Multiple Car Charging and PQ Analysis

EV Panel Session

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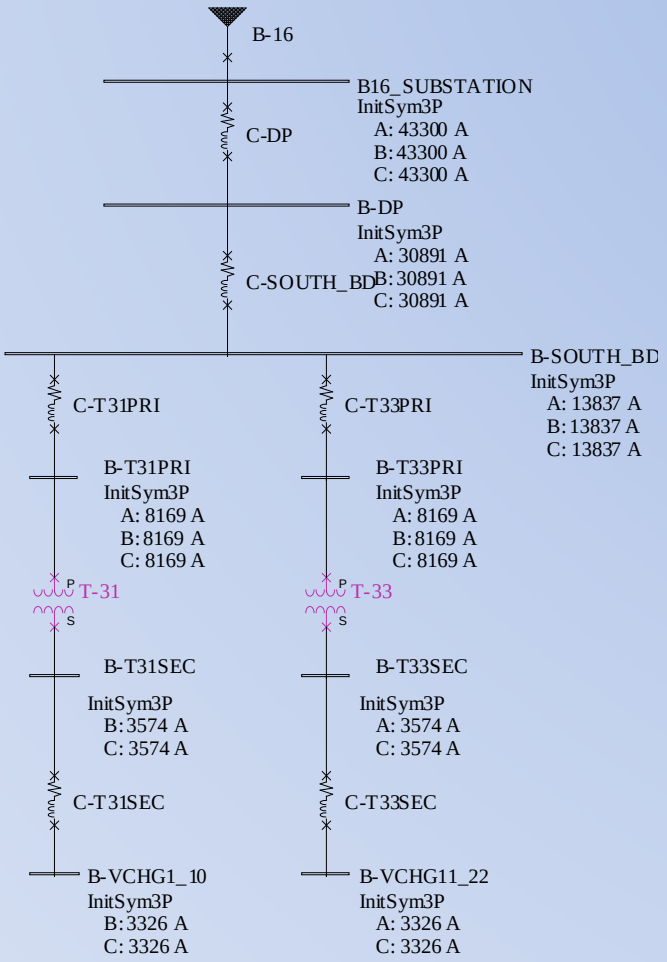
Analysis of 22 EV Charging Stations

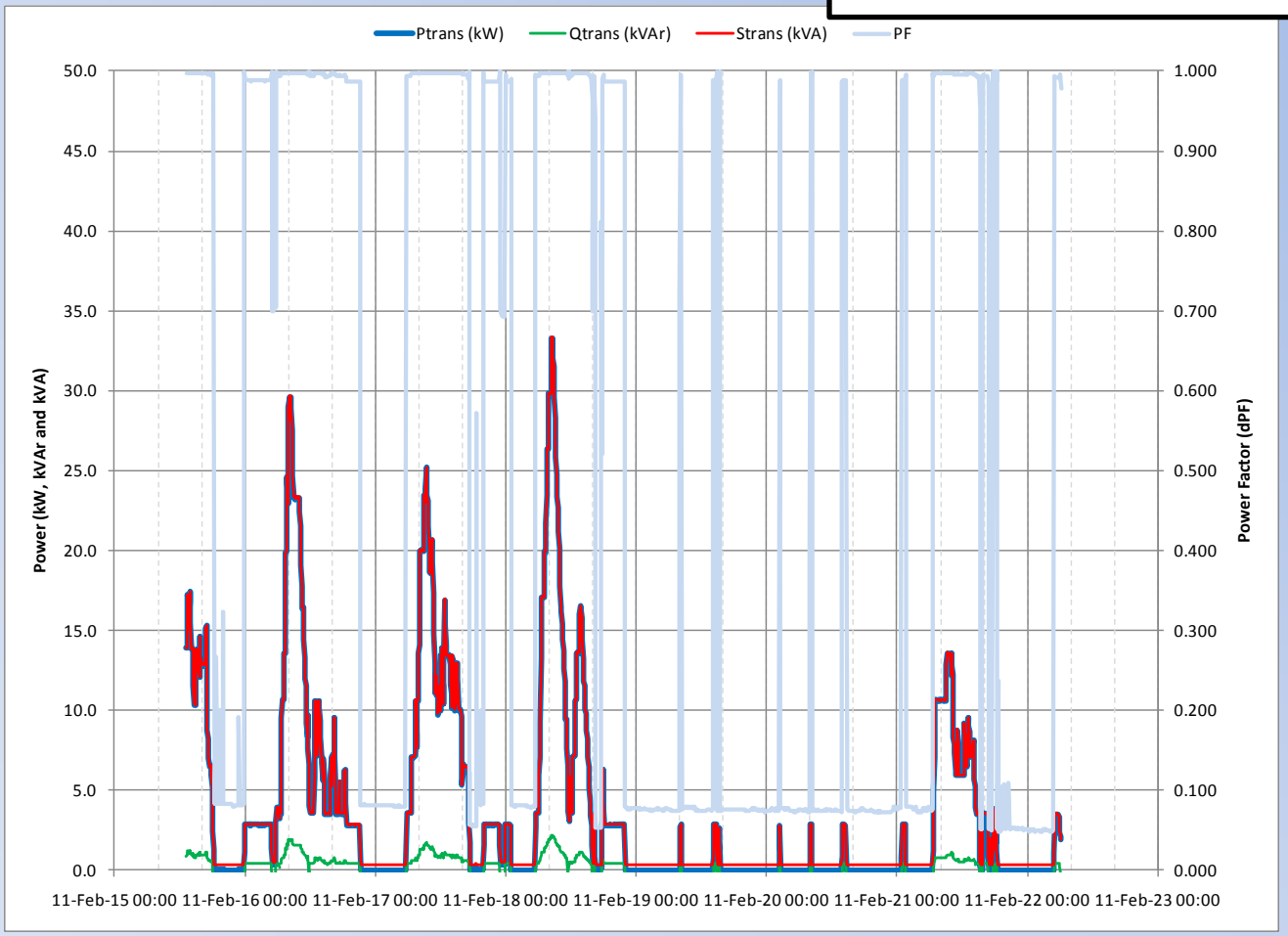
- Overview of Monitored Data
- Discussion of Diversity
- Power Quality of the Chargers

