Grid Integration of Solar Energy What Have We Learned

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Chief Engineer

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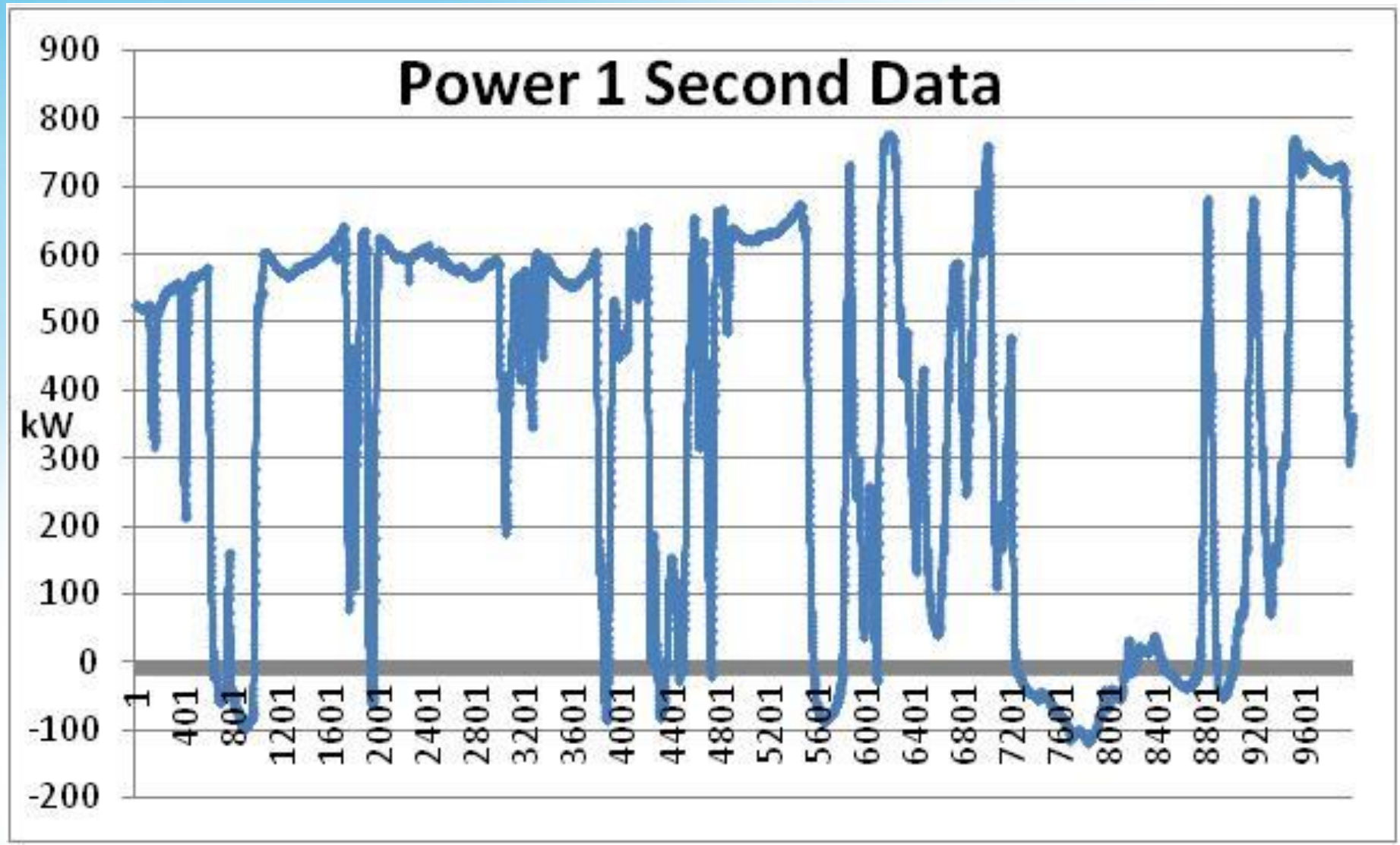
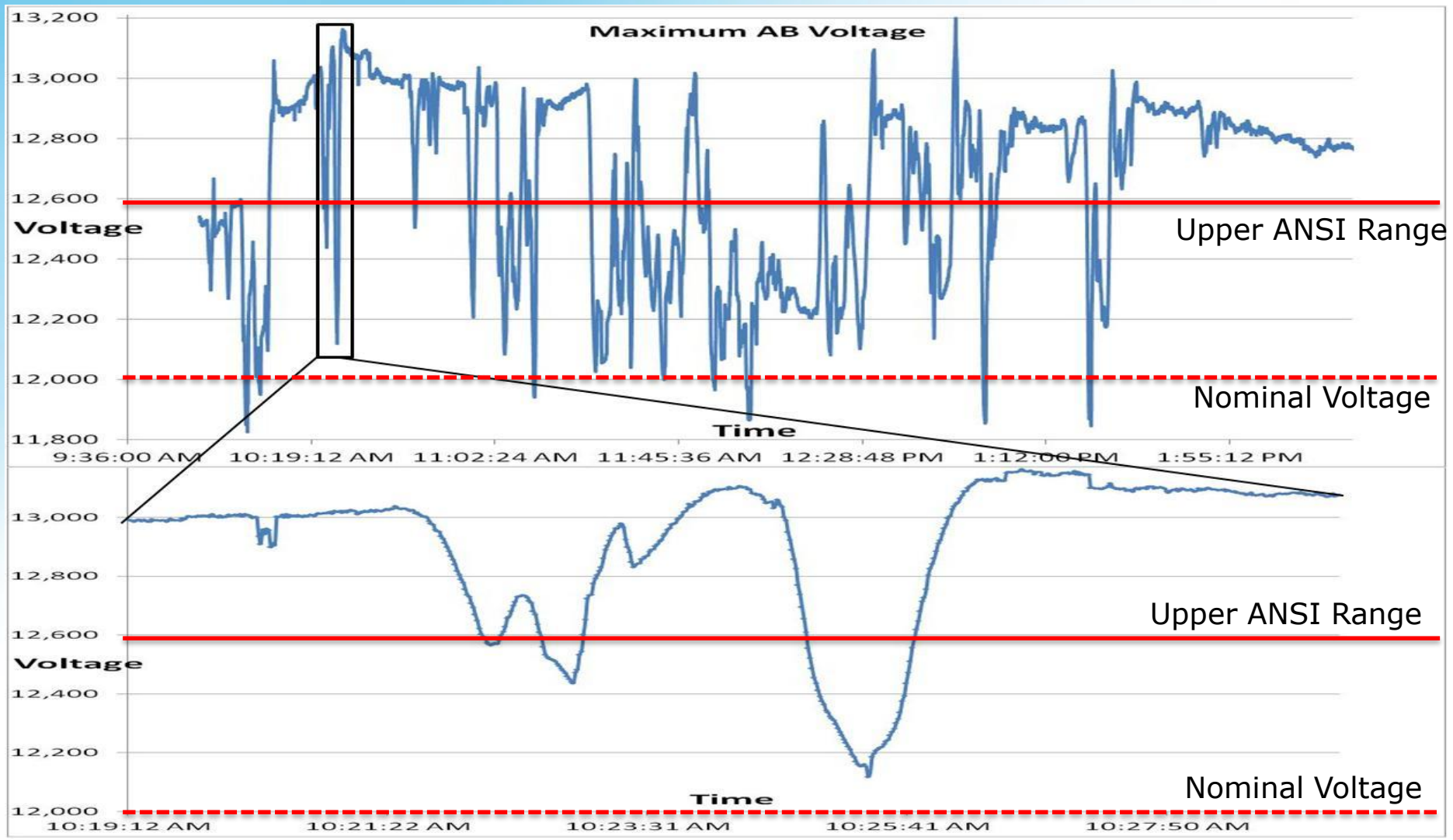
Measure

SDGE
A Sempra Energy utility®

