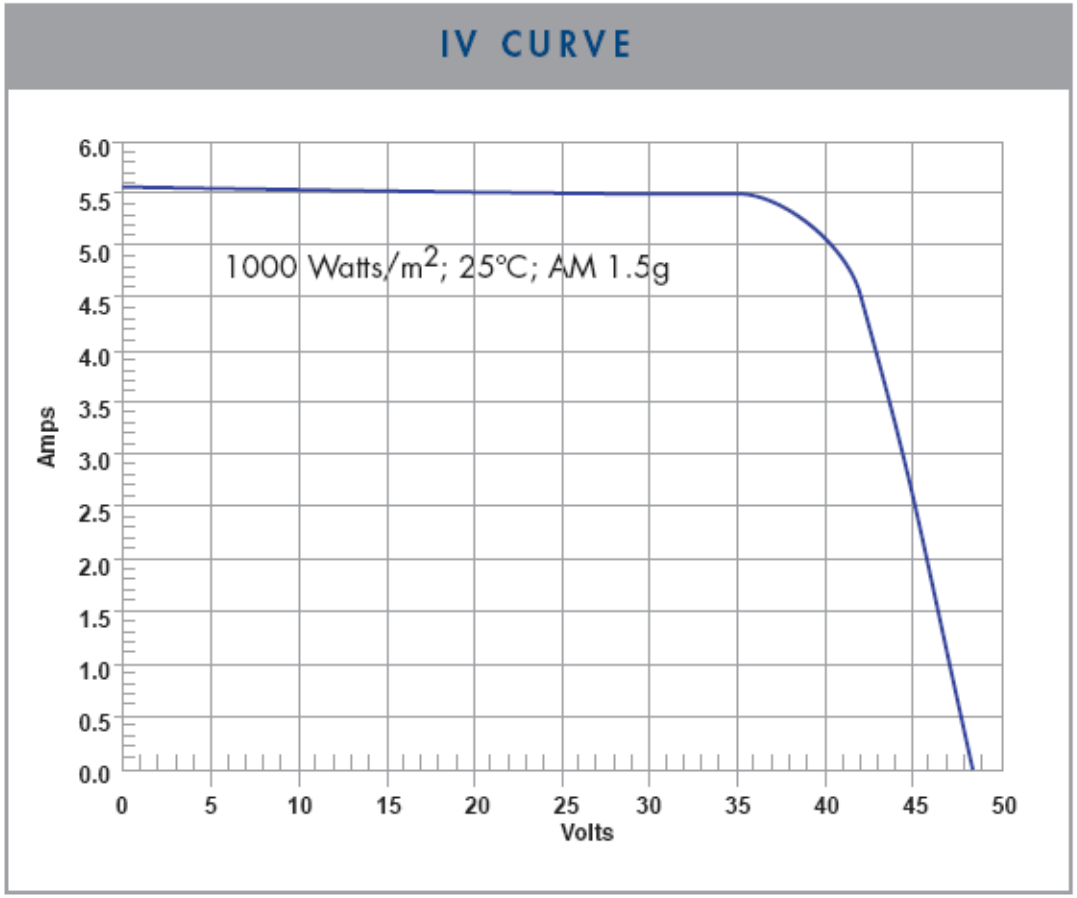
PV System Electric Characteristics

Single phase 120/240 VAC
Polyphase 120/208 277/480 AC
Module string 300-500 VDC

Inverter size in kW AC or Amperes AC

Voc - Open Circuit Voltage
Isc - Short Circuit Current
Vpp - Voltage at Peak Power
Ipp - Amperes Peak Power

IV Curve ; P = I * V = W



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Photovoltaic system types

- Grid Tied
- Grid Tied with Battery Backup
- Stand Alone
- Stand Alone hybrid
- Roof Mount, structural attachment
- Roof Mount, non-penetrating
- Ground Mount
- Tracking (single, dual axis)

kWp rating – CEC AC Watts

kWp = CEC rating

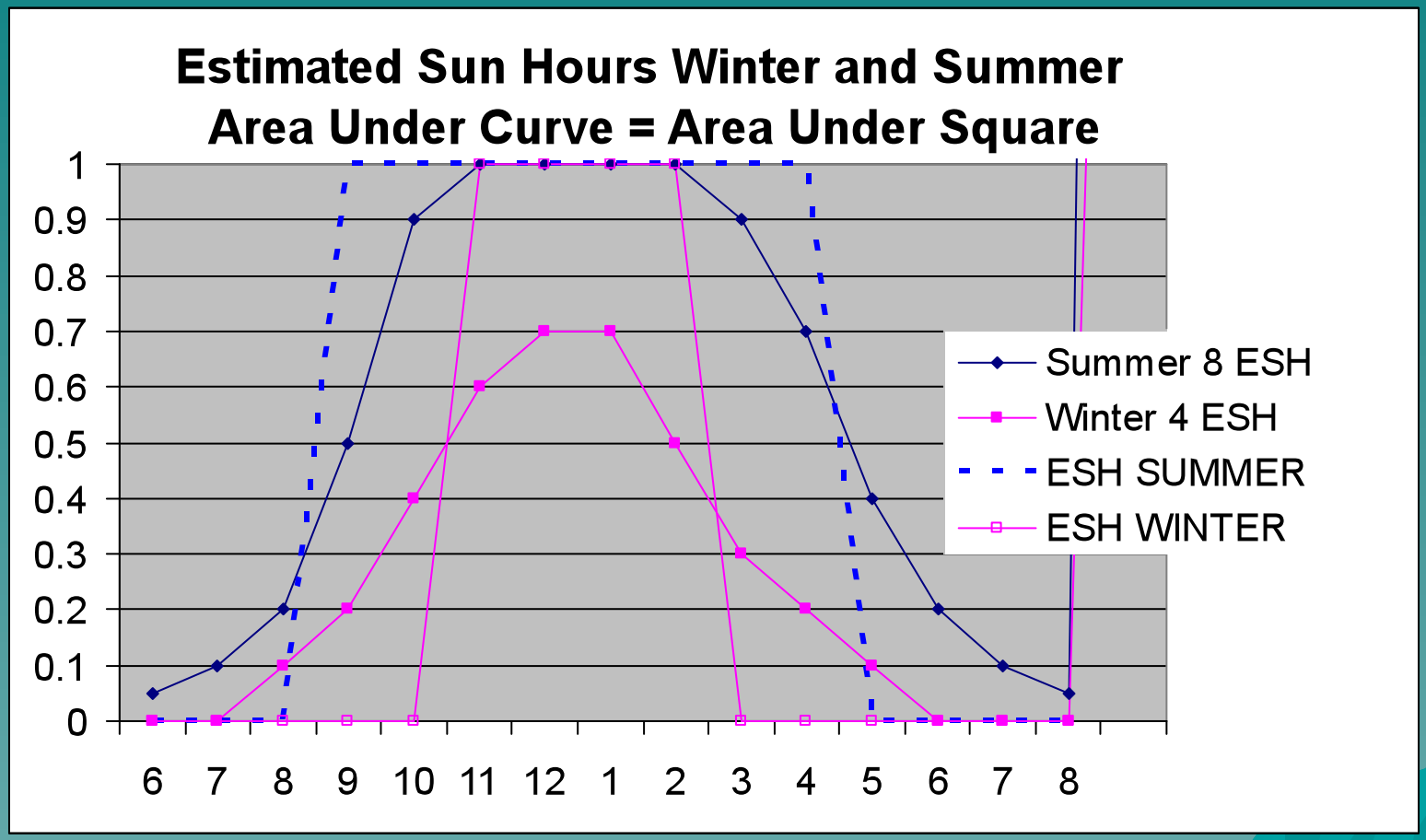
= # of panels * CEC rating per panel * inverter efficiency