Circuit Fault Diagram



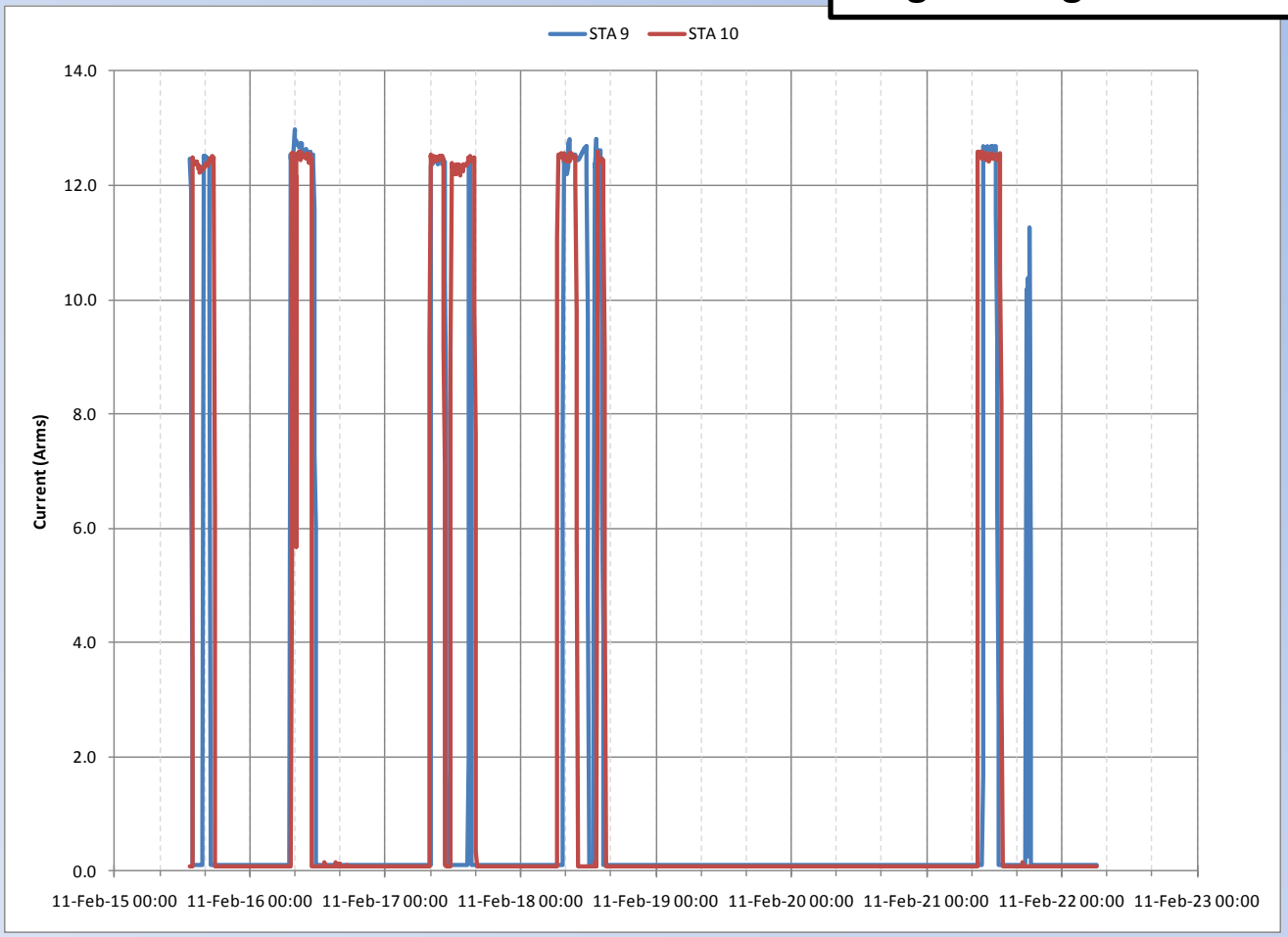
Monitoring of Stations 1-10

Stations 1 -10 over One Week



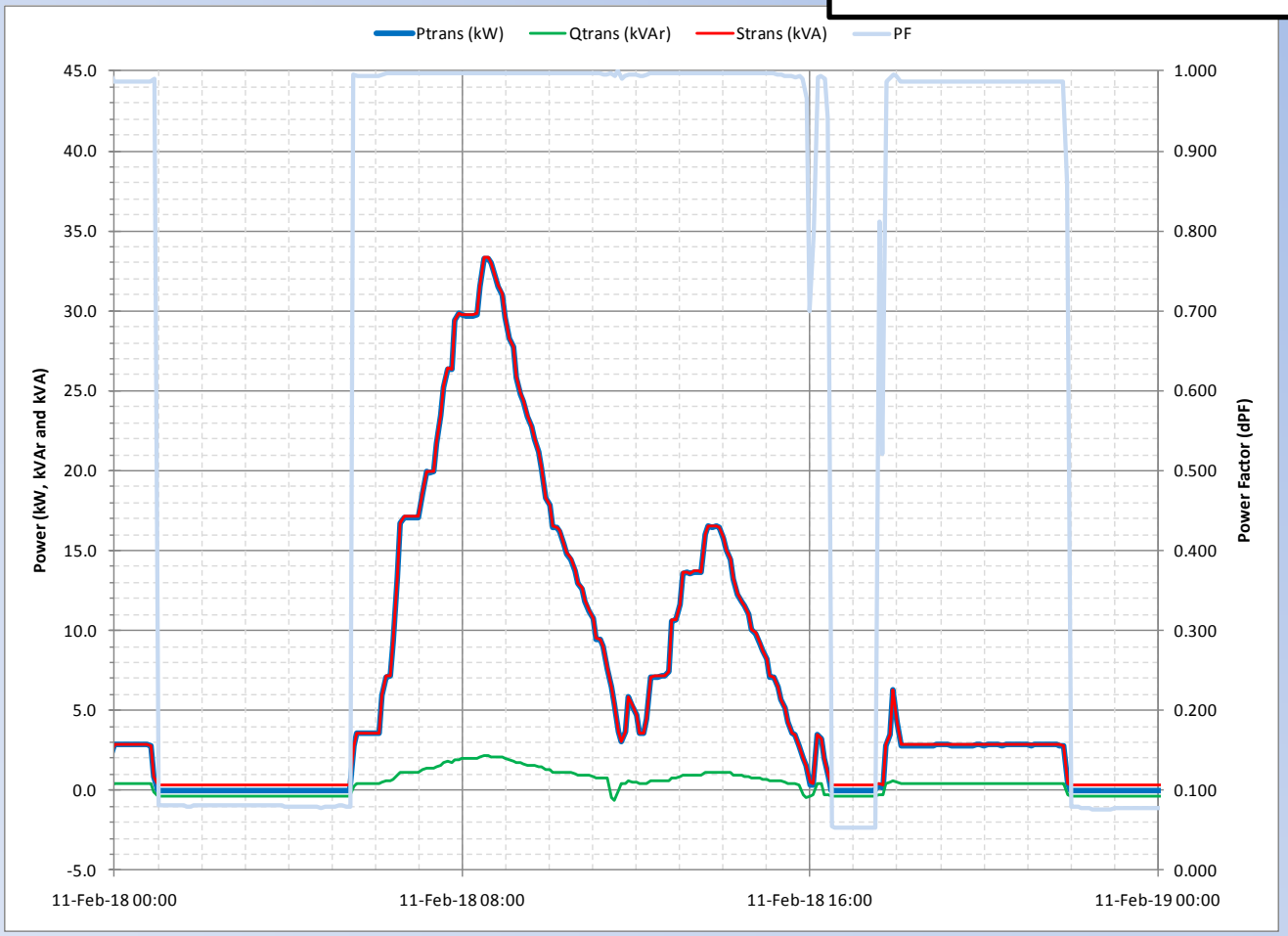
Monitoring of Stations 1-10

Single Chargers over One Week



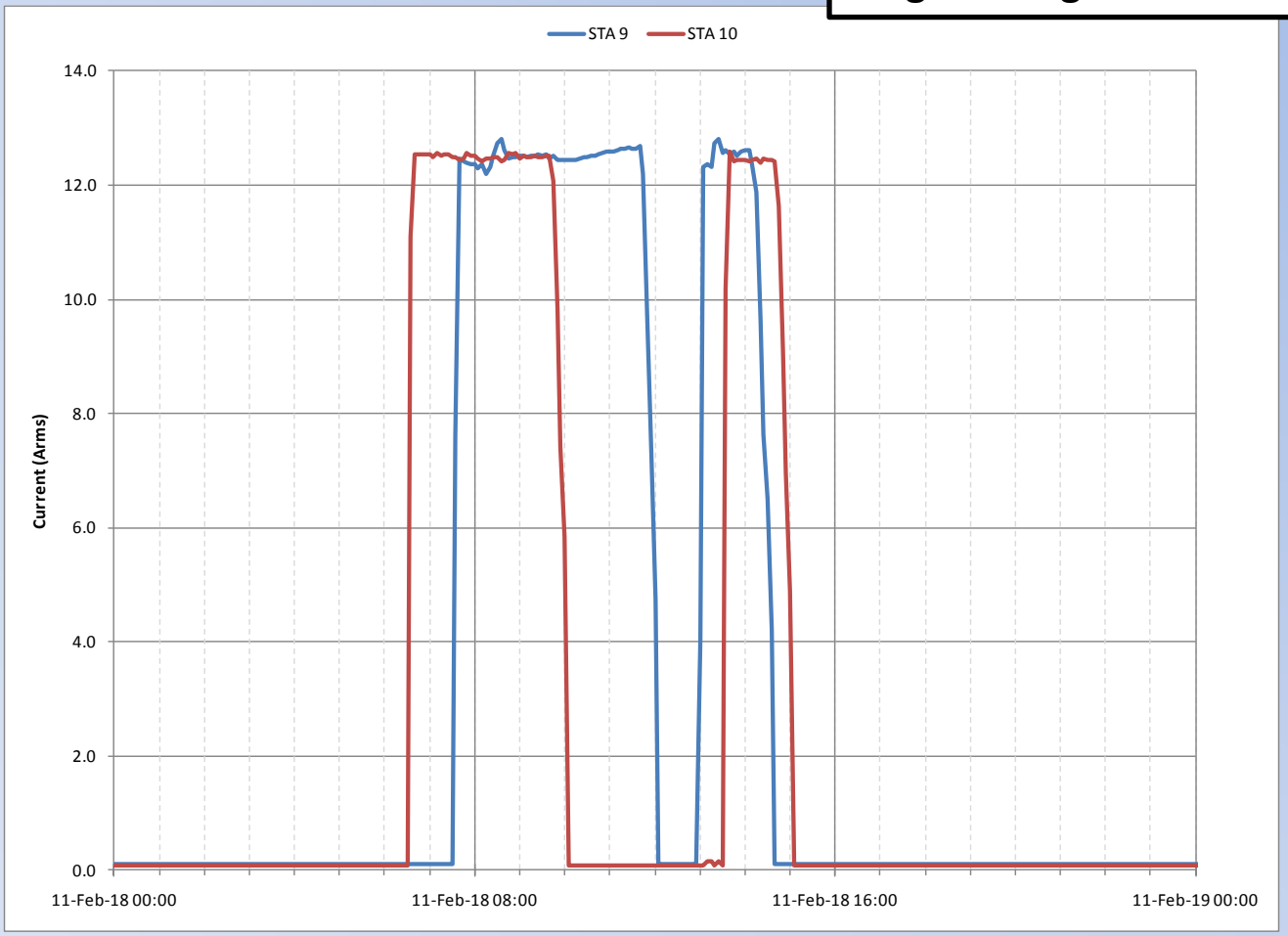
Monitoring of Stations 1-10

Stations 1 – 10 over One Day



Monitoring of Stations 1-10

Single Chargers over One Day

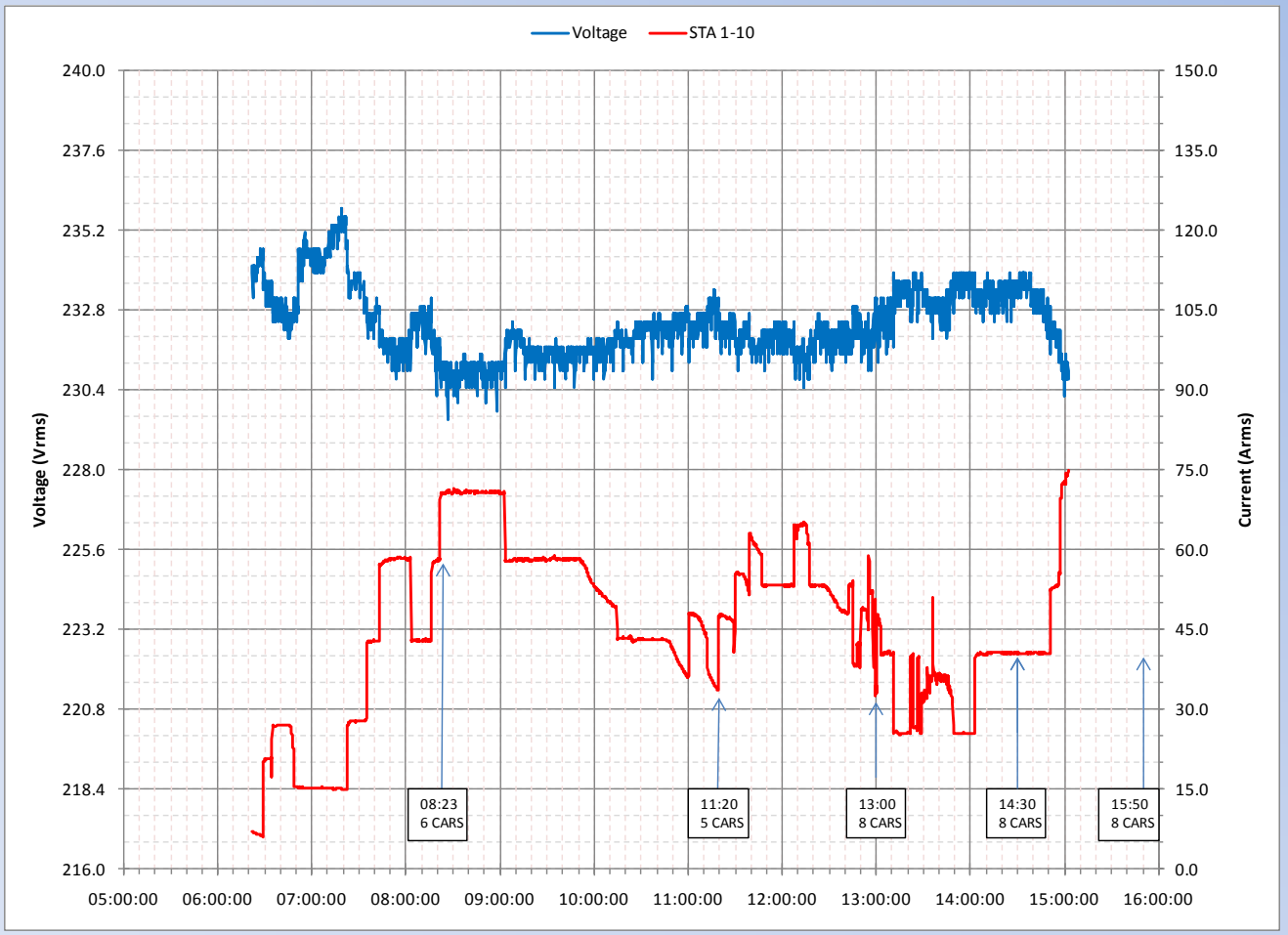


