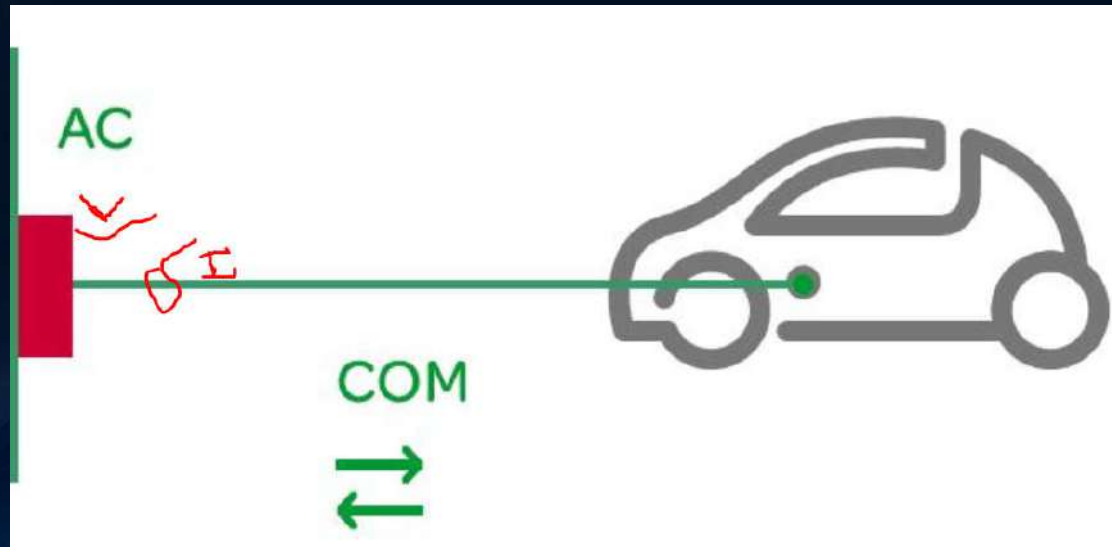


# Electric Vehicle charger case study

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# Power Quality study for EV charger post

- Manufacturer of EV has experienced several internal battery charger failures in new EV's
- 2 sites, 1 in Arizona USA, 1 in Seoul, Korea



# The plan for USA site and Korea site

- Monitor the voltage quality supplying the charger post.
- Monitor the Voltage quality and current load of the EV internal battery charger
- Record all voltage quality parameters
- Record all load factors including
  - Switching
  - Harmonics
  - Peak currents

# Charging post details

**FAST CHARGING** - 7.7kW of power to charge your vehicle quickly

- **QUALITY** - Technology that works for the life of your current plug-in vehicle and then some
- **CONVENIENT** - 25 feet of charging cable for installation and operation flexibility
- **DURABLE** - Rugged, fully sealed NEMA 4 enclosure for installation anywhere





# ELECTRICAL SPECIFICATIONS of charging post

- • **Service** - 208V to 240V - 40A, dedicated circuit
- • **Charge current output power** - 208V to 240V - 32A max
- • **Service ground monitor** - Constantly checks for presence of proper safety ground
- • **Automatic circuit reclosure after minor power faults**
- • **Charge Circuit Interruption Device** - Ground fault protection with fully automated self-test, eliminates manual user testing

# Charging Post normal operation

- Normally, the vehicle will immediately request a charge using a special communication line in the cable. Within a few seconds the green “Charging” light on the face of the HCS will turn on and the charging cycle will begin.
- After an average driving day the vehicle battery pack will require several hours to recharge completely. Charging overnight is the most convenient way to maintain healthy batteries and ensure the vehicle’s full range will be available for the next day.

The front panel on the HCS has four indicator lights, as shown in Figure 1:

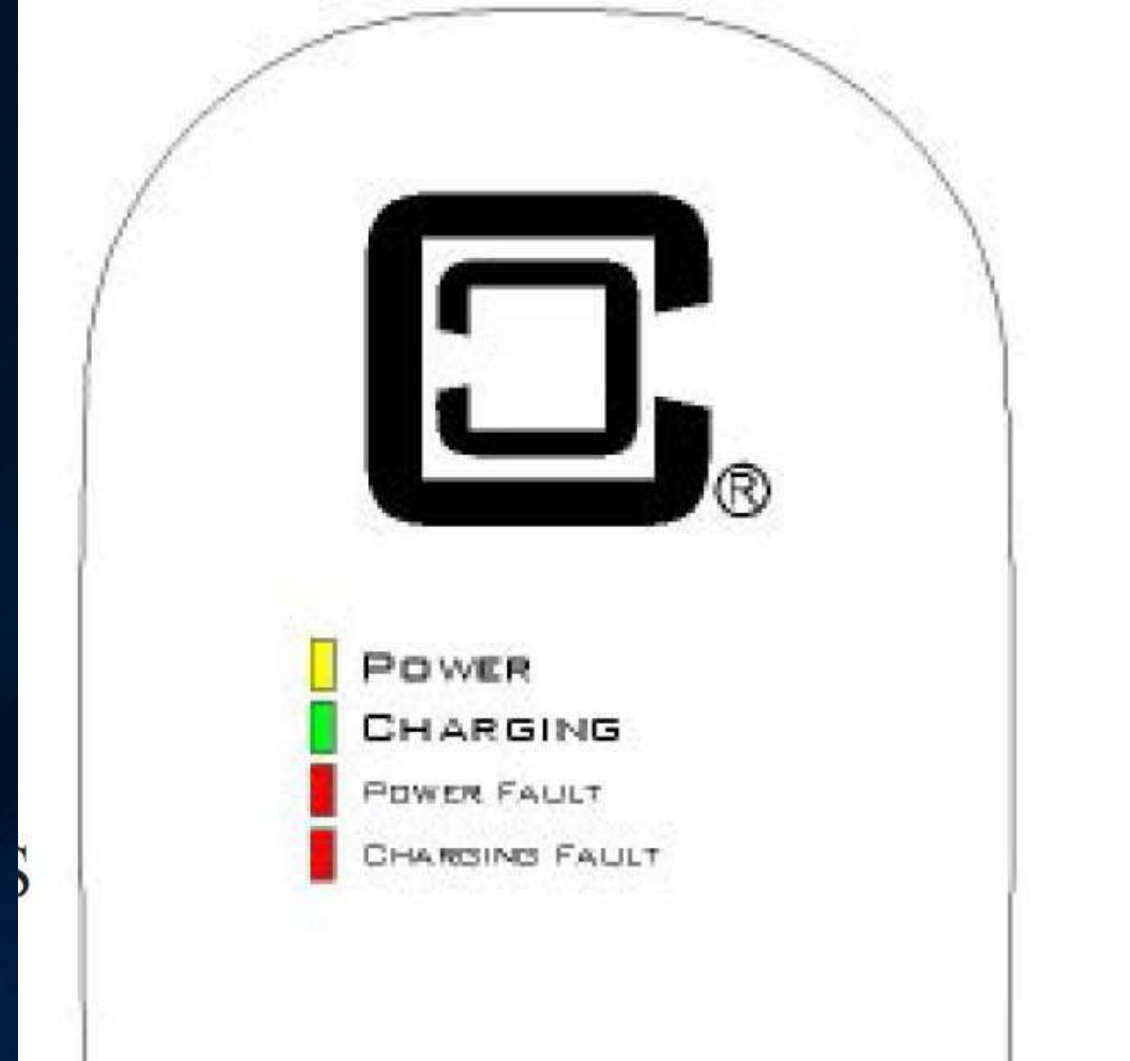
**POWER** (yellow), indicates that power is available to the HCS.

**CHARGING** (green), indicates that the vehicle is requesting a charge and AC power is currently applied to the vehicle.

**POWER FAULT** (red), indicates that the HCS is not wired correctly. The problem can be due to improper grounding or a missing Earth Ground. The wiring should be examined by a qualified electrician.

**CHARGING FAULT** (red), indicates that the HCS is unable to communicate with the vehicle correctly, or a safety fault condition has been detected by the unit.