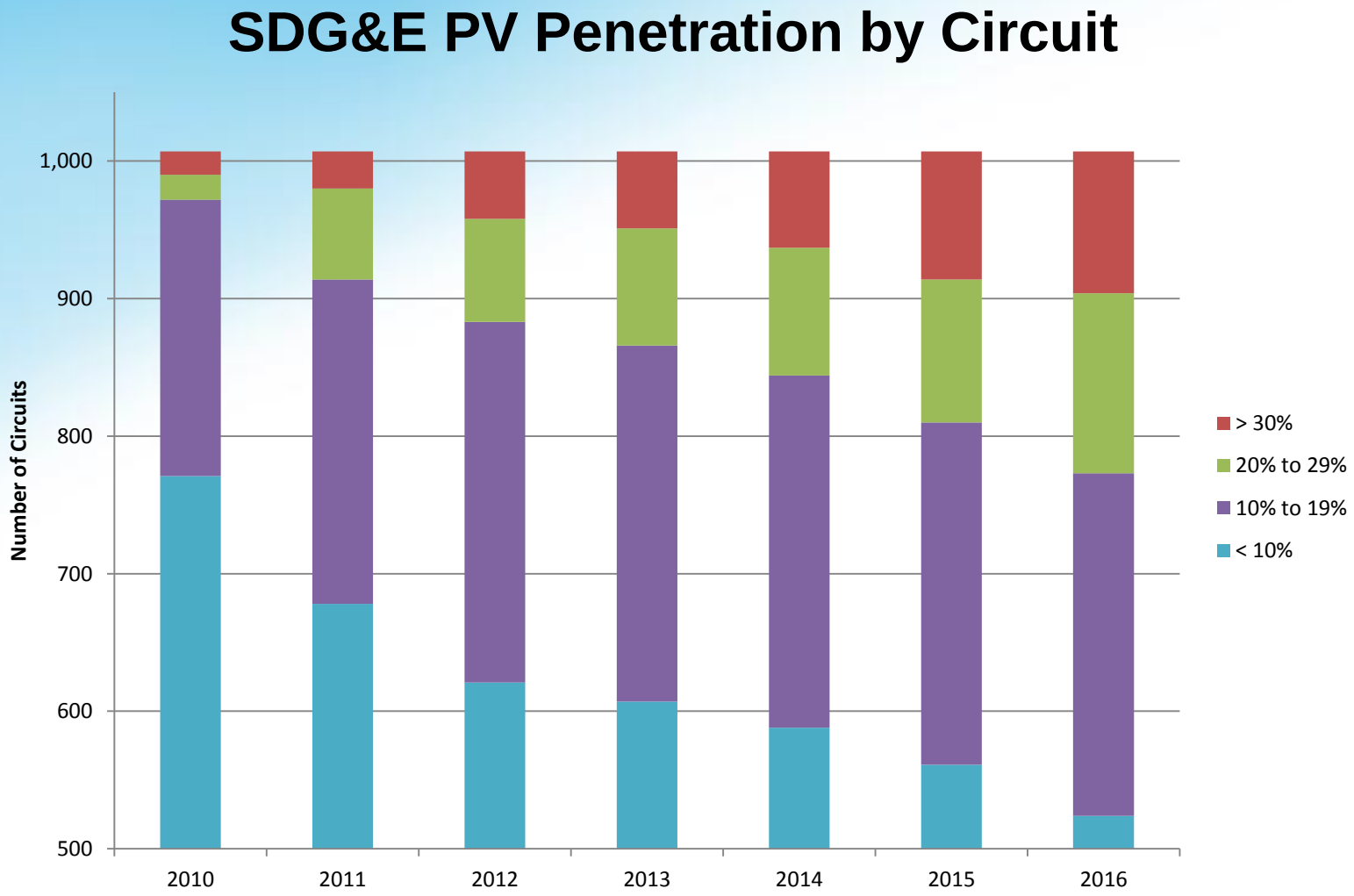
PV Intermittency



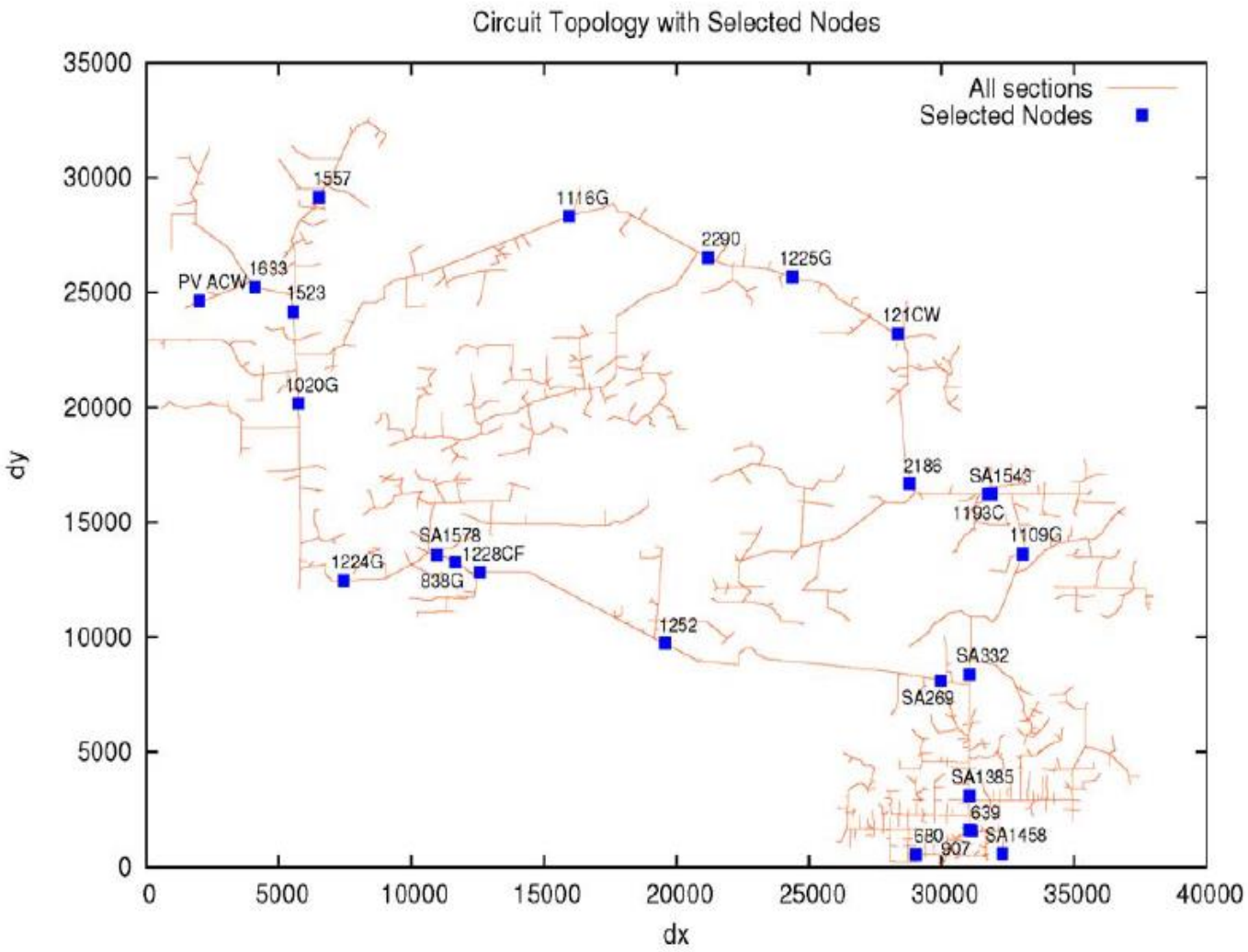
Measure


Maximum AB Voltage
13,200
13,000