Diversity Analysis

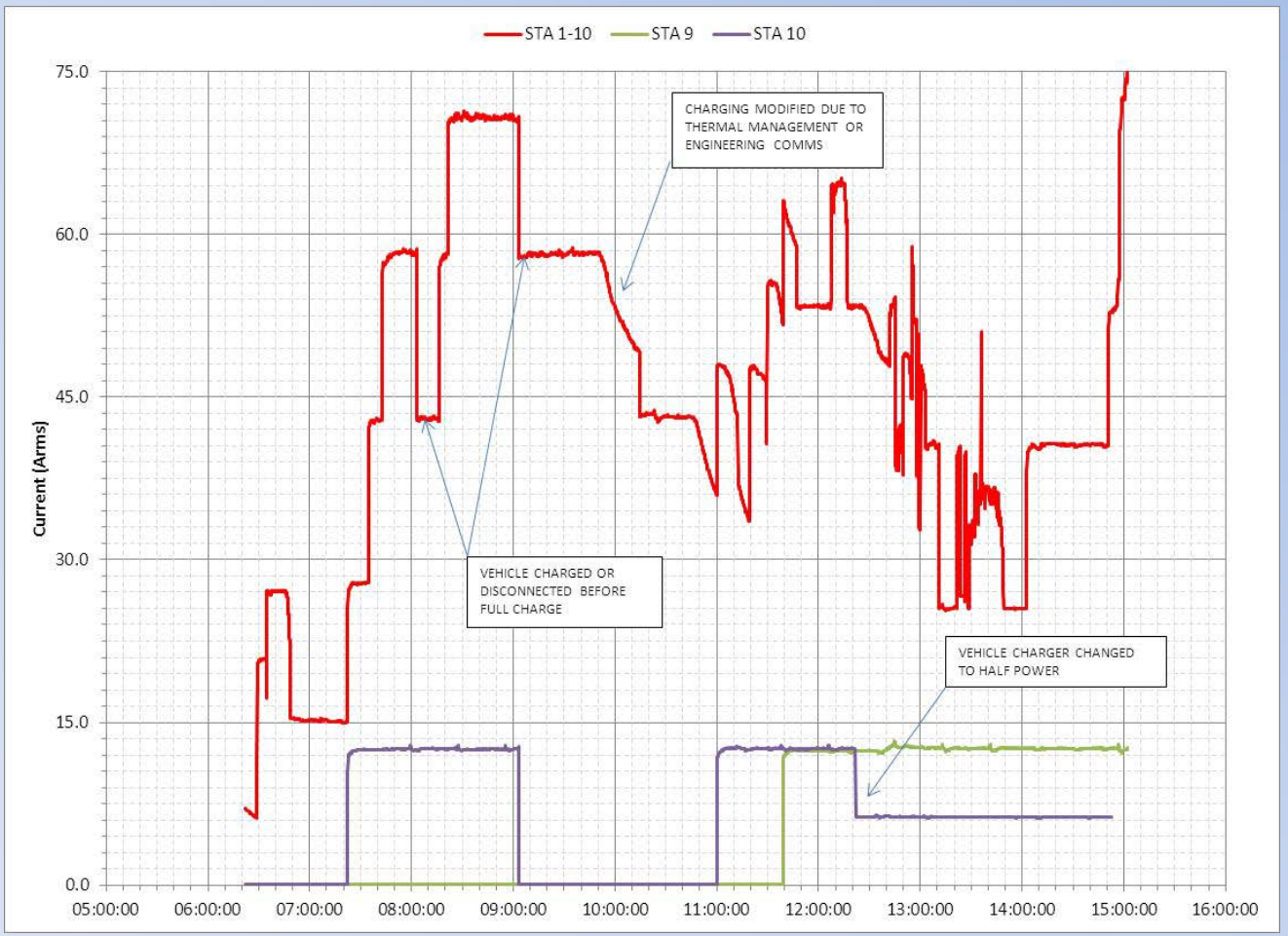
Observation of Vehicles (1-12) at Charging Stations 1 - 10

STA	8:23	11:20	13:00	14:30	15:50
1	*1*		*7*	*7*	*7*
2			*8*	*8*	*8*
3					*12*
4	*2*	*2*	*2*	*2*	
5	*3*		*3*	*3*	
6	*4*	*4*	*4*	*4*	*4*
7				*5*	*5*
8	*6*	*6*	*6*		*11*
9			*9*	*9*	*9*
10	*5*	*10*	*10*	*10*	*10*

Diversity Analysis

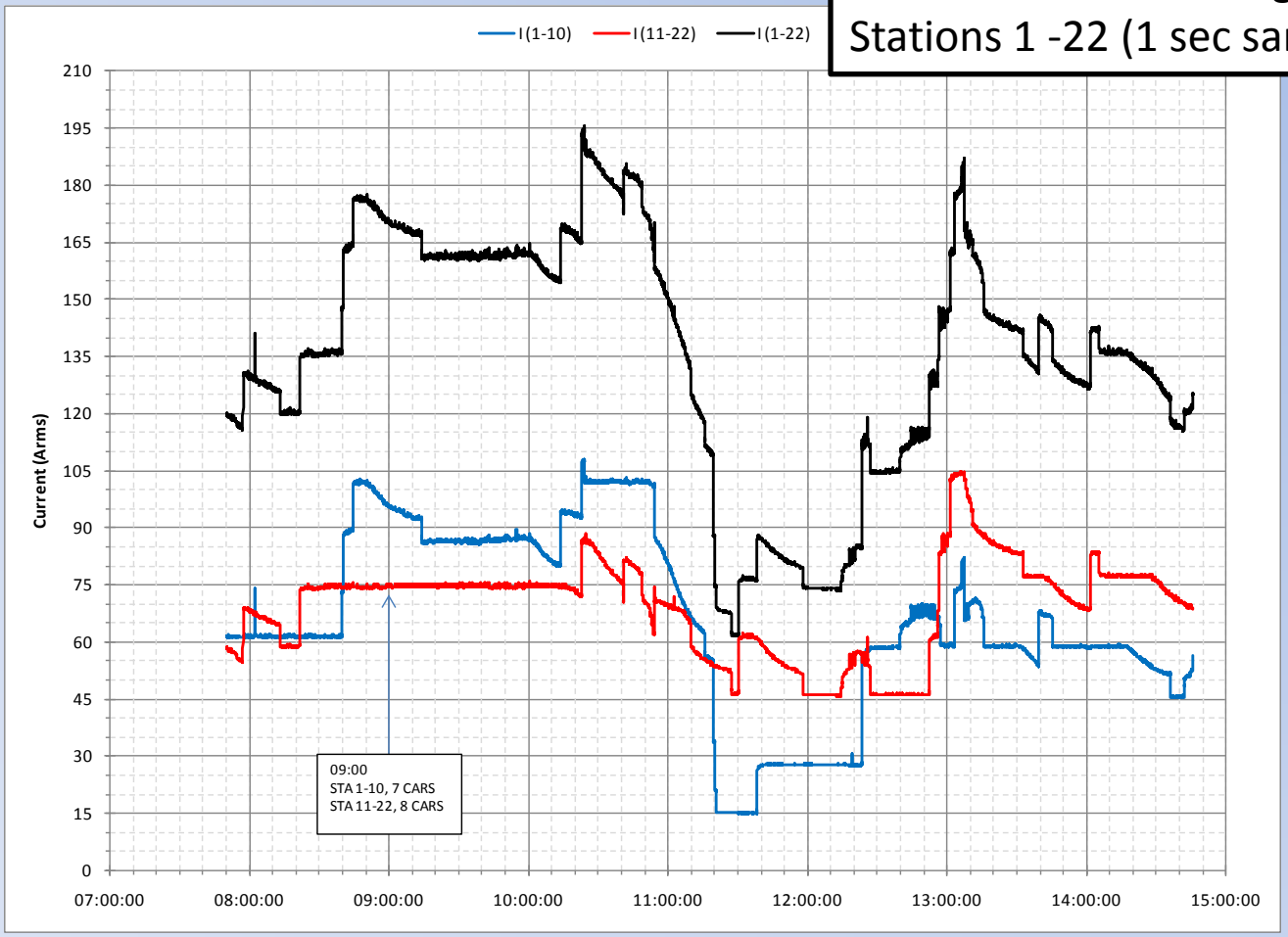


Diversity Analysis



Diversity Analysis

Seven Hour Monitoring of Stations 1 -22 (1 sec samples)



Diversity Analysis (Peak Load)

- Over a one week period, the three Peak Loads were found to be 97%, 87% and 73% of full load for Stations 1 through 10.
- These peaks always occurred in the morning and were never more than 10-minutes in duration.
- These measurements were made at a location that all twenty-two locations are expected to have a vehicle connected every business day.