*Figure 1. Front Panel*

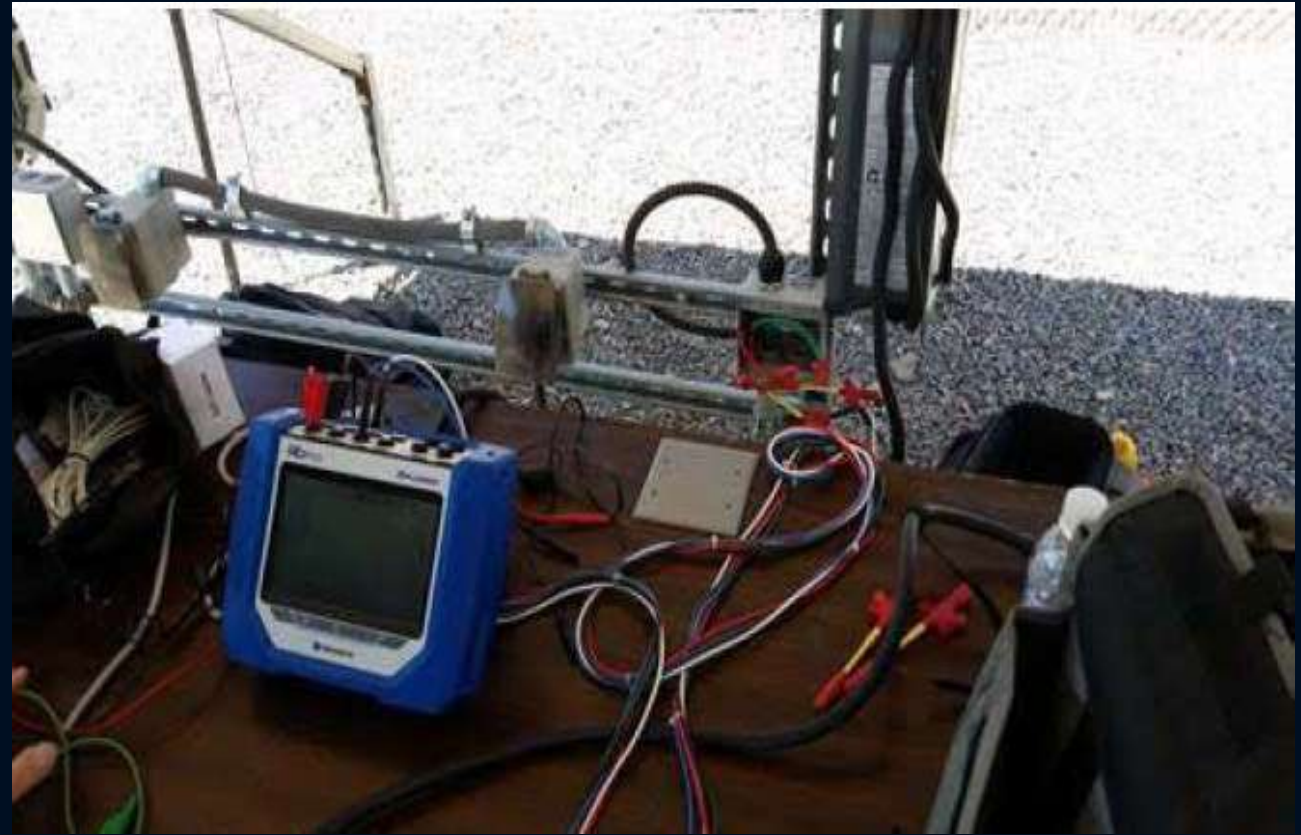


# Installation at the USA Test Setup

- Weather conditions, 105 to 120 degrees F.
  - HCS Maximum Operating Temperature:  $-30^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$  ( $-22^{\circ}\text{F}$  to  $+122^{\circ}\text{F}$ )
- Two cars were used for testing
- Dranetz HDPO Explorer with 3 range Flexi CTs for recording voltage and current
- Channel A was connected to the 208V input to NCS-40 charger control panel.
- Channel C was connected to a test cable from the charger to the car.
- Installed 1 each Dranetz PowerVisa PQ monitor at Charging post B



Dranetz HDPO monitor connected to incoming voltage of charger post



# Connection from Charger pedestal to EV



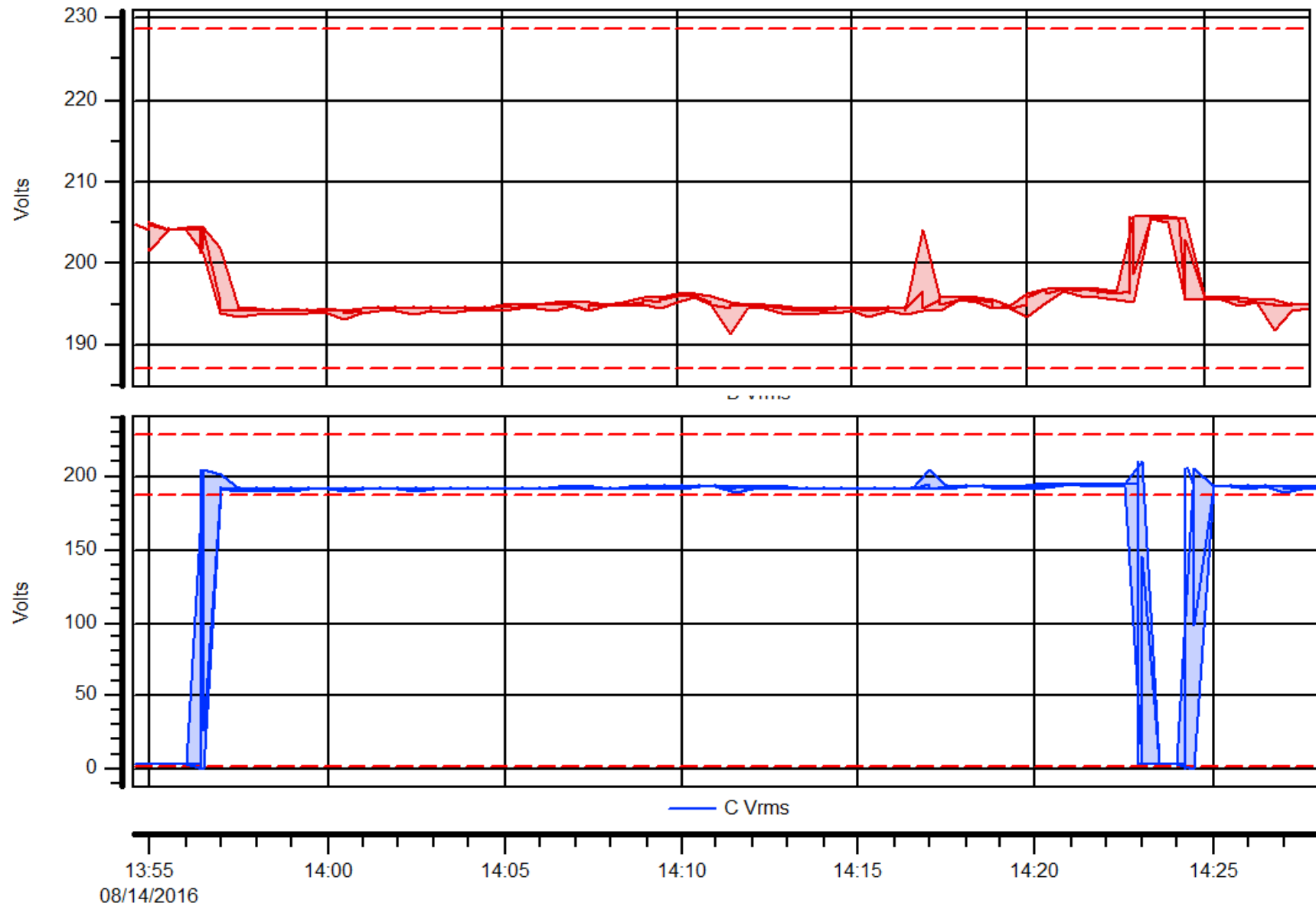
# Tests and monitoring included

- Input and output voltage and current of NCS not attached to car.
- Input and output voltage and current of NCS when attached to car and while charging
- Input and output voltage and current when connecting and disconnecting from car.
- Input and output voltage and current when connecting a second charger to a second car.
- Several repeats of these items

# Input and output voltage of NCS when attached to car and while charging

Site: OUTPUT INPUT

Measured from 08/14/2016 13:54:33.0 to 08/14/2016 14:28:00.0





# Test results

## INPUT/OUTPUT EV CAR NOT CONNECTED

208 volt source voltage waveform from facility source was stable and within normal tolerance of +/-5%; frequency 60.0 hertz

No current and no 208 volt output. Small squarewave output for signaling to EV car