Example : 100 kW AC nominal system

540 SP -210 , Xantrex PV-100208HE

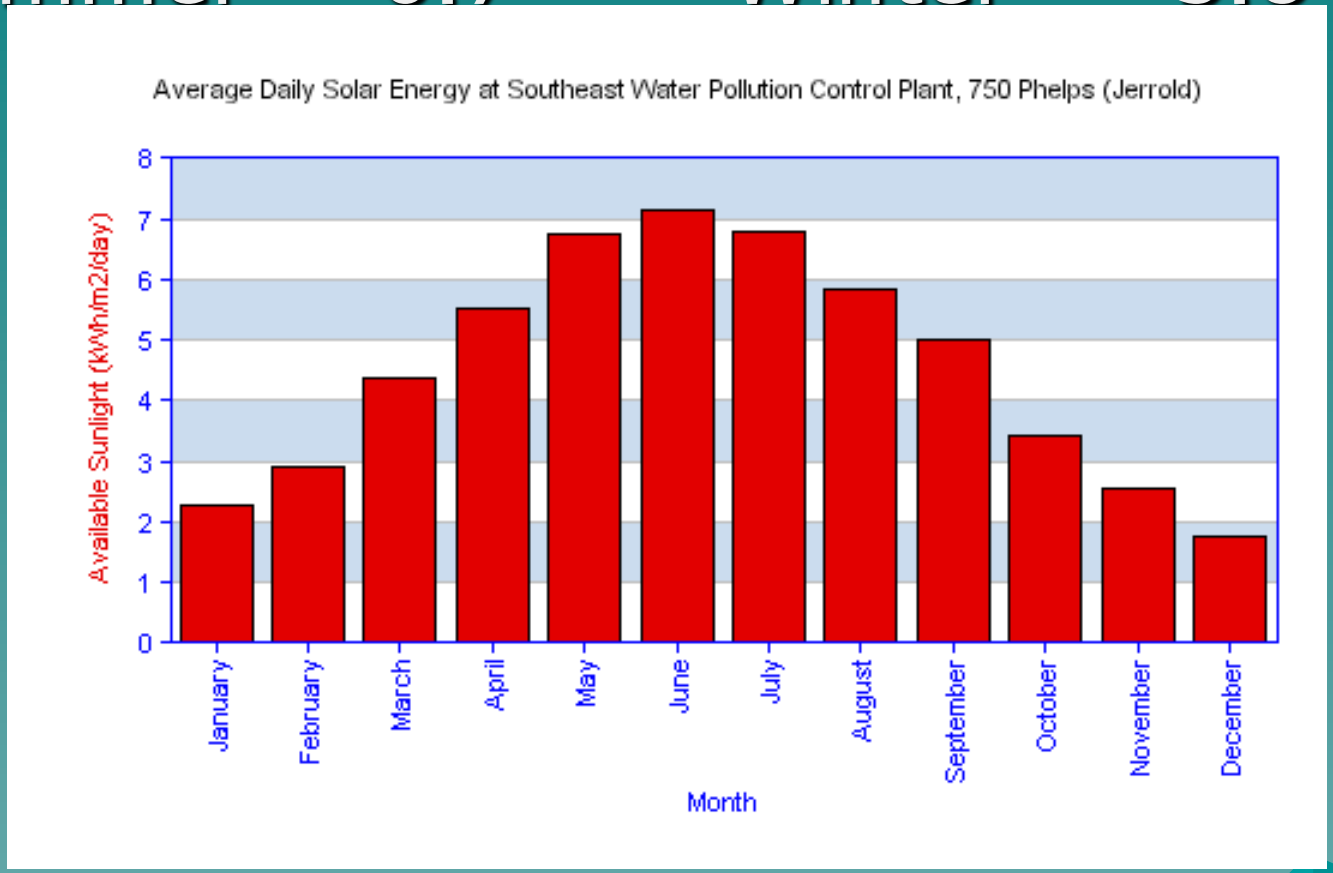
kWp = 540*193.7*0.95 = 99.368kW

Estimated Sun Hours (ESH)



Brisbane Sun Hours

Summer = 6.7 Winter = 3.8



Estimated AC kWh from 100kW Solar System in Brisbane, Ca

Summer = May 1 –Oct 31 (PG&E)

Monthly = 6.5*100* 30 days = 19,500 kWh

Winter = Nov 1 –Apr 30 (PG&E)

Monthly = 3.8*100* 30 days = 11,400 kWh

$ Value of Photovoltaic kWh

PG&E avoided cost for kWh

Total Energy Rates ($ per kWh)		
Peak Summer	$0.31883	(R)
Part-Peak Summer	$0.15658	(R)
Off-Peak Summer	$0.09291	(I)
Part-Peak Winter	$0.13796	(R)
Off-Peak Winter	$0.10177	(I)

A6 rate structure

No demand charges

Brisbane 100 kW avoided cost value Feb 2007 PG&E A6 rate

- Summer Savings = - $ 3,943.27
- Winter Savings = - $ 1,465.28
- Annual avoided cost = $ 32,541
- Cannot get credit $ from PG&E now

Photovoltaic kWh : Long Term Valuation

1) Avoided Cost to Utility

2) REC - Renewable Energy Credits
   PBI – performance based incentives

REC, PBI = "green" value of electricity

Total Value = Avoided Cost + REC value

Net Real Time Metering

- Net metering law requires buy-sell kWh at the same rate.
- Real Time metering will be standard
- Photovoltaics reliably match real time peak values for $ / MWh