Diversity Analysis (Why the Load is Diverse)

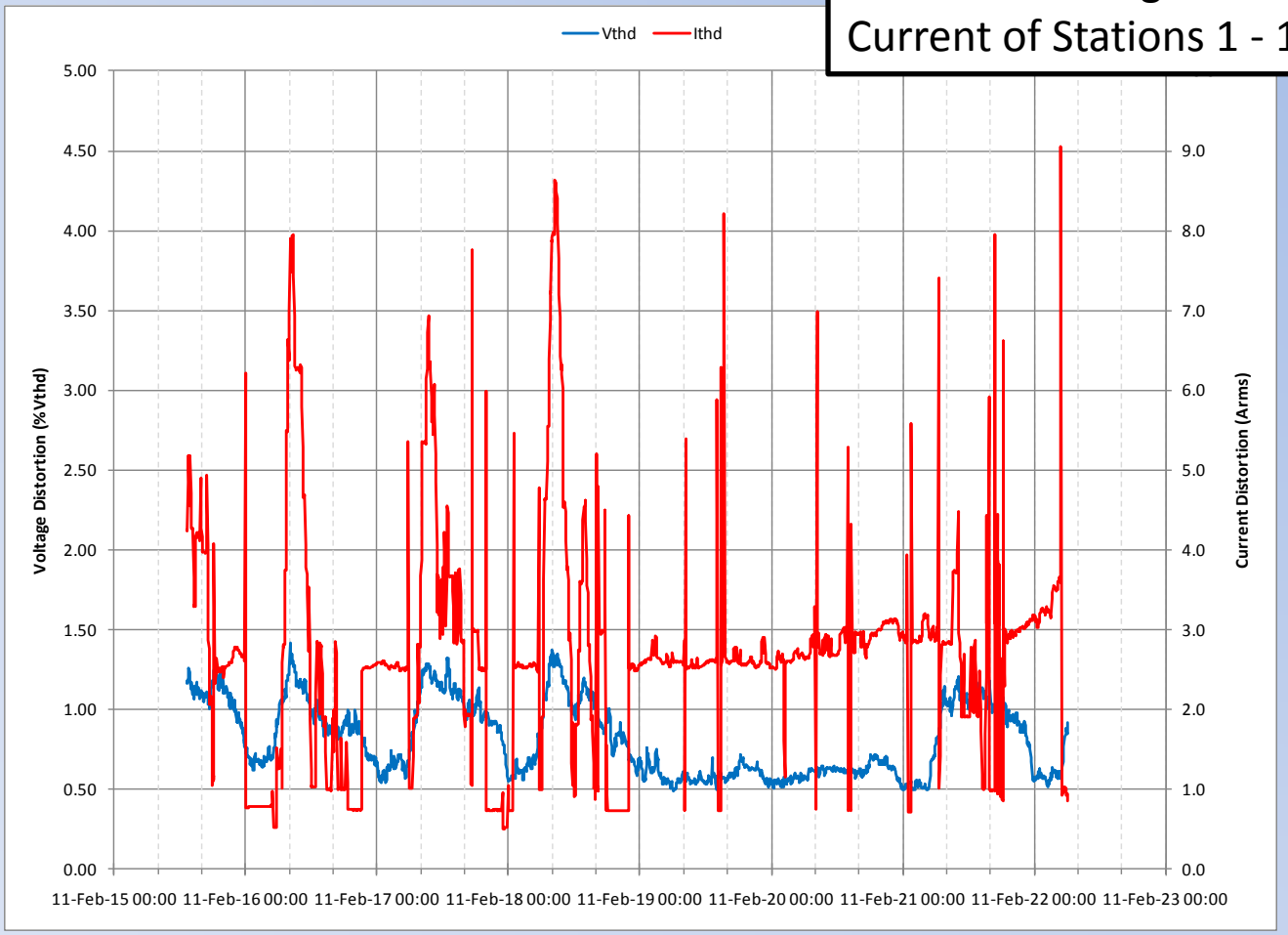
- Vehicle arrival is staggered.
- They are also at various states of discharge and rarely require the full four hours to recharge.
- Cars also may not stay for an entire charge. People come and go for meetings, lunch, etc.
- It was common to see a smaller second peak in the afternoon after lunch time.

Diversity Analysis (Charging is not On/Off)

- Monitoring of individual charger circuits showed that the chargers are not a simple full on or off device.
- Instead there were periods of sloped current, varying current and partial current draw.
- The majority of the time it was seen that the current for individual chargers was on or off.
- These variations also contributed to diversity in the aggregate of multiple charging stations.
- For large groups of chargers, communication between chargers would help better manage the power!