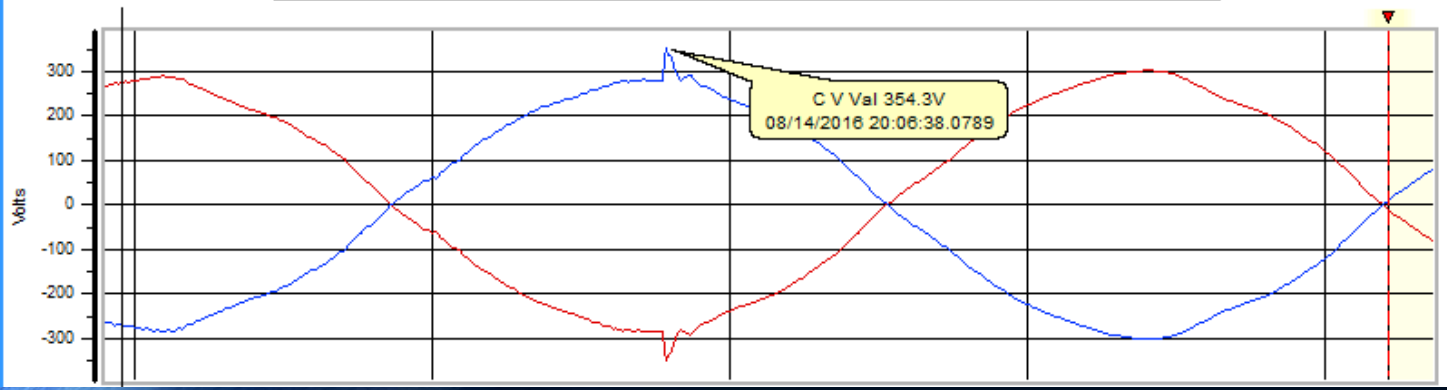
## Input/output with car connected.

- Output voltage delayed until car charger signal
- Output current delayed and slowly ramps up. More details needed. But apparent “soft start”
- Large very fast voltage transient recorded during connection time
- Voltage dropped when charging started.

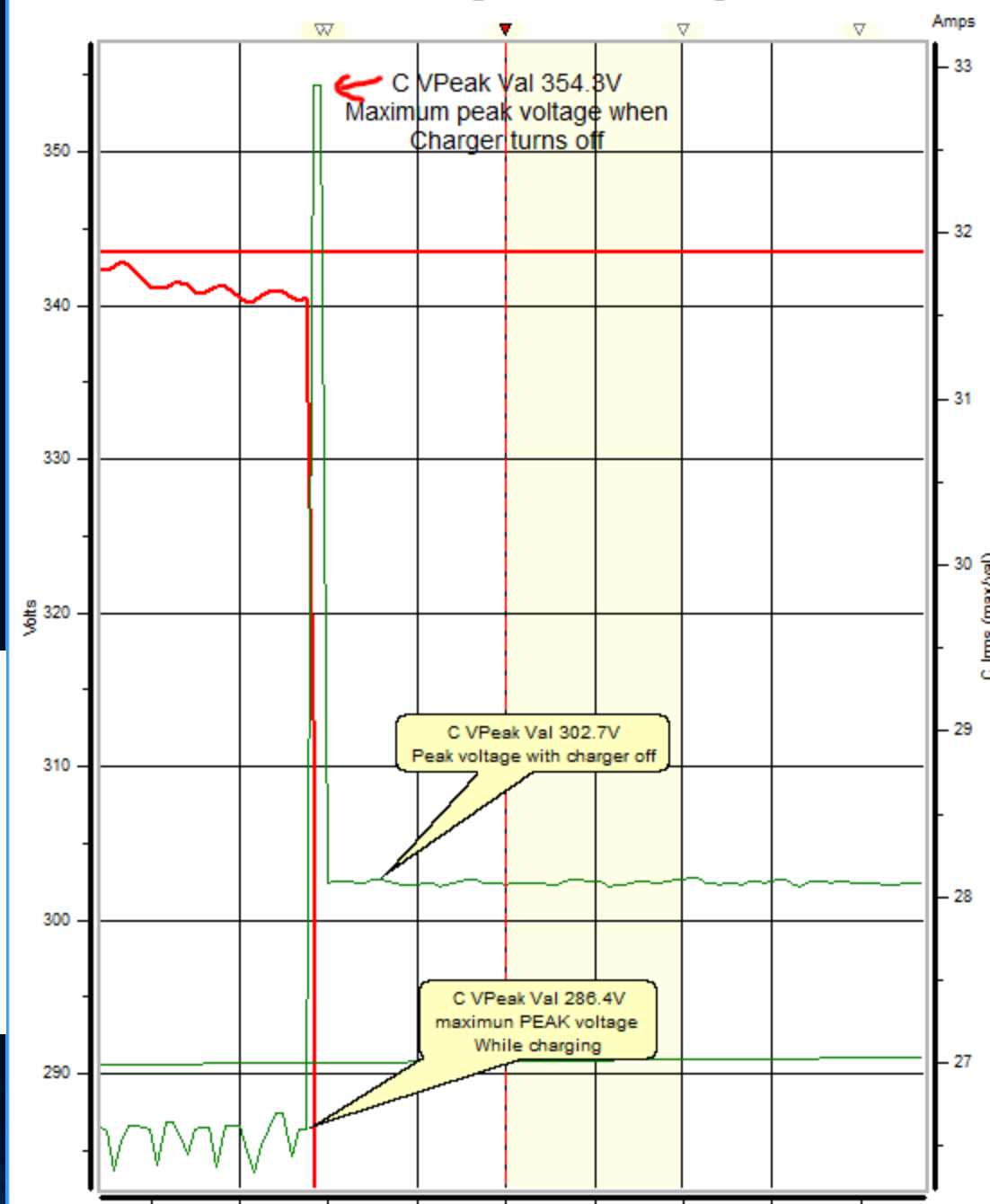
# Input/output during charging switching off

- When charger shuts off, voltage transient.

Peak of RMS voltage occurs after the charger current is off

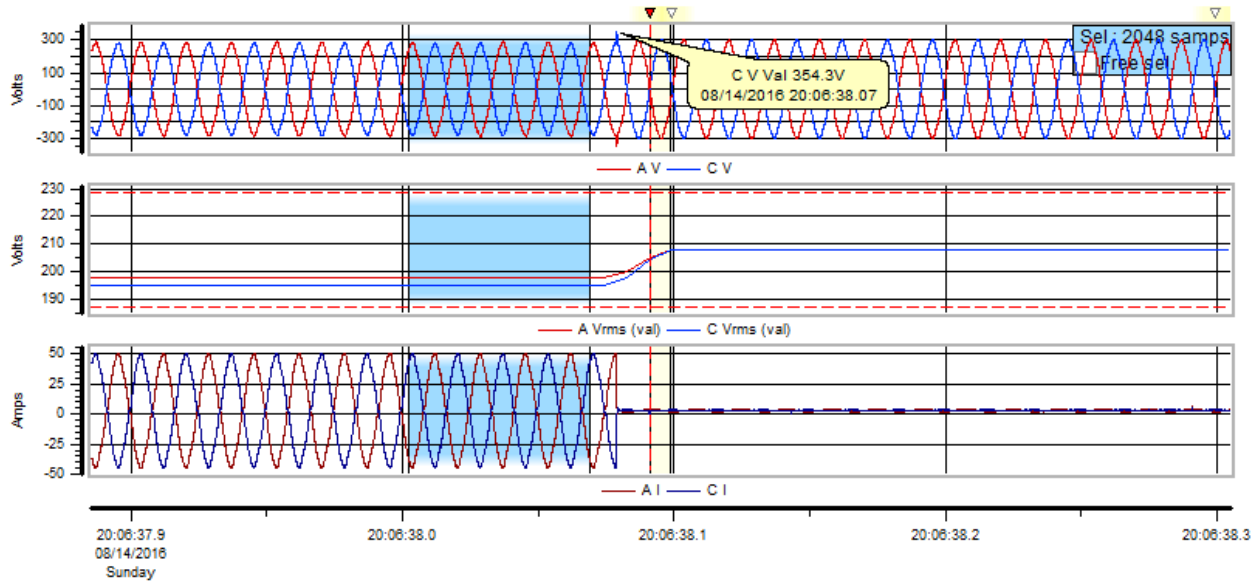


RMS voltage and peak of cycle voltage when charger turns off the current during maintain charge time