NJCEP SREC TABLE

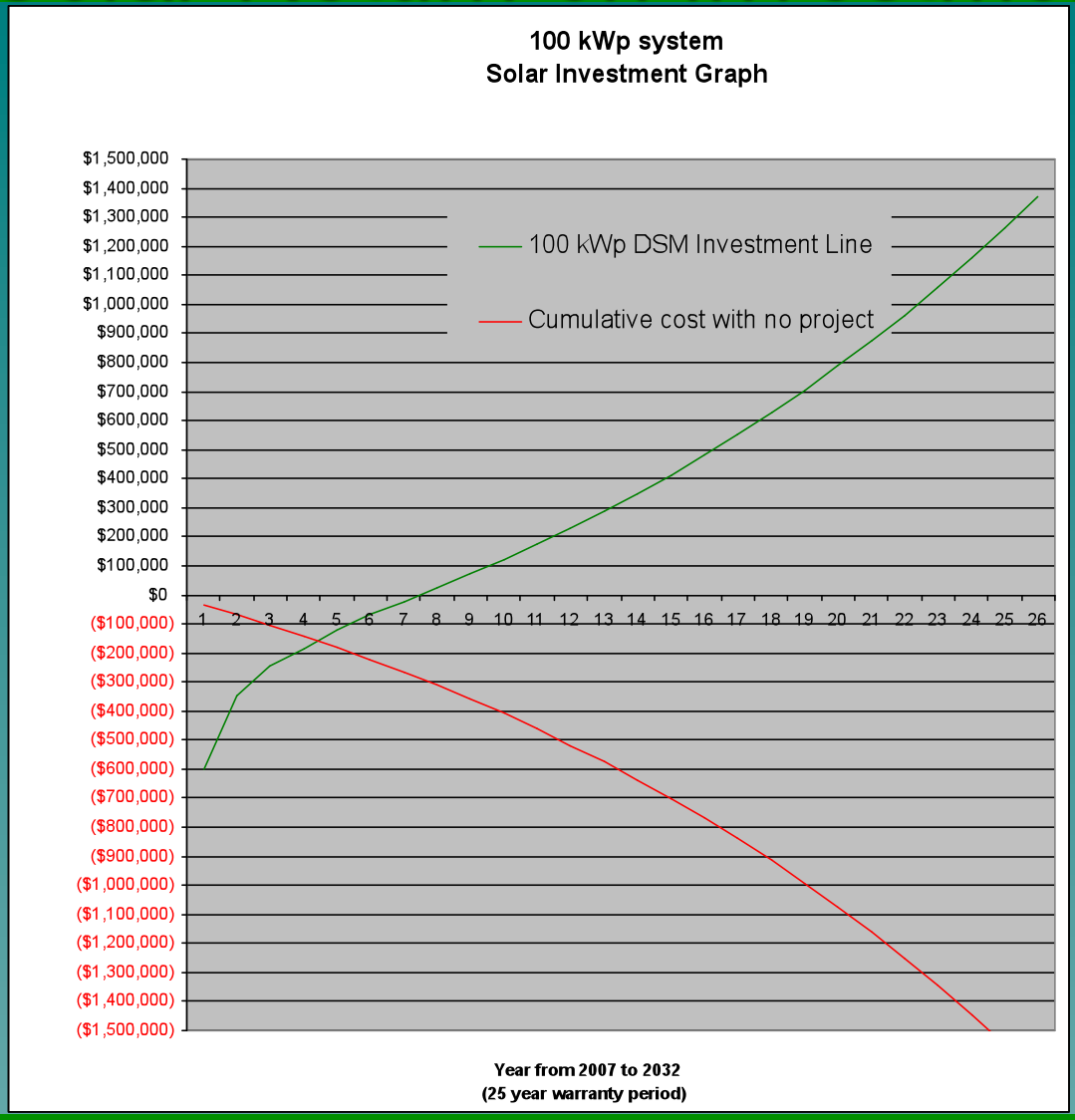
Range = 170$ - 218$ / MWh

= $ 0.17 -0.22 / kWh

Month	Year	# SRECs Traded in Month	Monthly High ($/MWh)	Monthly Low ($/MWh)	Cumulative # SRECs Traded	Cumulative Weighted Average Price ($/MWh)
Dec	2006	2750	$260	$110	5351	$195.44
Nov	2006	1022	$260	$110	2601	$197.89
Oct	2006	464	$250	$160	1579	$205.99
Sept	2006	747	$255	$174	1115	$206.08
Aug	2006	131	$235	$150	368	$213.77
July	2006	237	$240	$150	237	$218.60

Source : www.njcep.com

Solar Return on Investment



100 kWp ROI numbers

- installed system cost = $ 825,000
- CEC rebate = $ 225,000
- (or PBI = ~$ 341,250 in 5 years)
- 30% FETC = 0.3*600K = $ 180,000
- 5 year MACRS = approx $ 207,000
- net 5 year cost = $ 213 K
- 5% annual rate increases
- 1st year avoided cost = $ 32,500

25 year 100 kW PV value

- Total PG&E avoided costs = ~$ 1.6 M
- (with 5% increases , no real time metering)

- 25 year REC Value = ?
- 25 year PBI Value = ?

ROI, min = $ 1.6 M / 213 K = 750%

Solar Advantages

Completely Modular – from 100 W - 1 MW

Simple Interconnection standards

No noise, moving parts, maintenance

Long Life (50+ years) ; no degradation

Peak output coincident with utility

DSM Demand Side Management

Energy Efficiency – Asset protection

Reduce solar system size

Lighting

HVACR

Induction Motor efficiency

Power Quality

Uninterruptible Power

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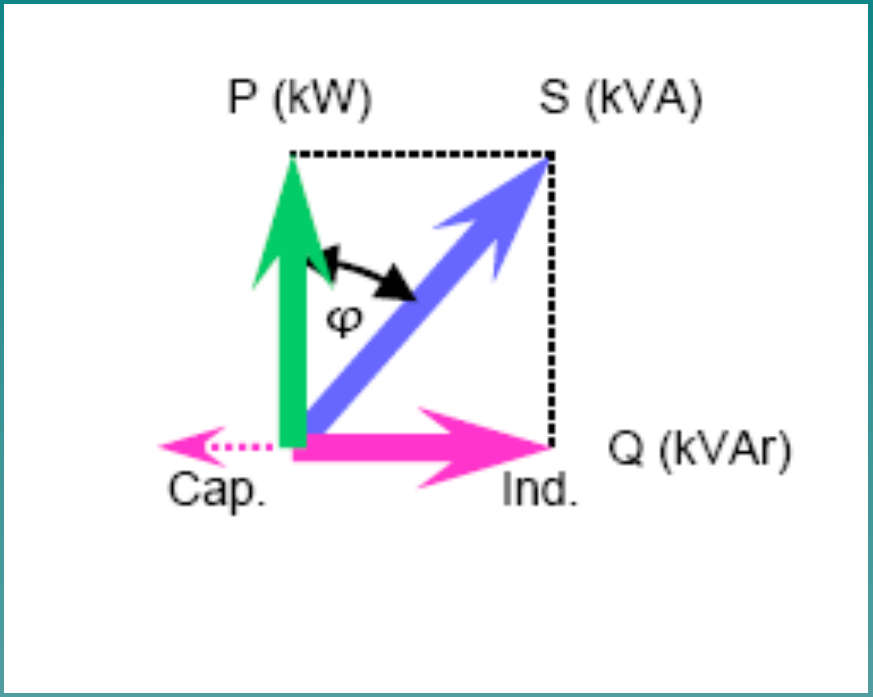
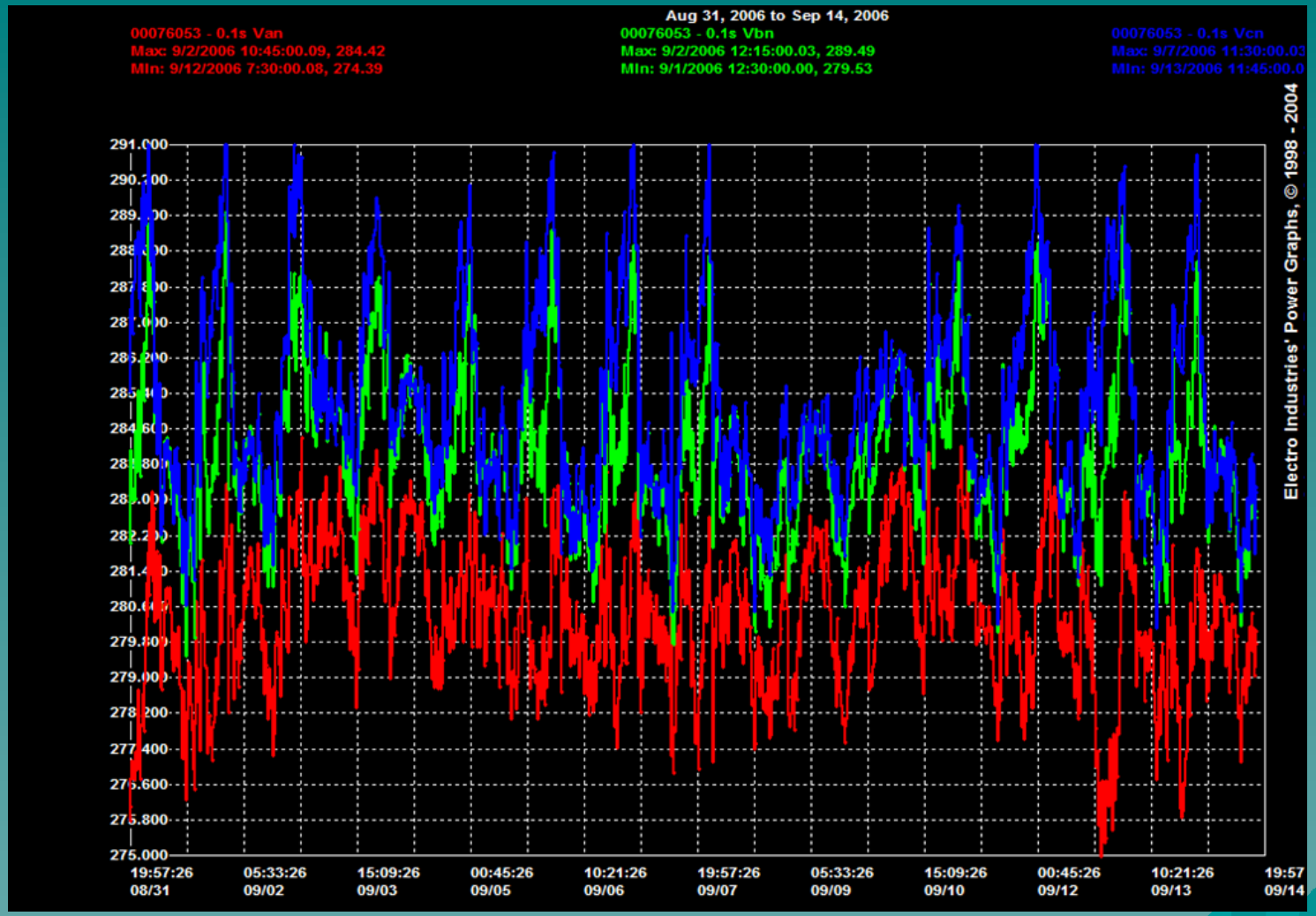
Power Quality