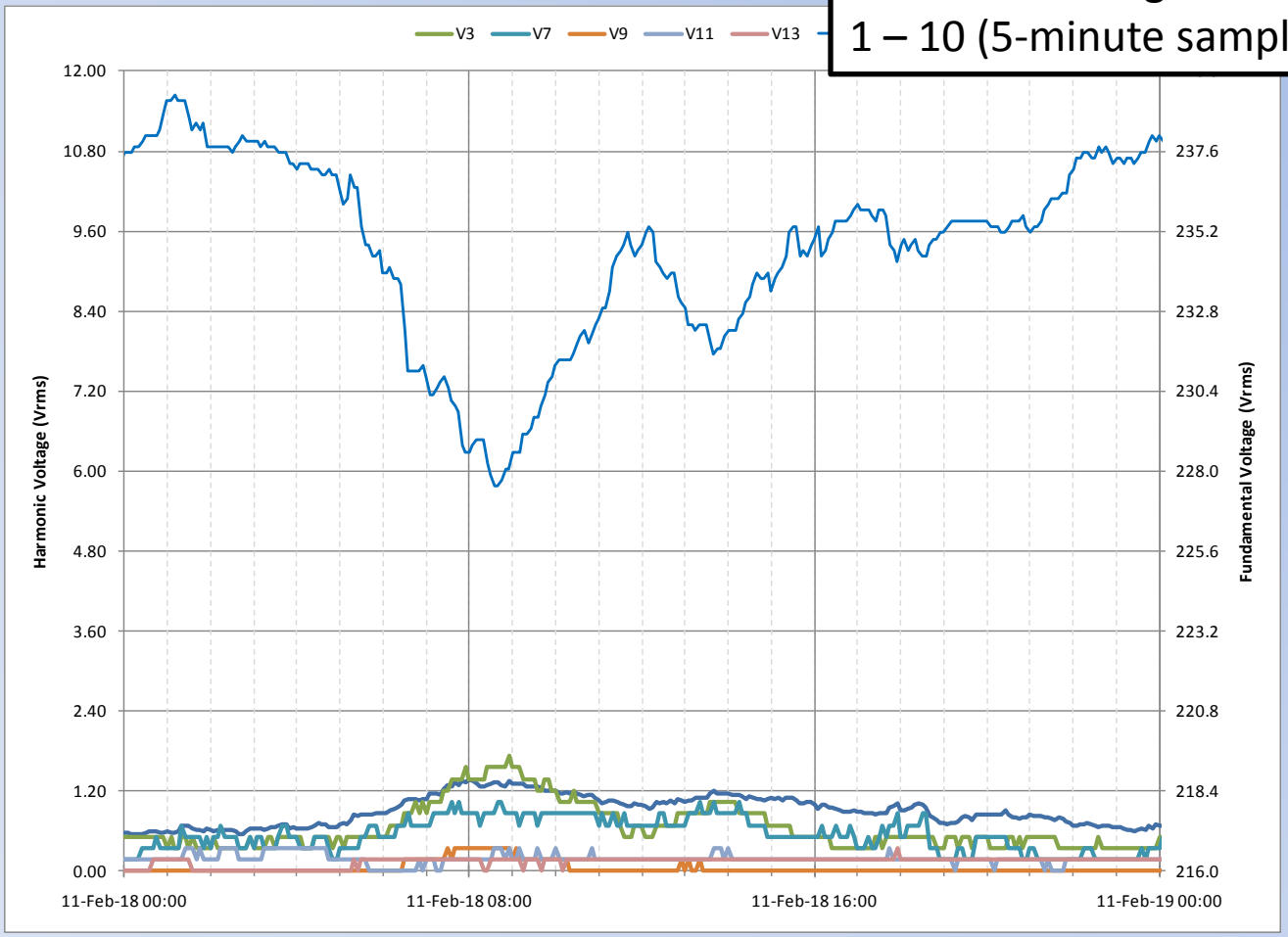
Power Quality

Harmonic Voltage and Current of Stations 1 - 10



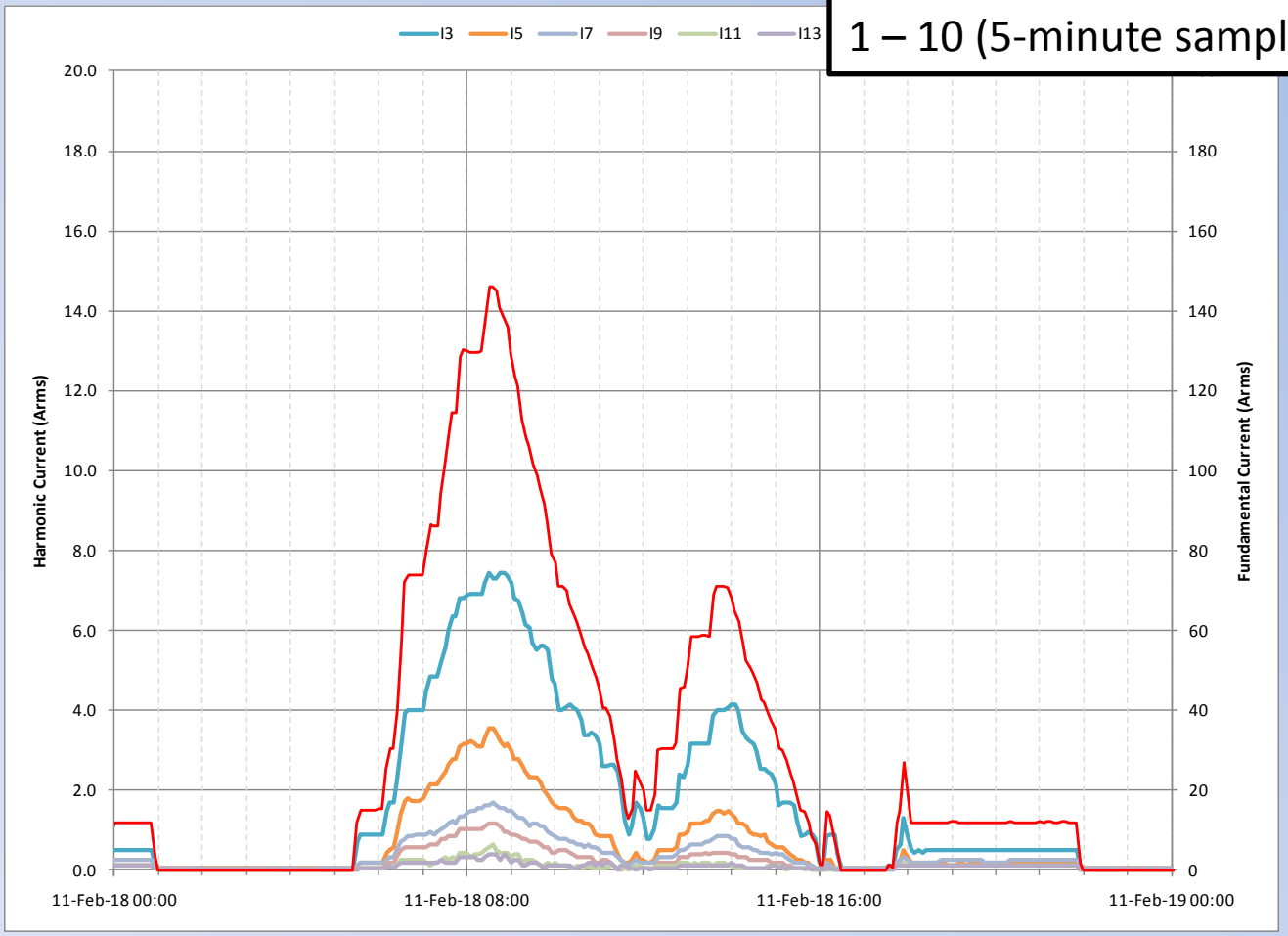
Power Quality

Harmonic Voltage for Stations 1 – 10 (5-minute samples)



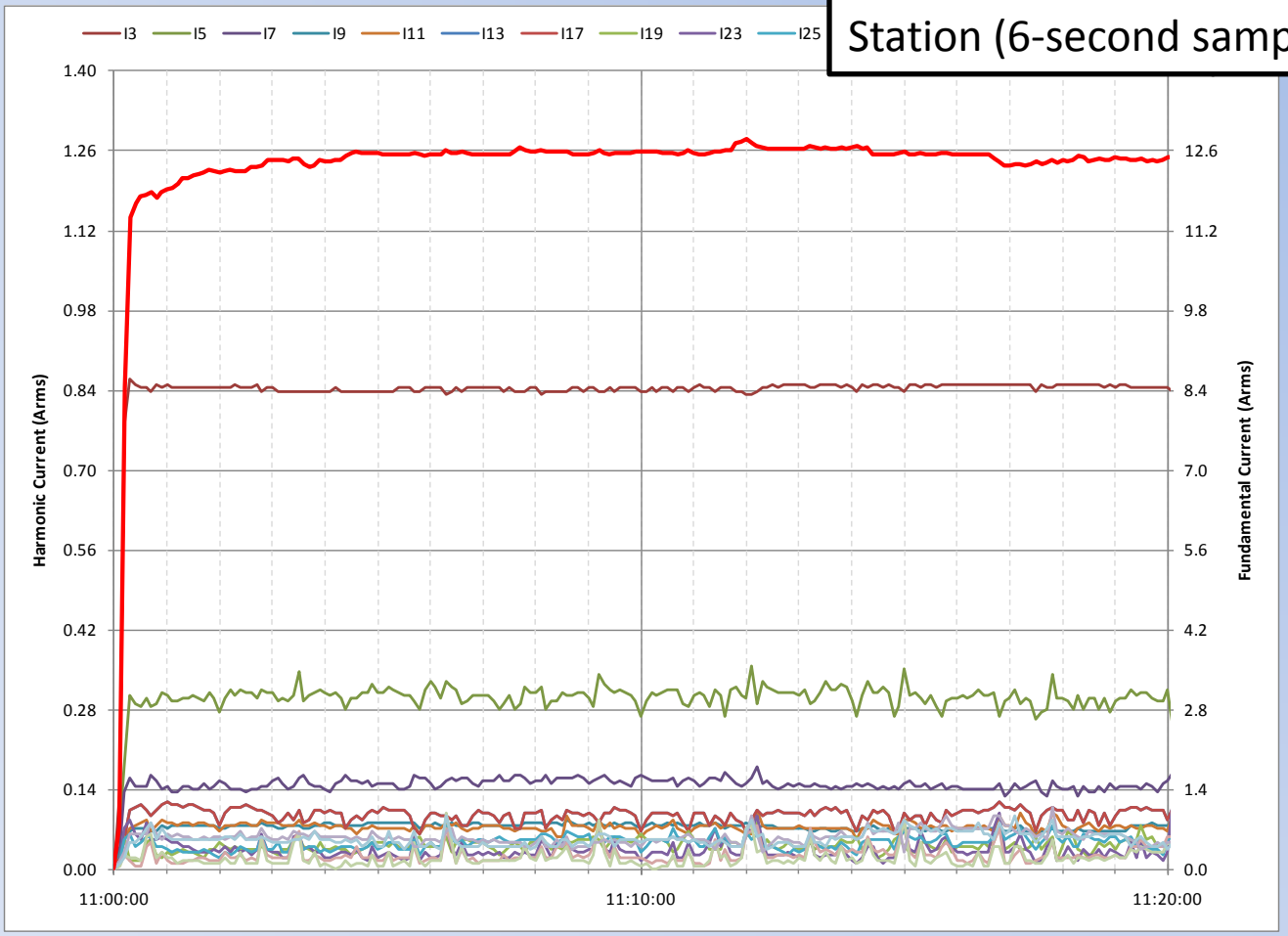
Power Quality

Harmonic Current for Stations 1 – 10 (5-minute samples)