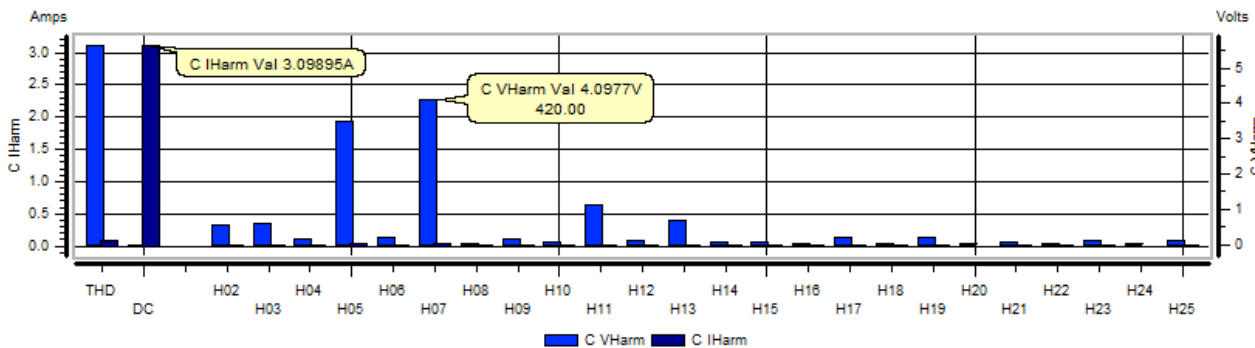


# Harmonic voltage and current with charger on and off

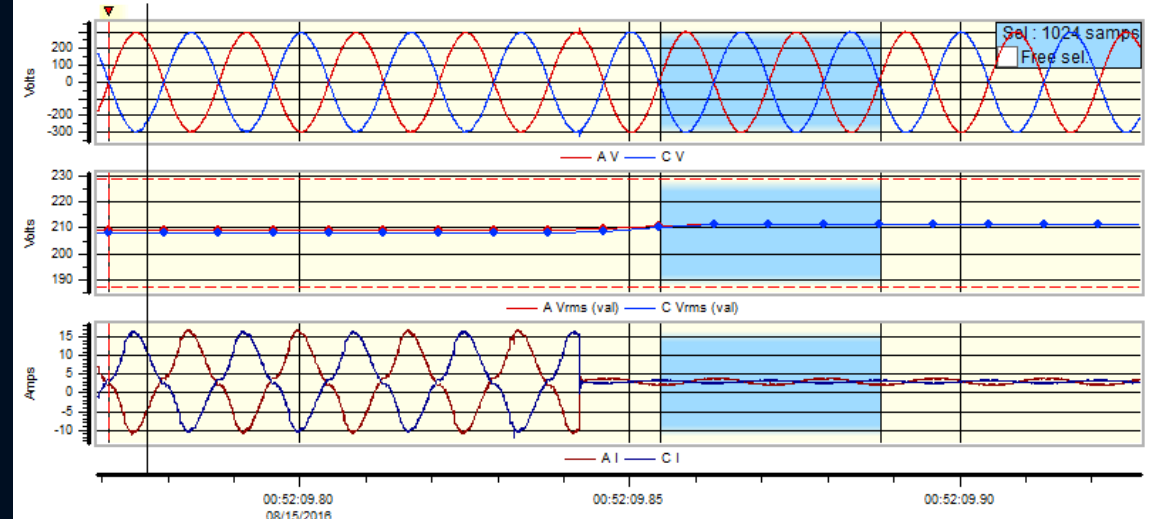
voltage before and after the charger current turns off



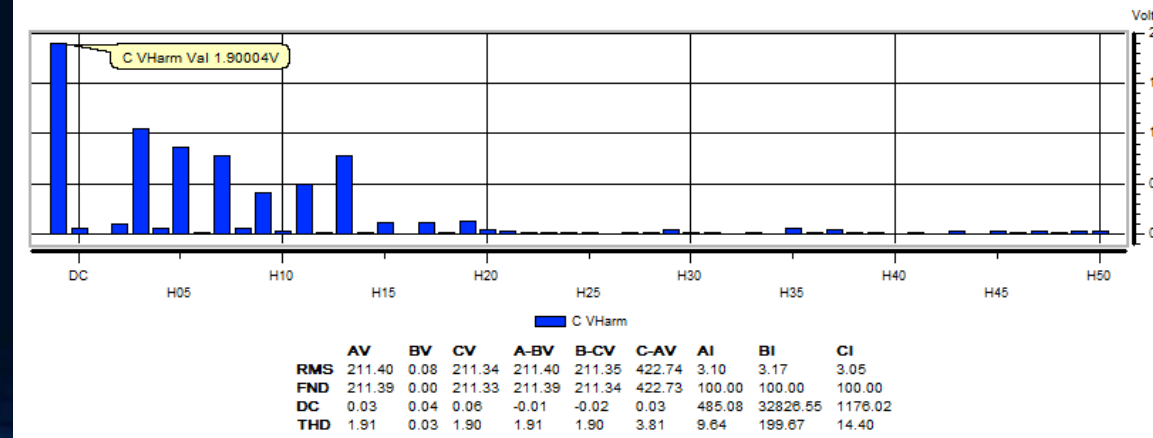
Waveform harmonics



Peak of RMS voltage occurs after the charger current is off



Waveform harmonics





## Input/Output during connection of second car

- Voltage dropped further when second car connected.
- No noticeable transient when second car connected.
- Harmonic voltage distortion increase.....

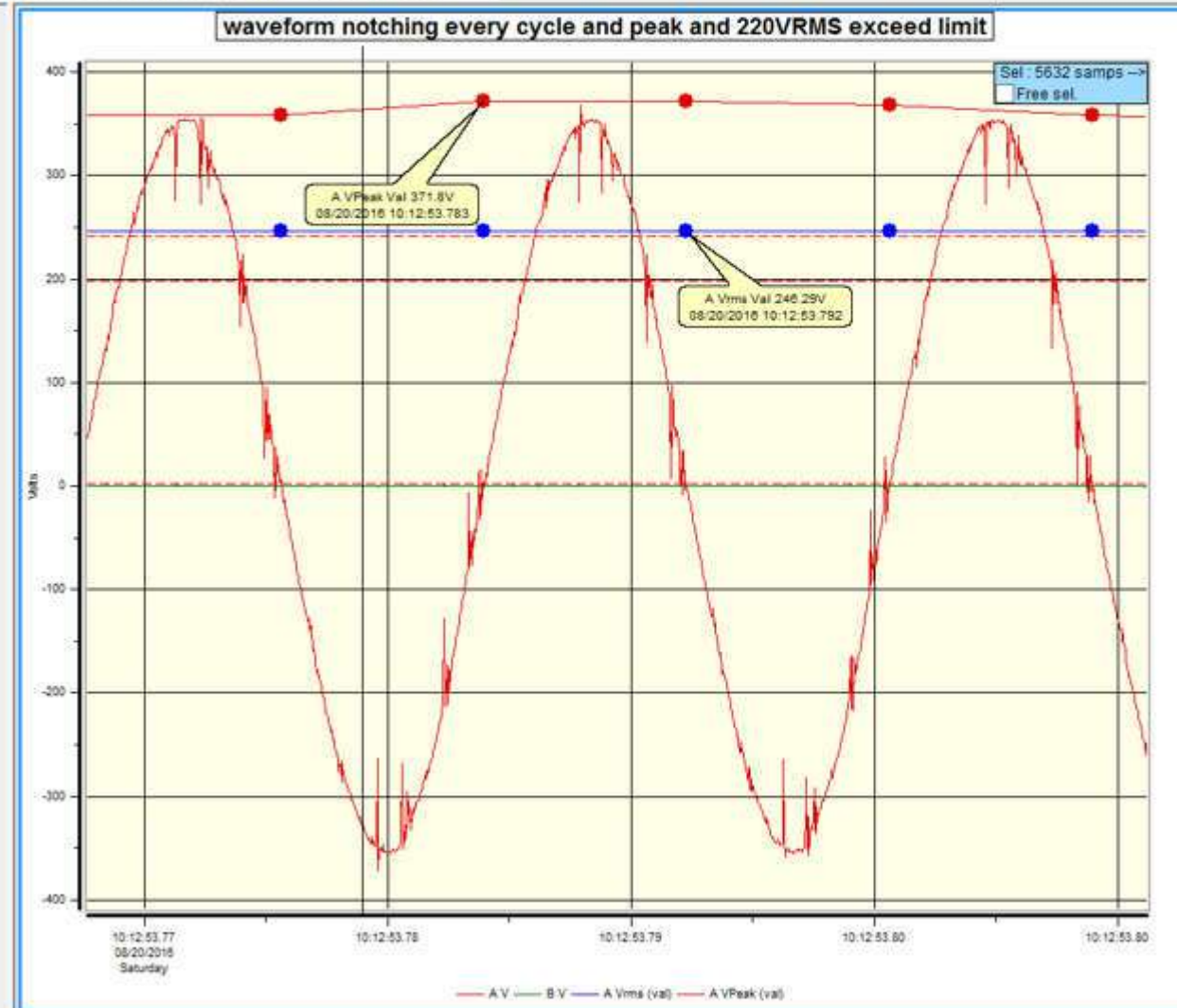
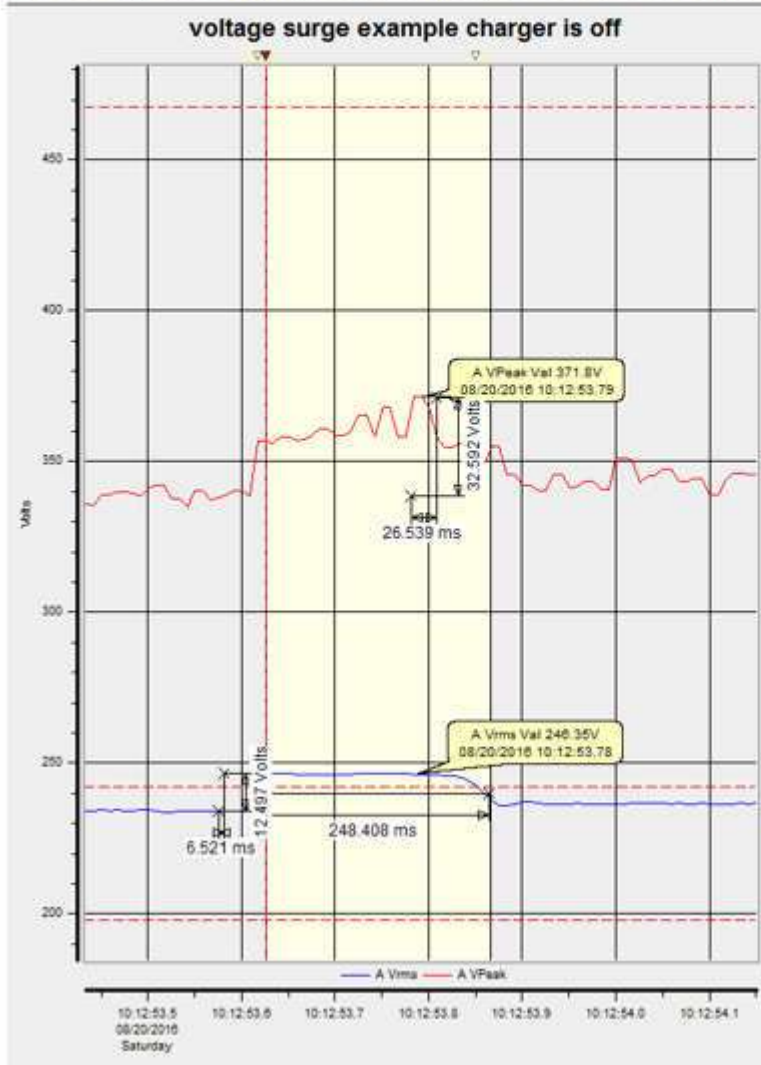
# Change instrument setup to provide better details for inrush current.