- Reactive Power Compensation in Real Time
- Voltage Control
- Harmonic Distortion Suppression



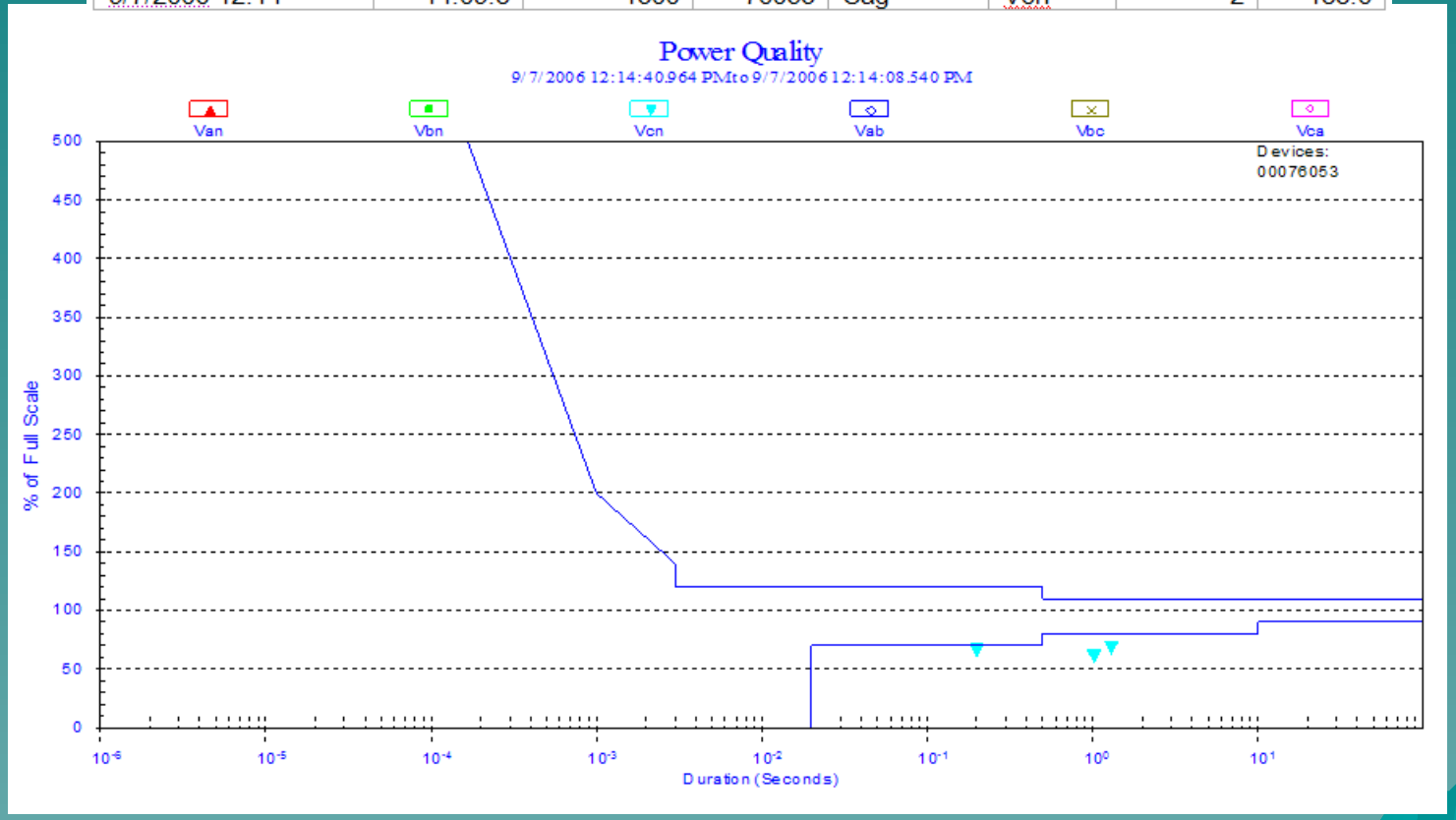
Elspec Equalizer

VOLTAGE : PHASE TO NEUTRAL
from PG&E at main



POWER QUALITY EVENT - SAG 09-07-06 9:14 AM PST

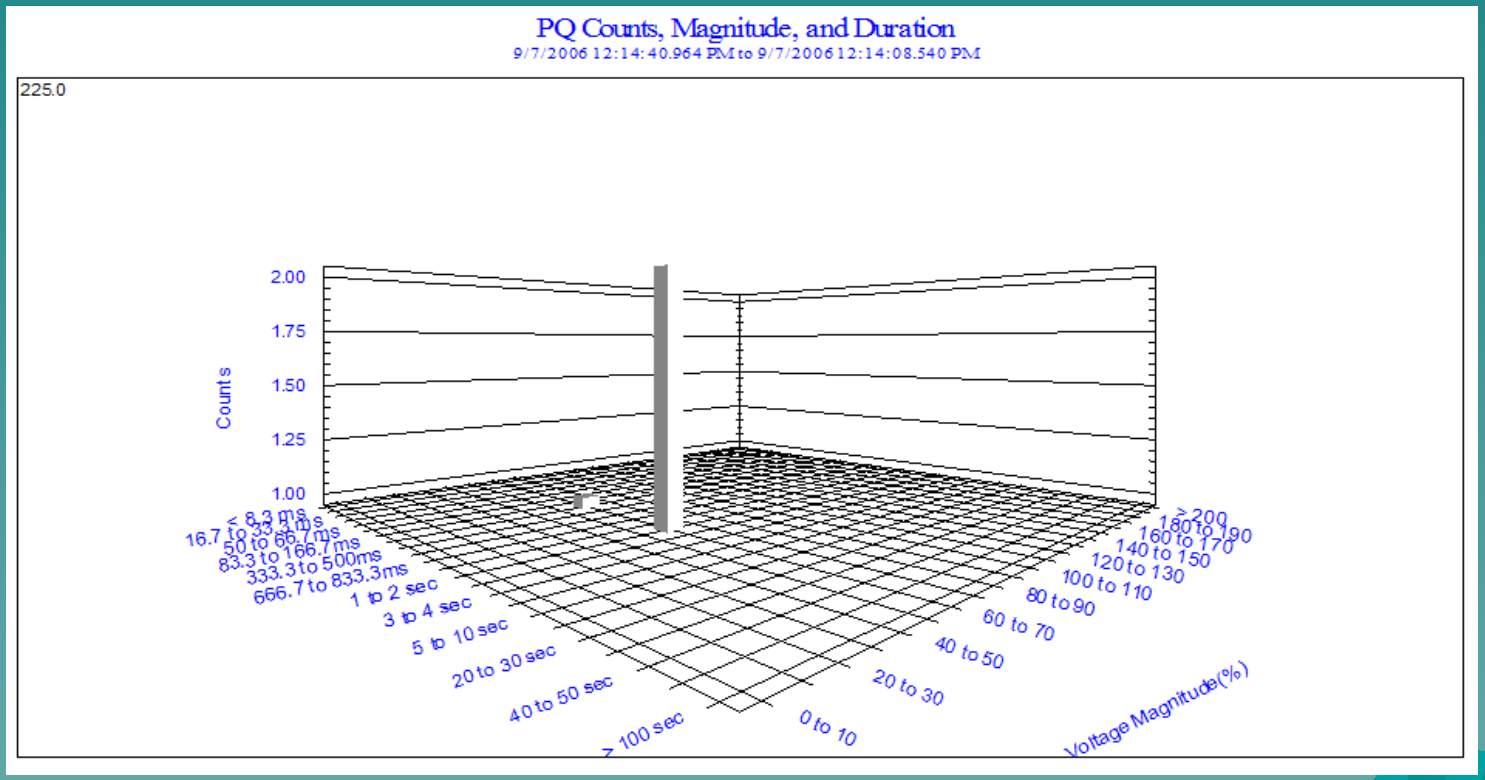
Start Date/Time	End Date/Time	Duration ms	Device	Condition	Channel	Channel ID	Value
9/7/2006 12:14	14:41.0	1024	76053	Sag	Vcn	2	168.46
9/7/2006 12:14	14:15.1	200	76053	Sag	Vcn	2	183.46
9/7/2006 12:14	14:09.8	1300	76053	Sag	Vcn	2	188.6