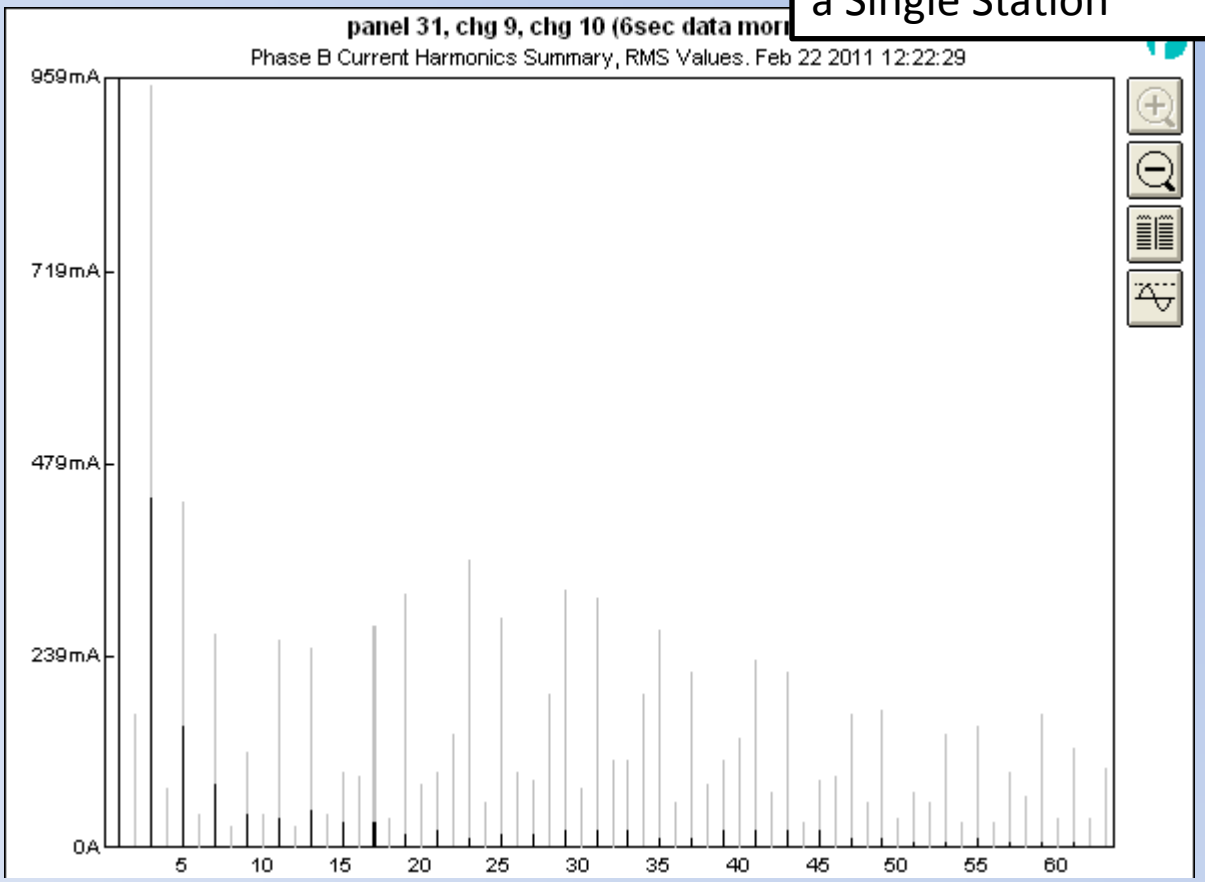
Power Quality

Harmonic Current for a Single Station (6-second samples)