- During connection to car and intermittent connection was observed. This may be a contributing factor. Further investigation required

# Monitoring AC source before Charger connected to EVS

Voltage surge and sever notching of waveform RMS value and Waveform peak exceed 220vac limits of +10% and -10%

EVSE input output GM KOREA\_session19 time corrected plus vrms thd plots

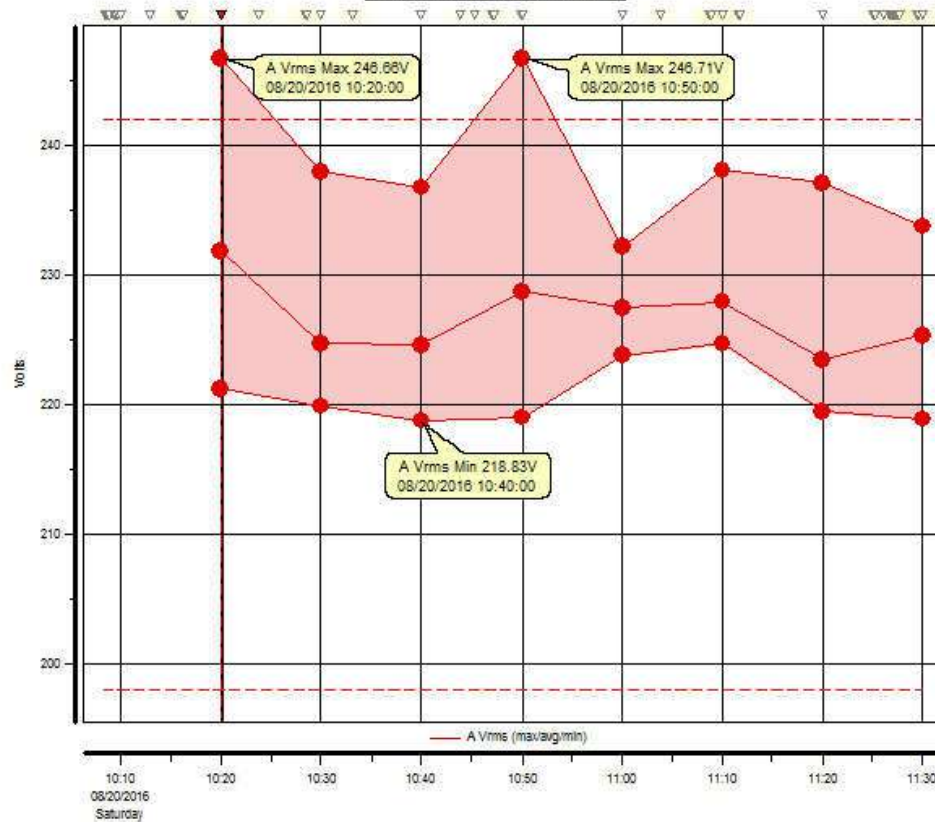


# Voltage rise during test not due to testing of charger post or charger

Monitoring Vrms during charger testing long term graph show Voltage surge during the charger connection test. No voltage sags occurred.

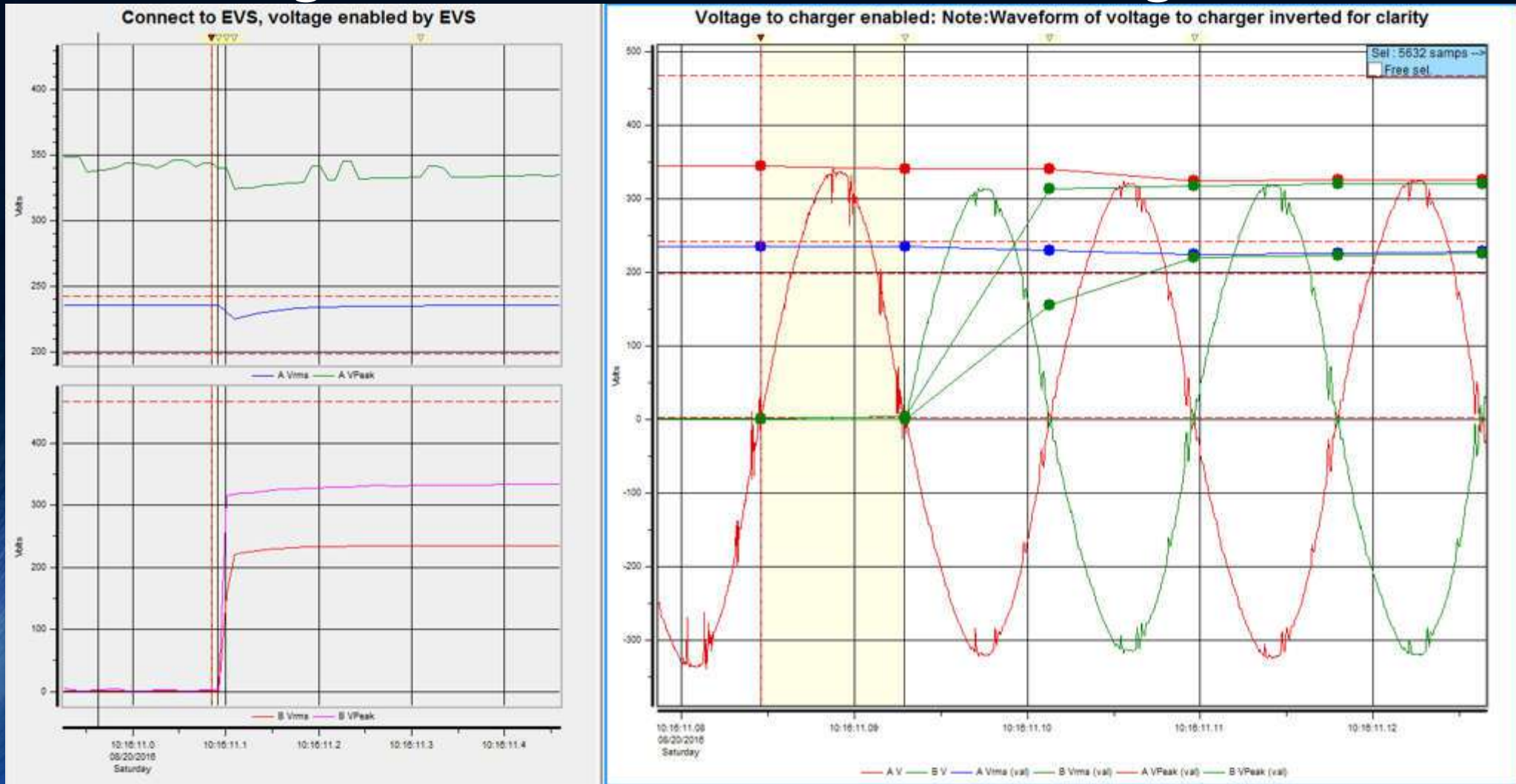
Input Vrms 220V nominal 10 am to 11:30 am