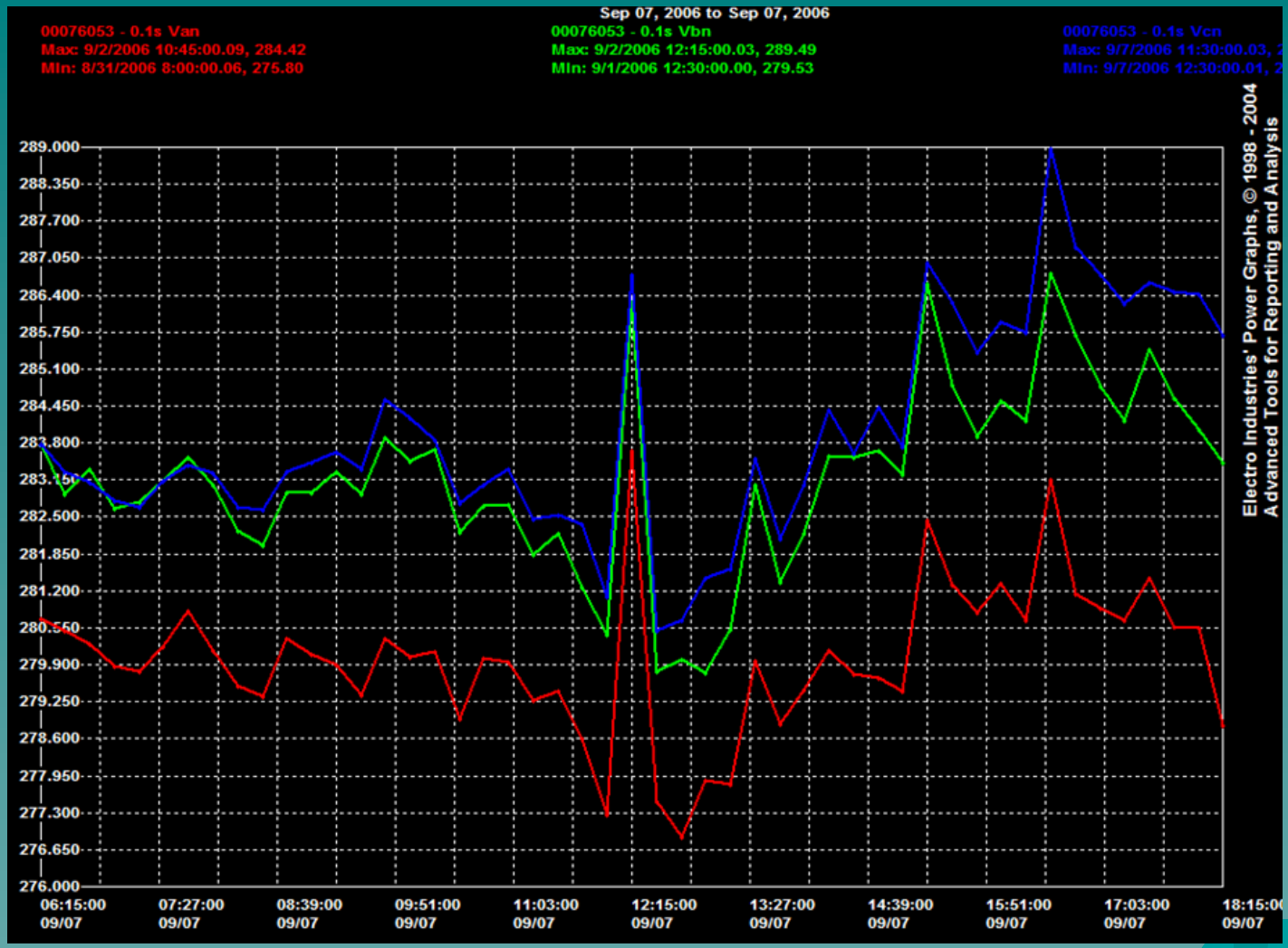
9/07/06 POWER QUALITY EVENT : PG&E REPORTS "CROW ON TRANSMISSION LINE"

3 SAGS IN Vcn in total of 32 seconds elapsed time at 9:14 am September 07 , 2006

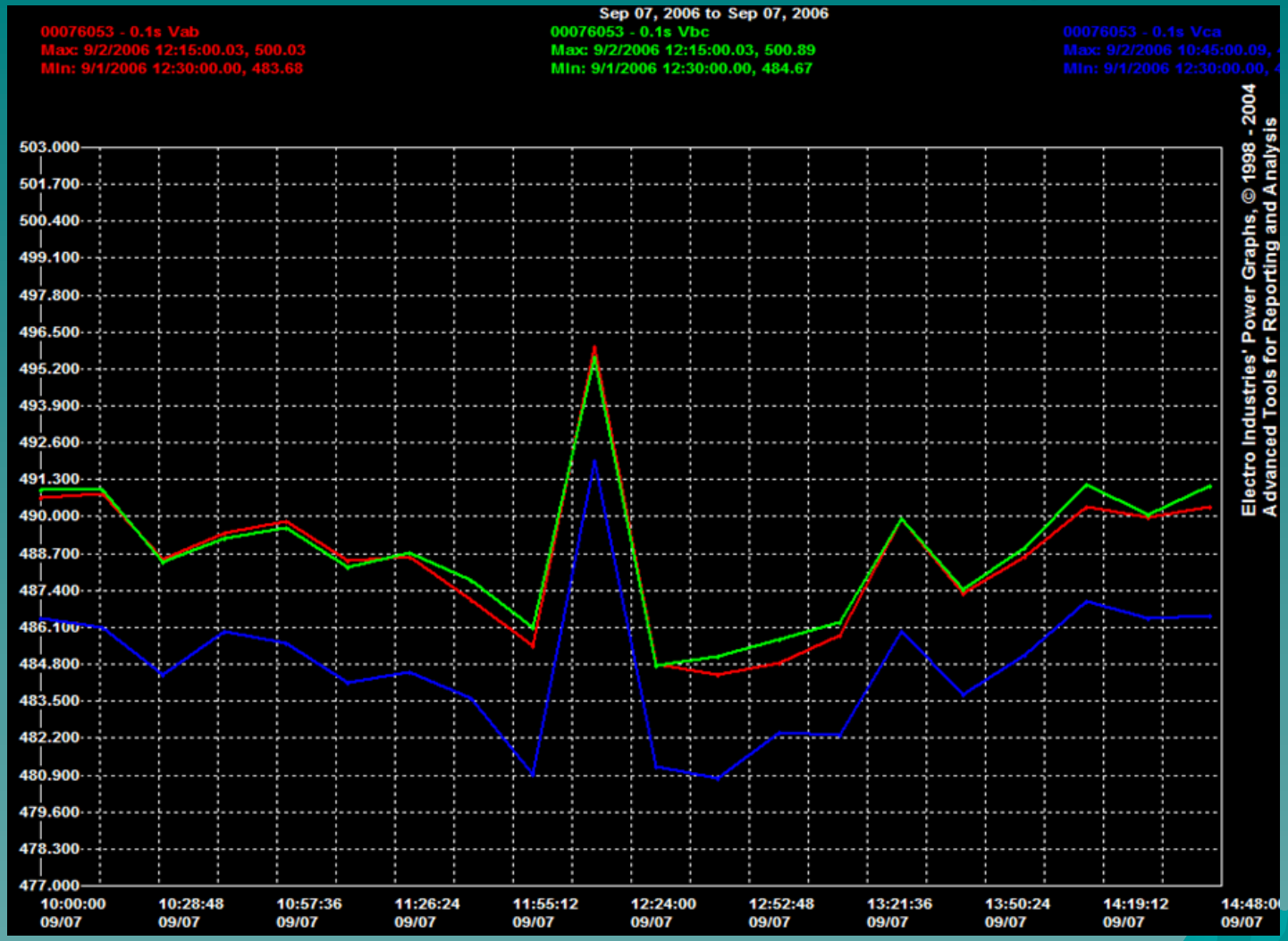
1.024 ms @ 168.46 VOLTS P-N
0.200 ms @ 183.46 VOLTS P-N
1.300 ms @ 188.6 VOLTS P-N