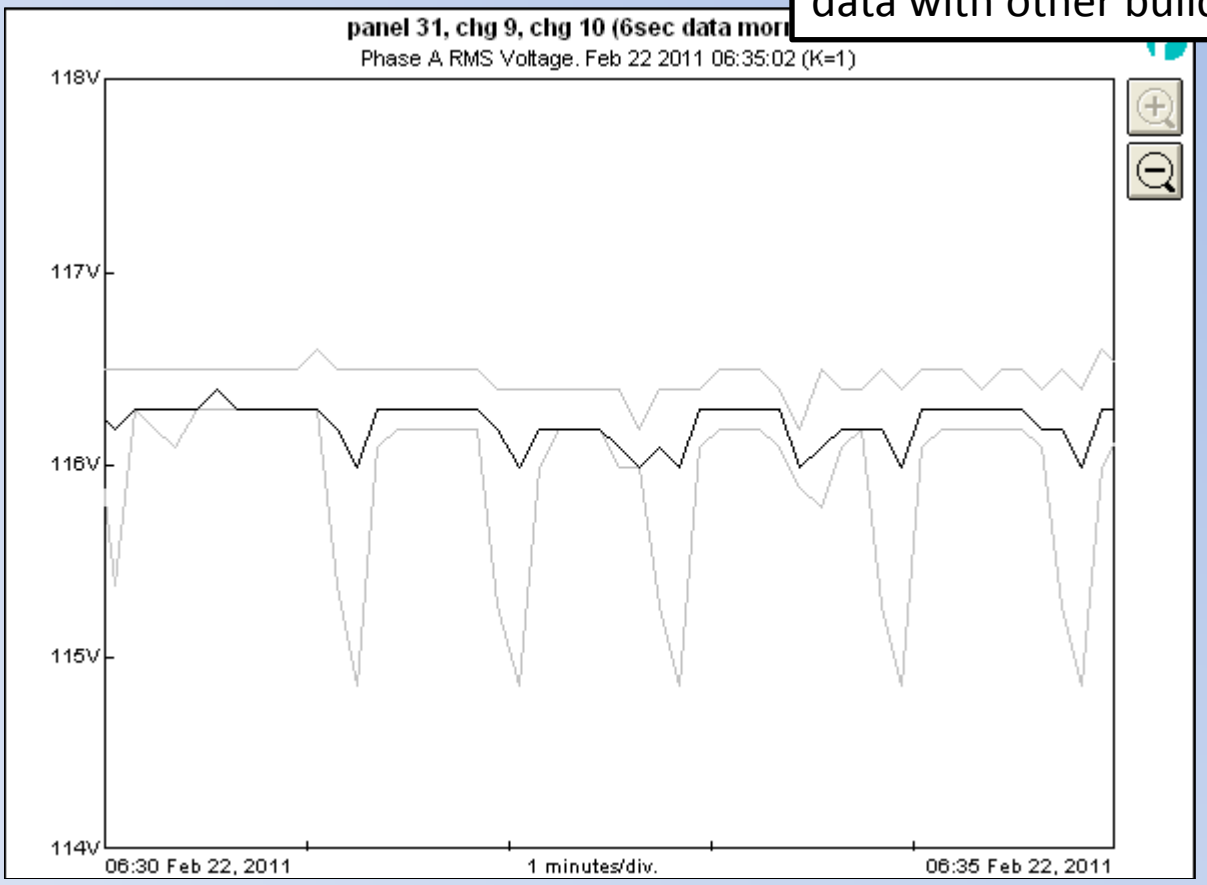
Power Quality

Harmonic Current Spectra for a Single Station



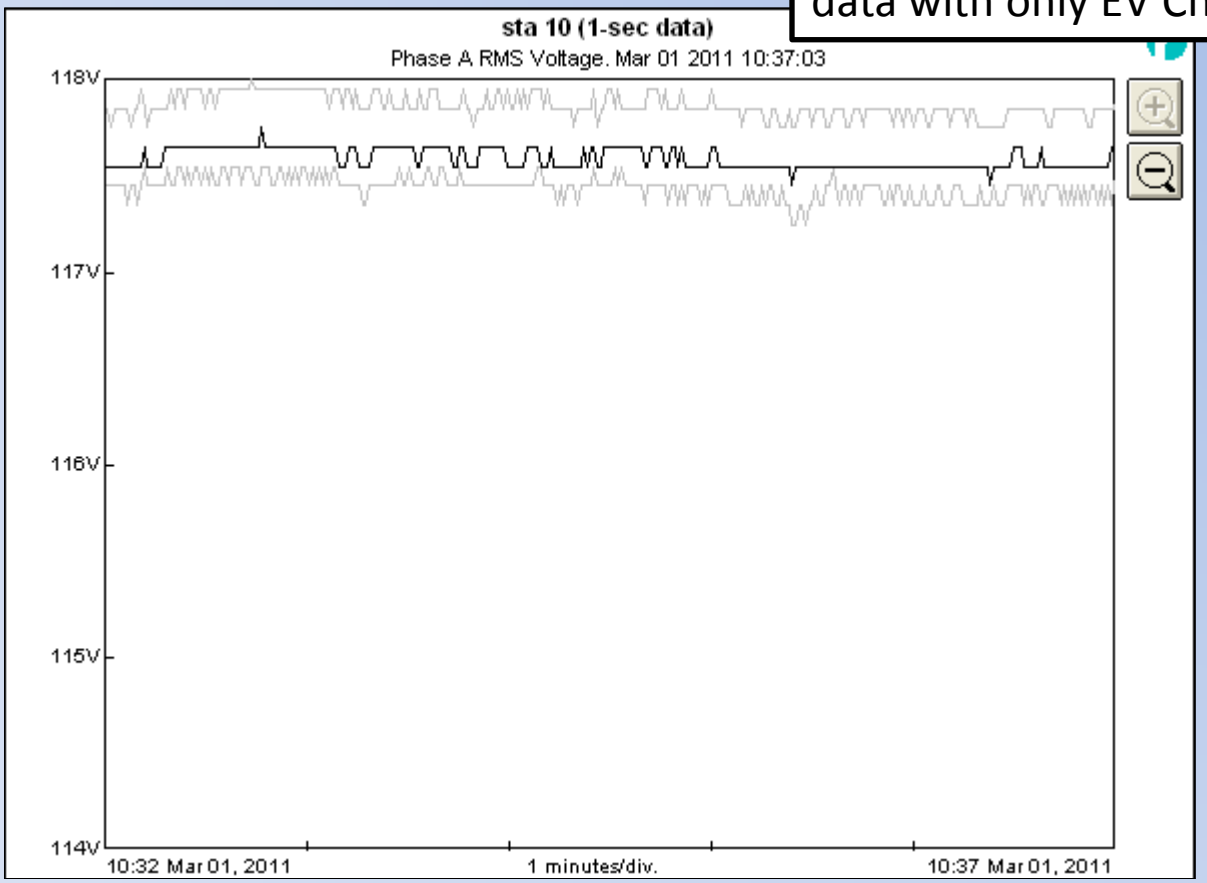
Power Quality

Voltage Regulation 6-second data with other building loads



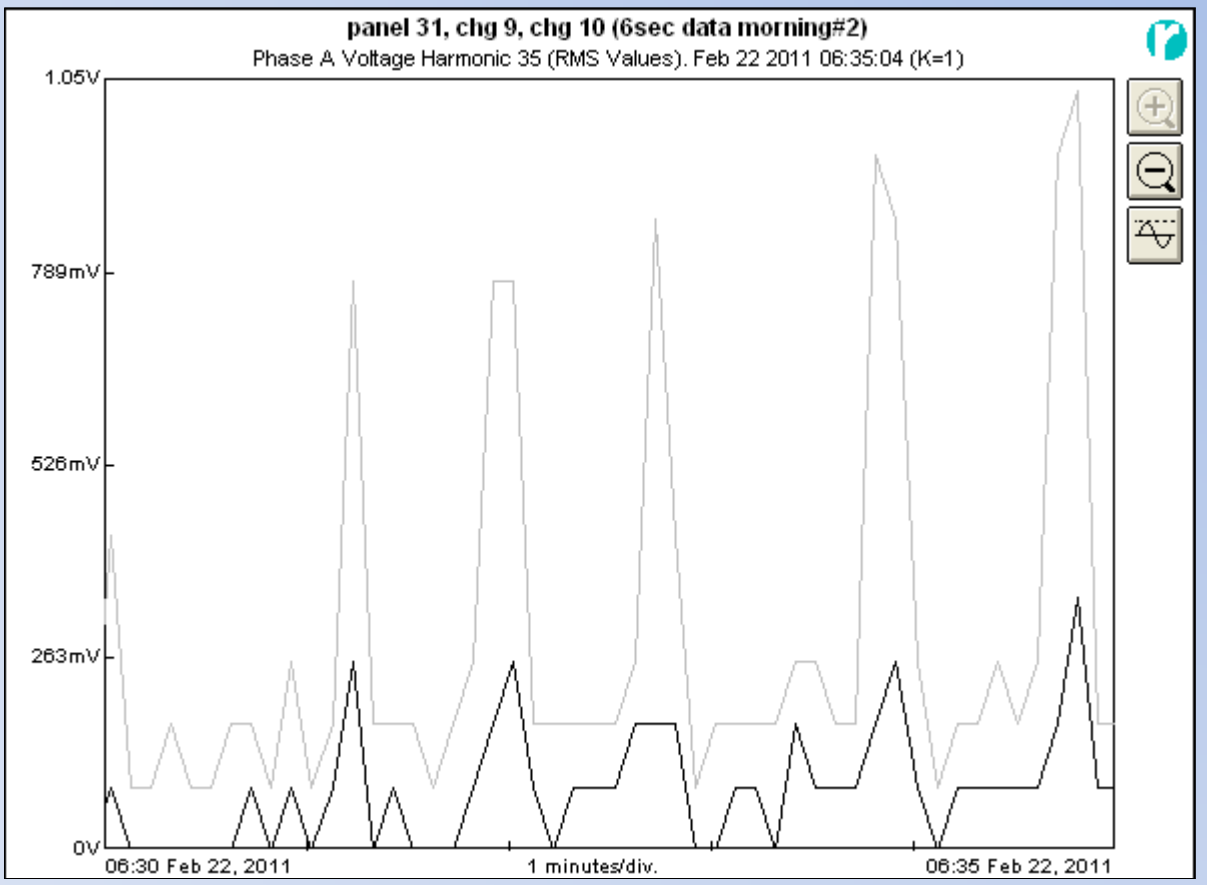
Power Quality

Voltage Regulation 1-second data with only EV Chargers



Power Quality

Bursts of 35th Harmonic Voltage



Power Quality

- Harmonic distortion was relatively low and had the expected spectrum of a single phase converter with the 3rd harmonic being dominant and decreasing as the harmonic order increased.
- Overall harmonic distortion was low.

Power Quality

- There was voltage flicker measured at the panel feeding stations 1 through 10, but this was confirmed to be due to brake dynamometers fed from the same service.
- It was found that high order harmonic distortion was created by the chargers during these voltage variations.
- These harmonics were in excess of 1kHz and most dominant at the 35^{th}, 37^{th}, 41^{st} and 43^{rd} harmonics.
- This may be an issue at home installations when air conditioning or other large cyclical loads come on.

Power Quality

- There have been no captured transient events during any monitoring of the chargers over the past year.
- Overall the charger load has minimal power quality impact on the system.