	Min	Max	Avg
A Vrms	218.8	246.7	227.0



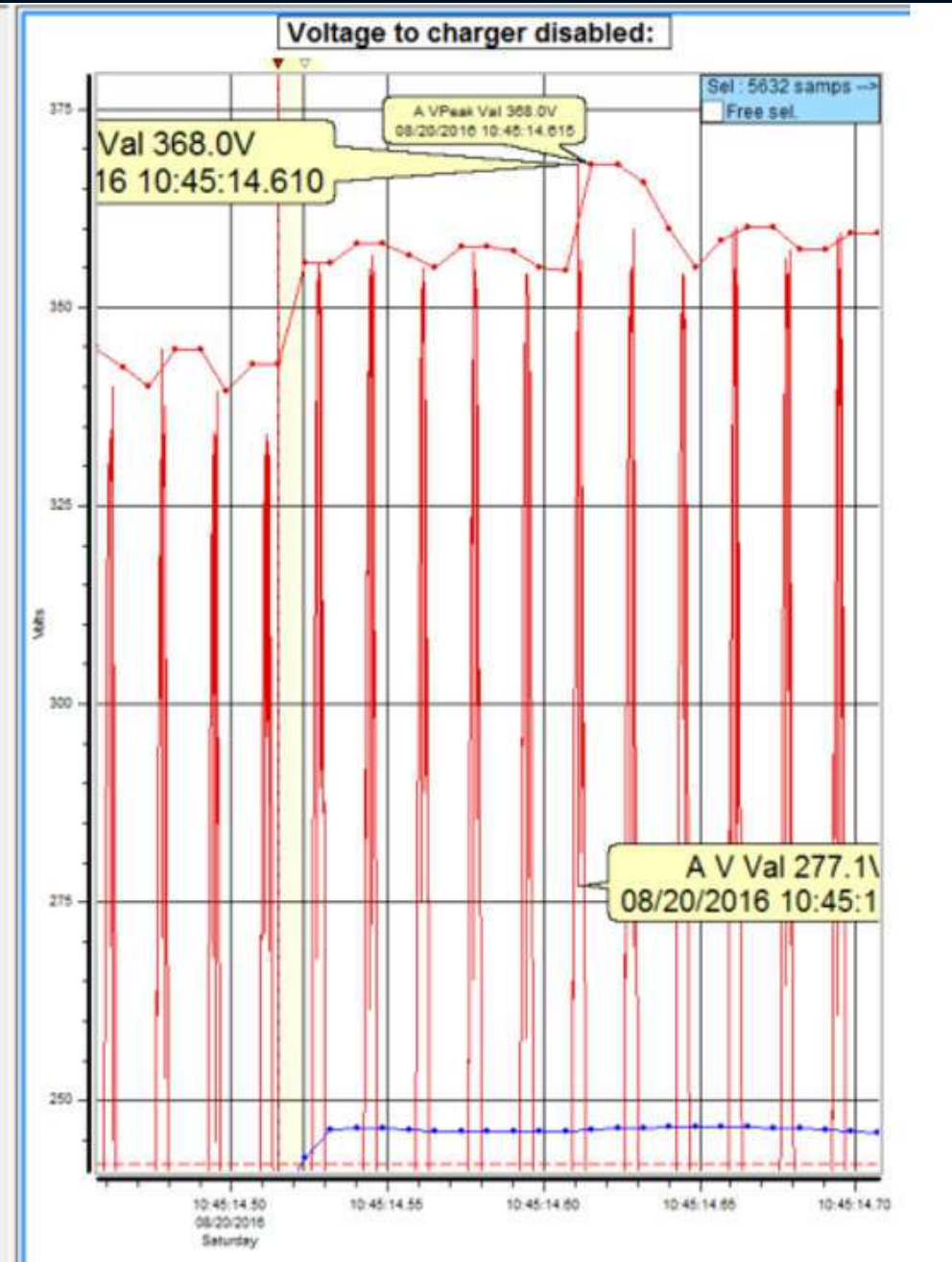
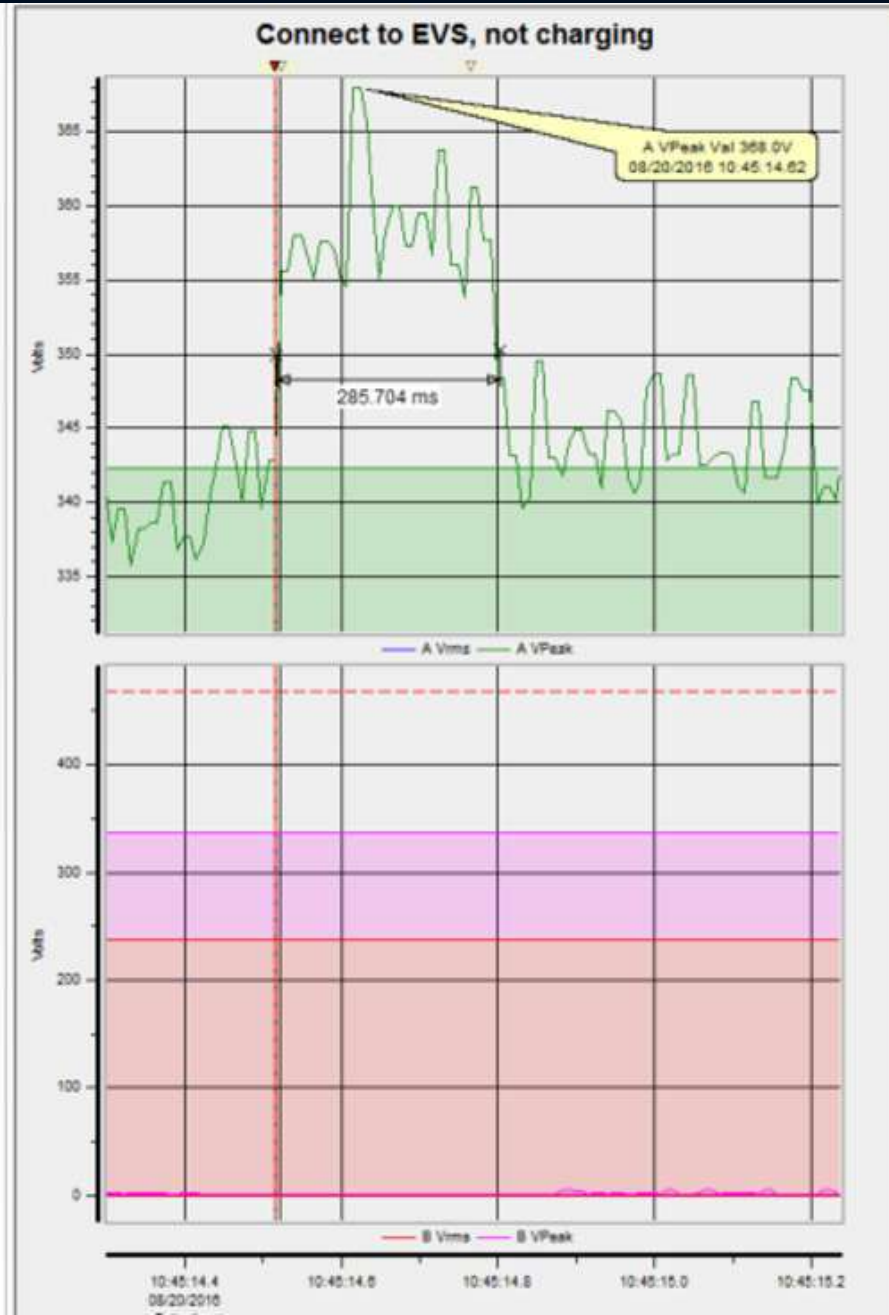