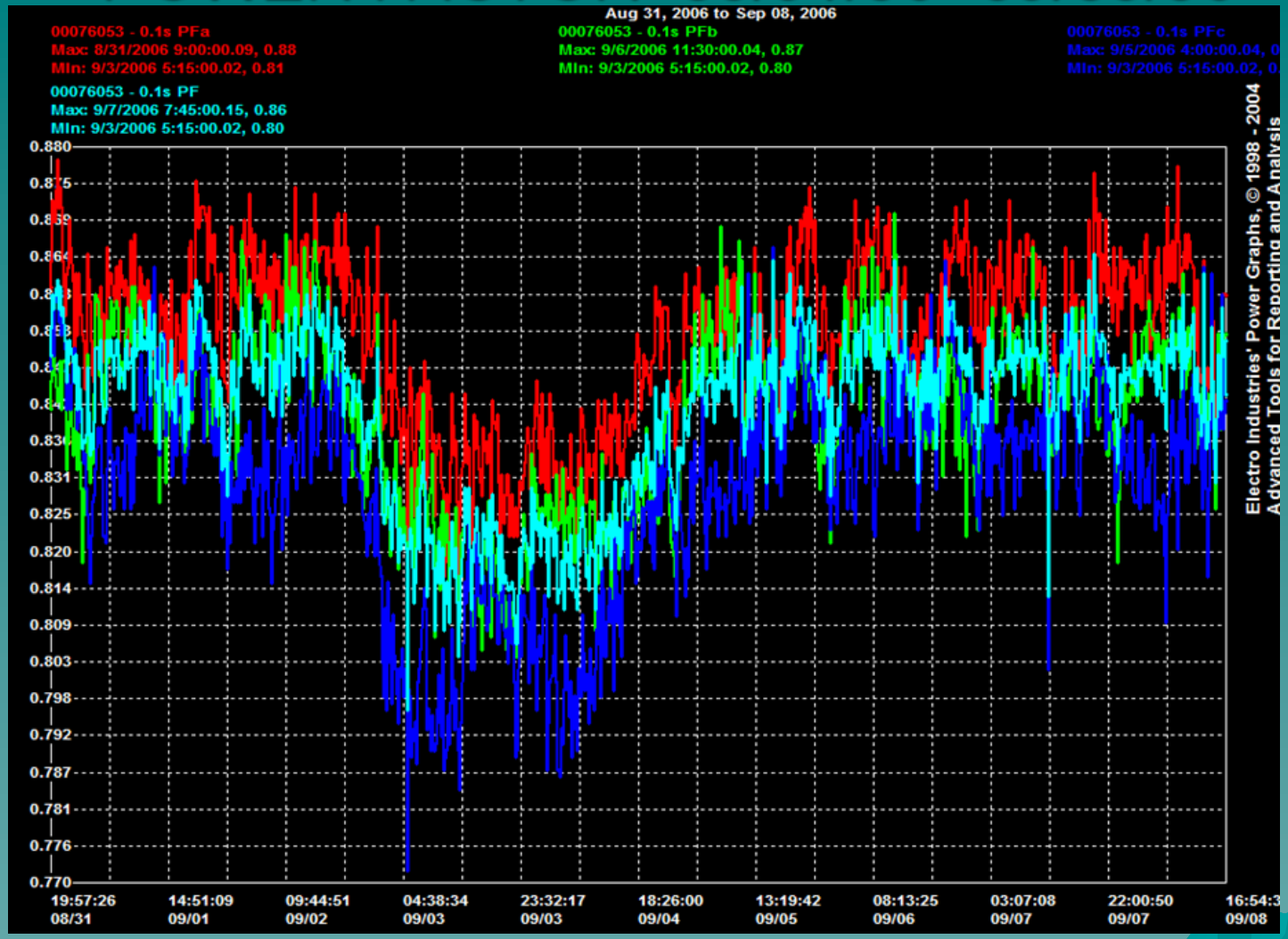
PHASE TO NEUTRAL DURING PQ EVENT



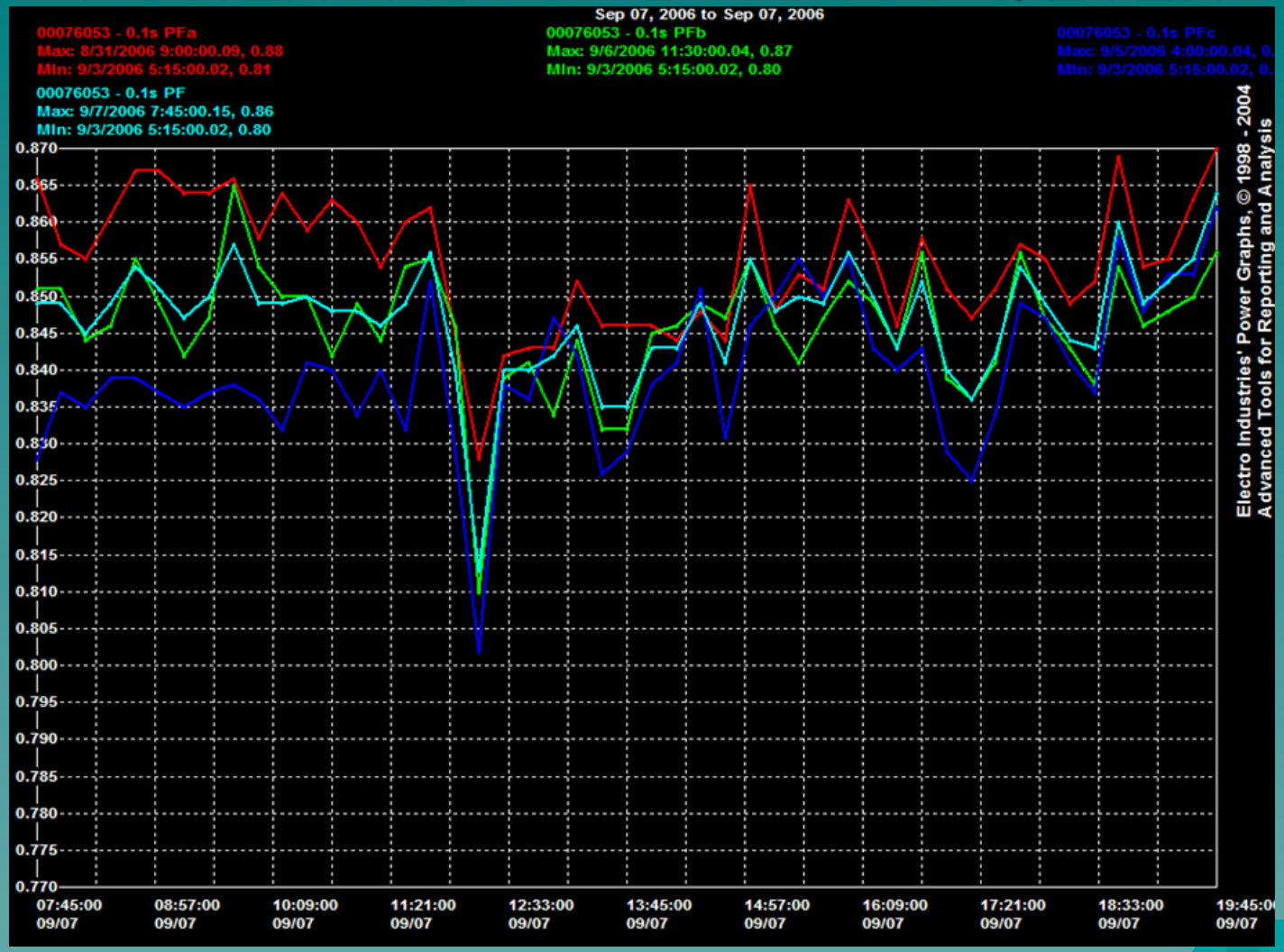
PHASE TO PHASE DURING PQ EVENT



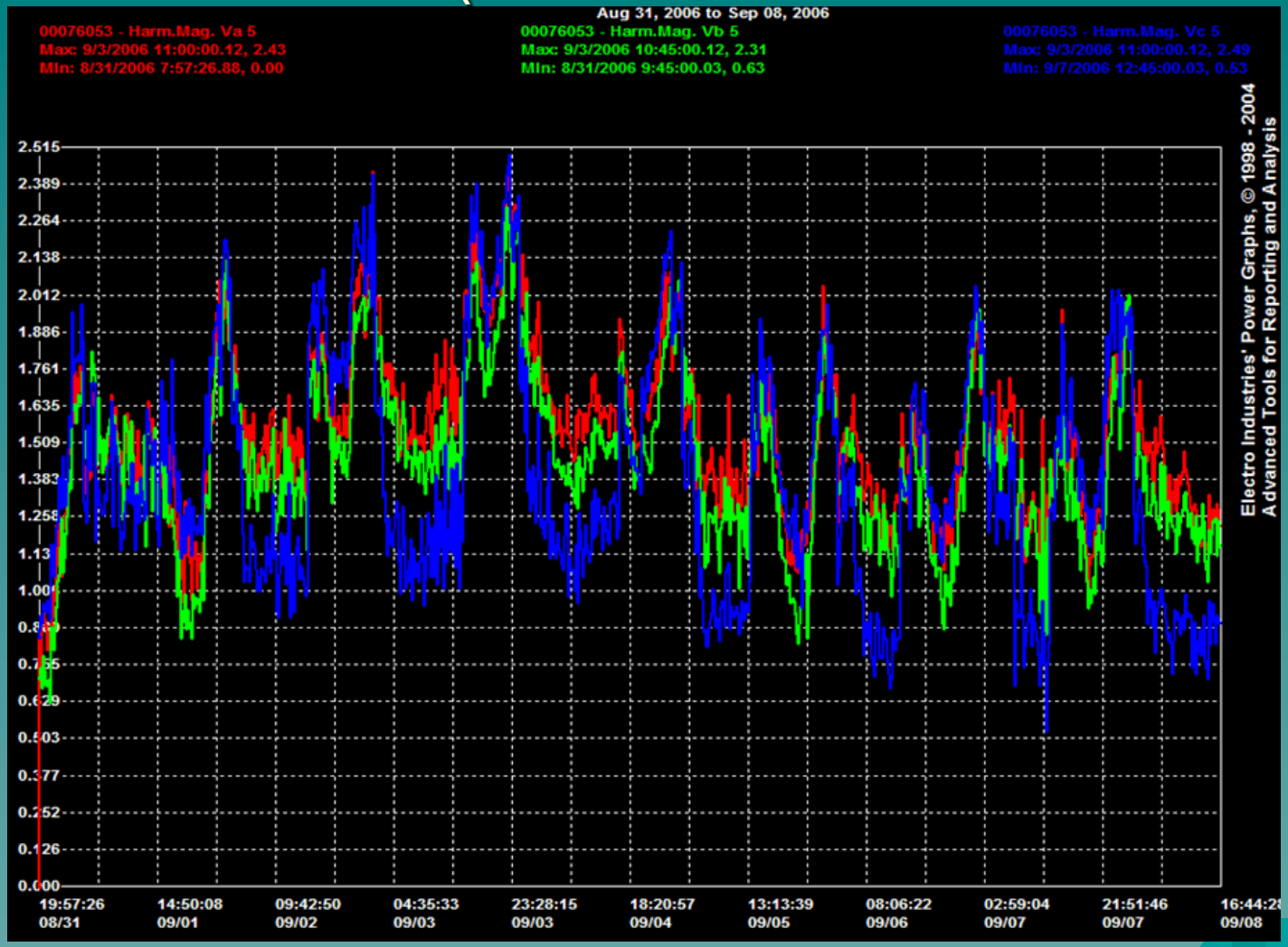
POWER FACTOR 08/31/06- 09/08/06



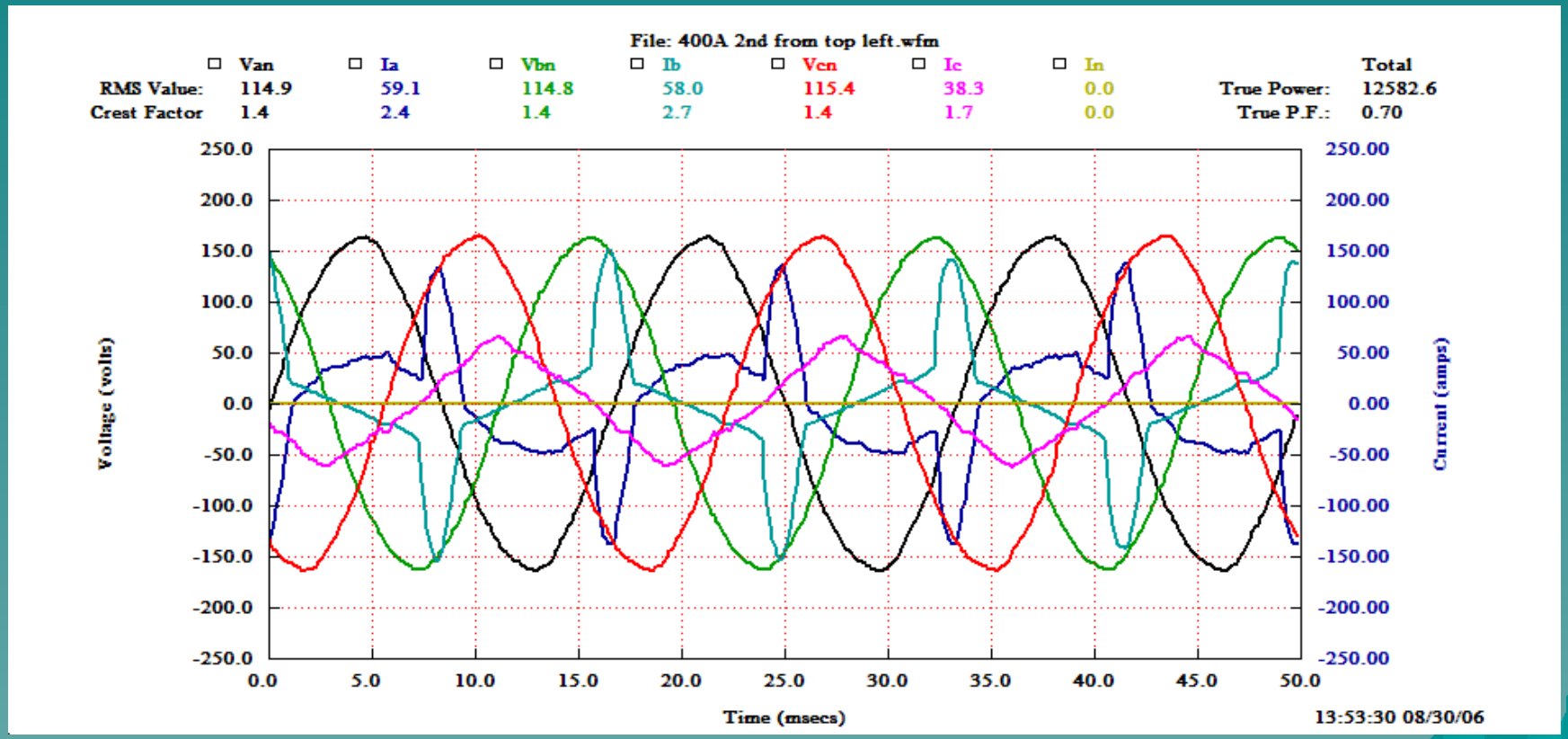
POWER FACTOR DURING PQ EVENT



HARMONICS (5th HARMONIC - VOLTAGE)

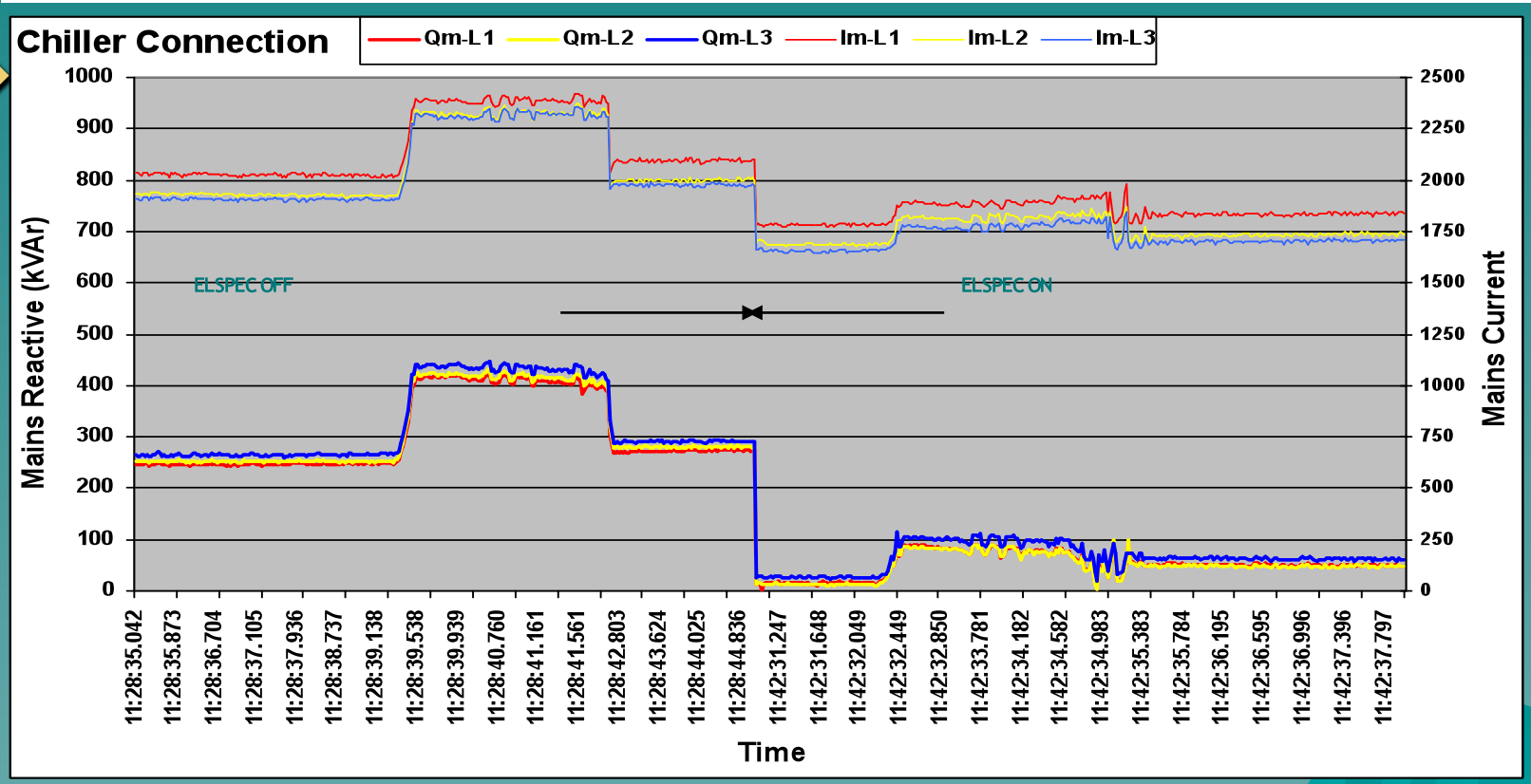


Typical Waveform of High Tech Circuit



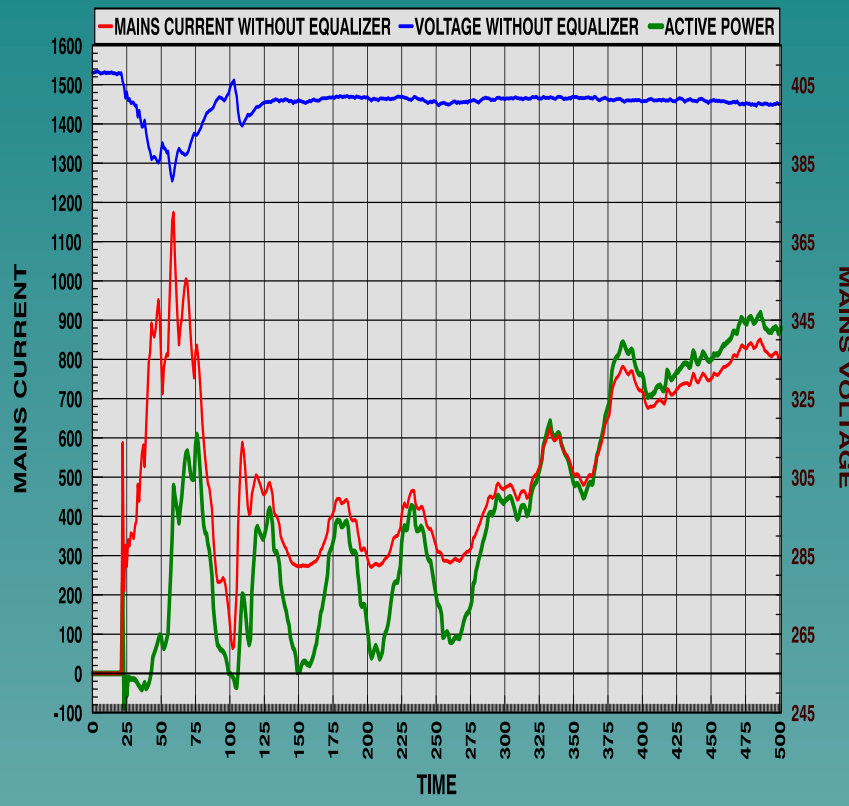
Effect of Elspec on Chiller

Graph 1:
Effect of Chillers on Reactive Power & Current



Elspec Effect on Wind Generator Startup

Graph 2:
Typical Start-up Current & Voltage



Graph 3:
Start-up Current & Voltage w/ EQ-W