# Voltage rms and waveform during test

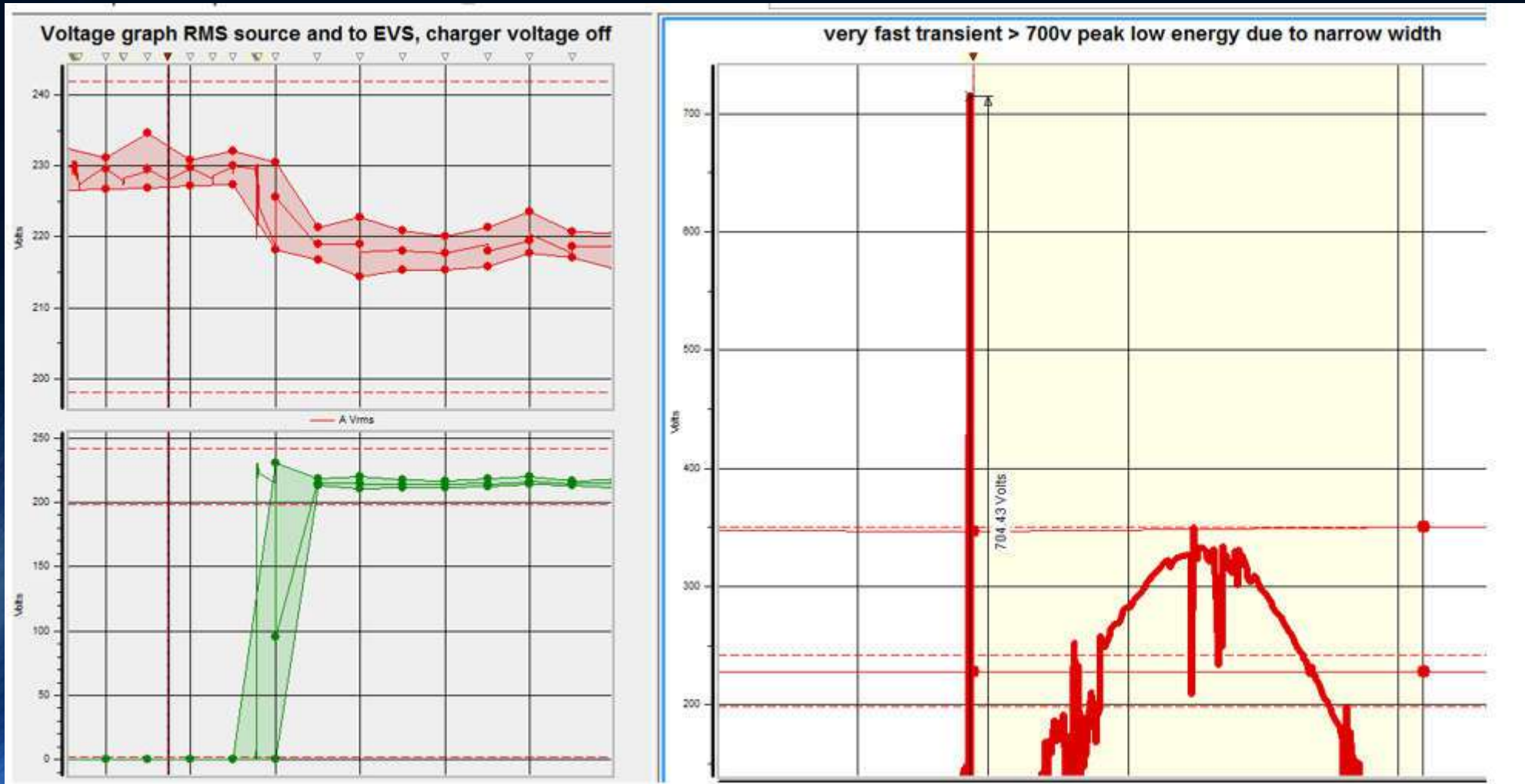


Green graph is peak voltage and waveform every half cycle, red graph waveform is source voltage, blue

# Source voltage variations with charger off

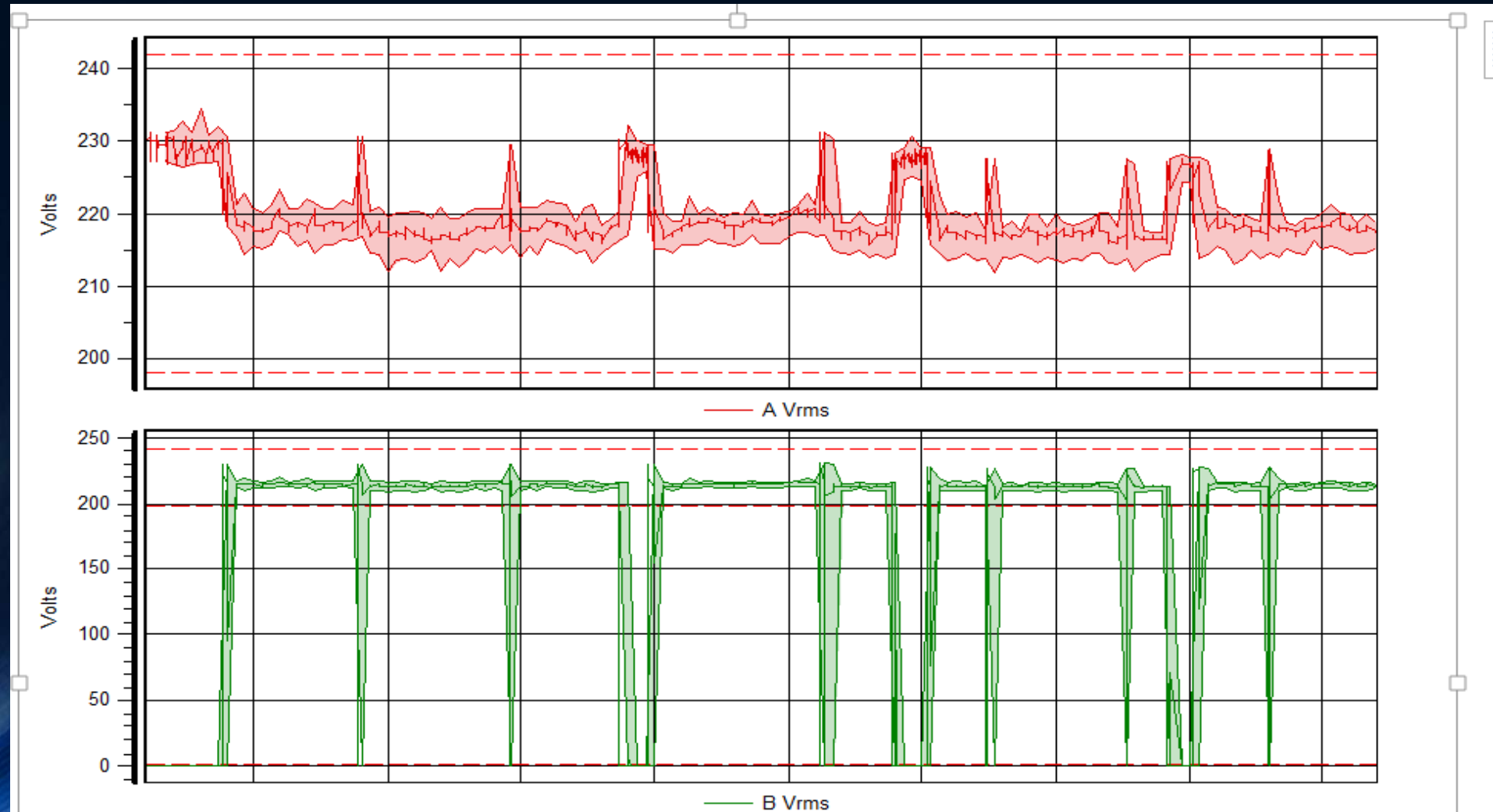


# Source voltage transient to charger post





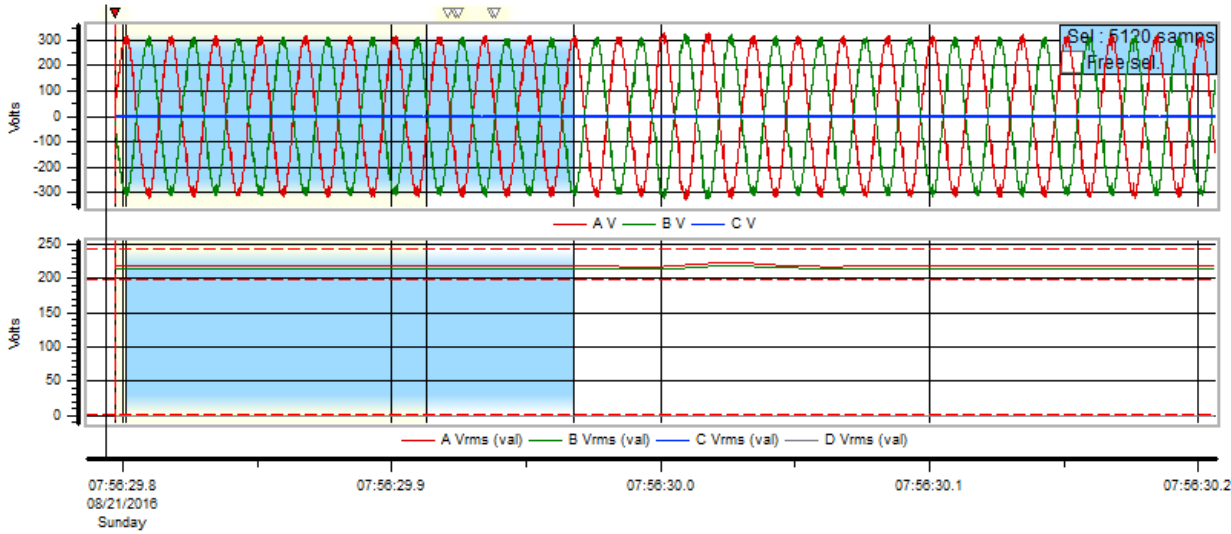
# RMS Voltage variations due to charger operation





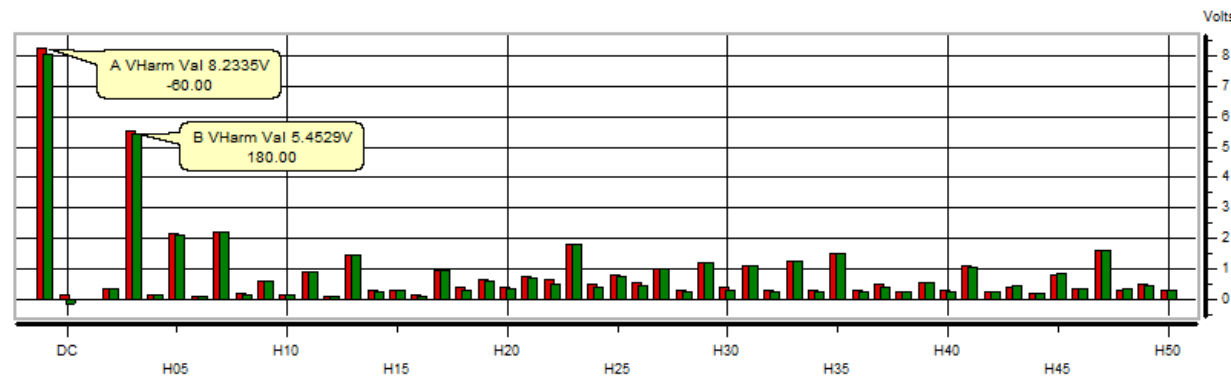
# Charger on and off harmonics

charger on

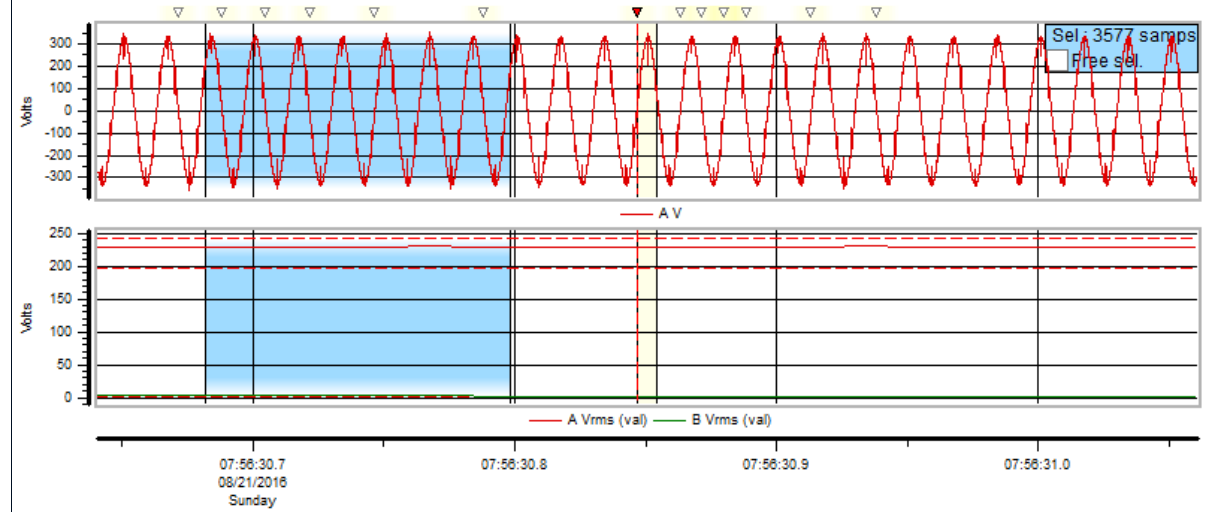


Event #428 at 08/21/2016 07:56:29.798  
Pre-trigger

Waveform harmonics

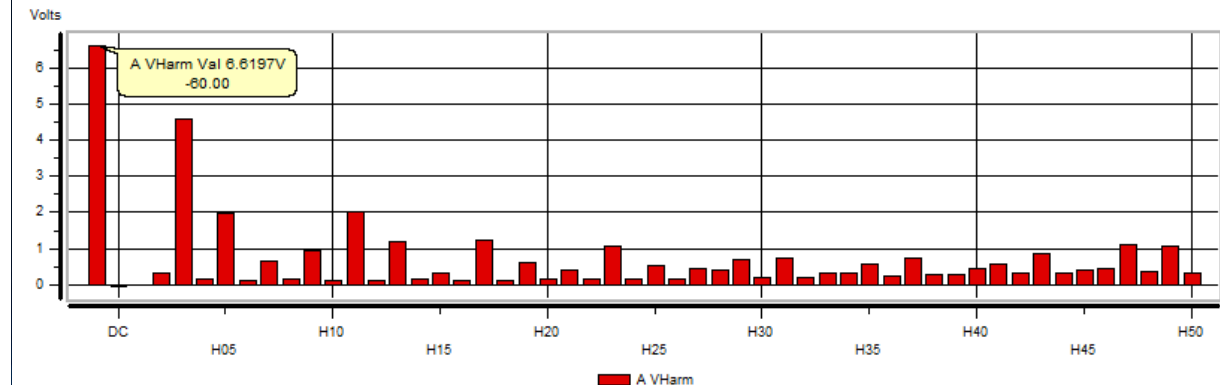


charger off



Event #456 at 08/21/2016 07:56:30.846  
AVPeak Normal To High  
Threshold crossed 350.0

Waveform harmonics



# Summary

- Source voltage is fed direct to EV charger without filtering, regulation or surge protection.
- Harmonics increase when EV charger comes on is dependent on the source impedance and will vary site to site.
- The EV chargers are at risk to damage due to source voltage PQ events.
- Not all source voltage PQ issues are from the utility
- Some charger sites have transient voltage surge suppression.
- The EV charger loads will vary by EV manufacturer. Tested units showed charger current and supply voltage from the charger post are controlled by the EV charger

# Thank you

- Questions
- Contact [TerryC@powerquality.org](mailto:TerryC@powerquality.org)