12,800
12,600
12,400
12,200
12,000
11,800
Voltage
Upper ANSI Range
Nominal Voltage
Time
9:36:00 AM
10:19:12 AM
11:02:24 AM
11:45:36 AM
12:28:48 PM
1:12:00 PM
1:55:12 PM
13,000
12,800
12,600
12,400
12,200
12,000
Voltage
Upper ANSI Range
Nominal Voltage
Time
10:19:12 AM
10:21:22 AM
10:23:31 AM
10:25:41 AM
10:27:50 AM

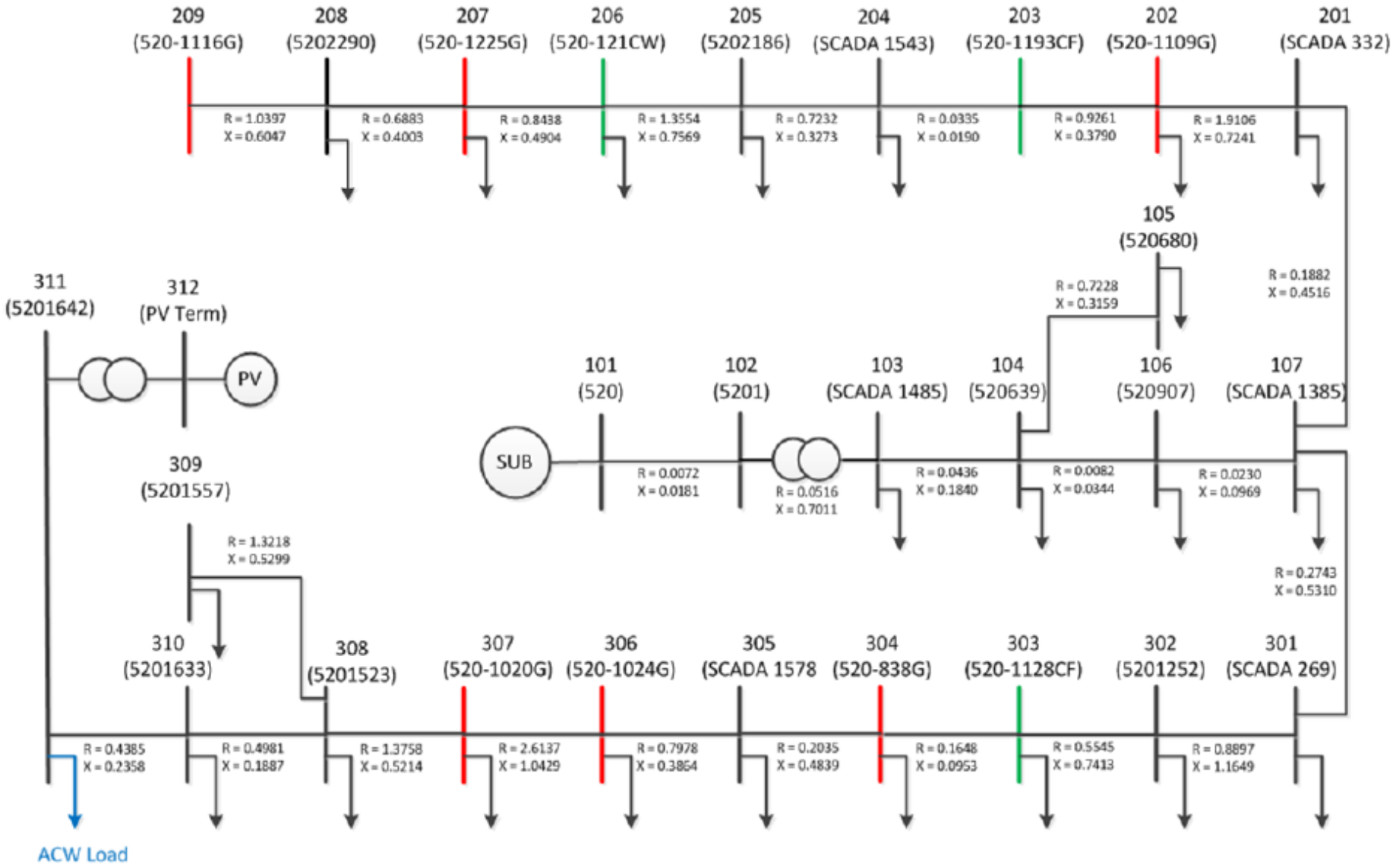
Data Analysis



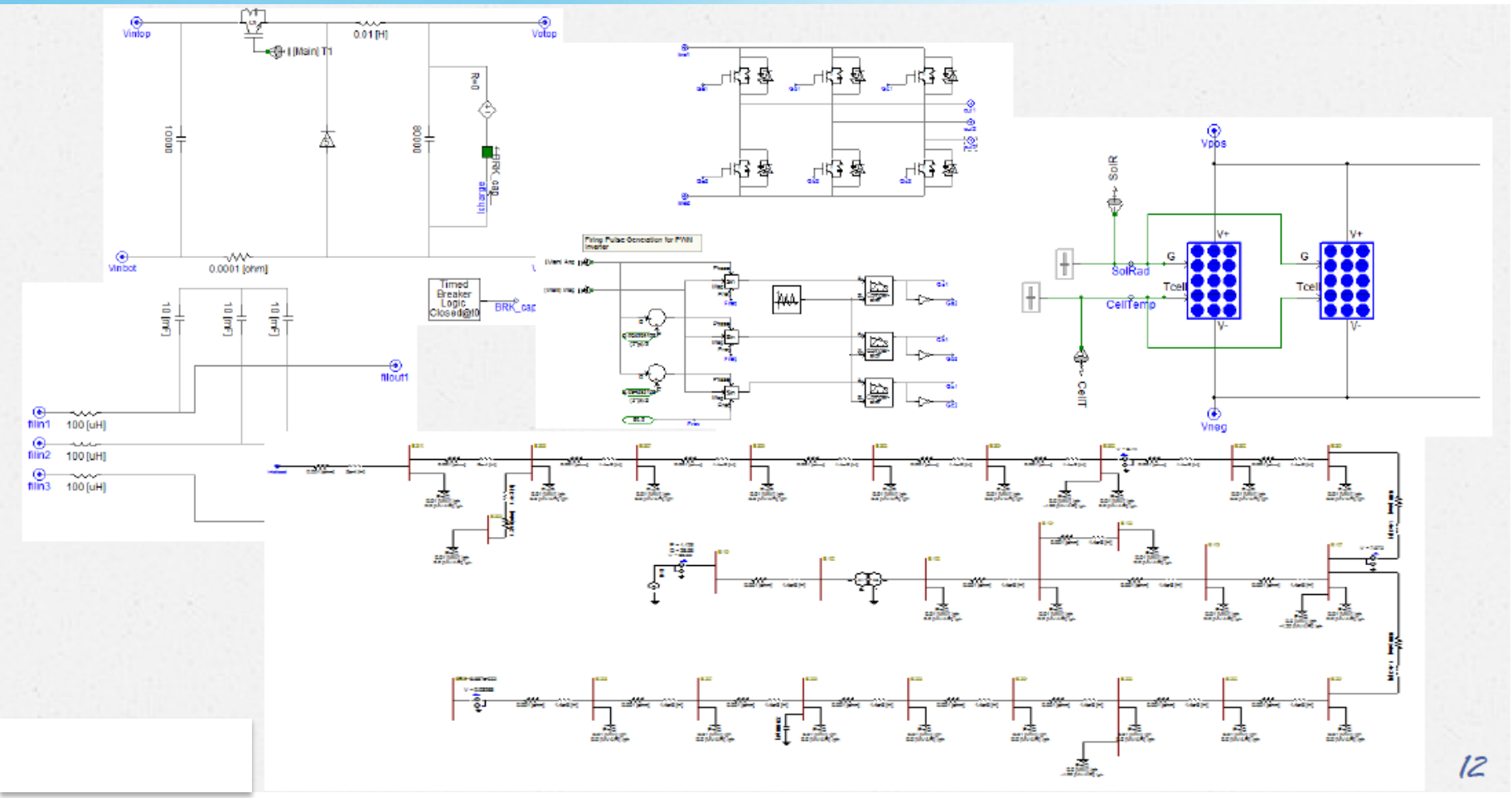
Modeling DER Integration



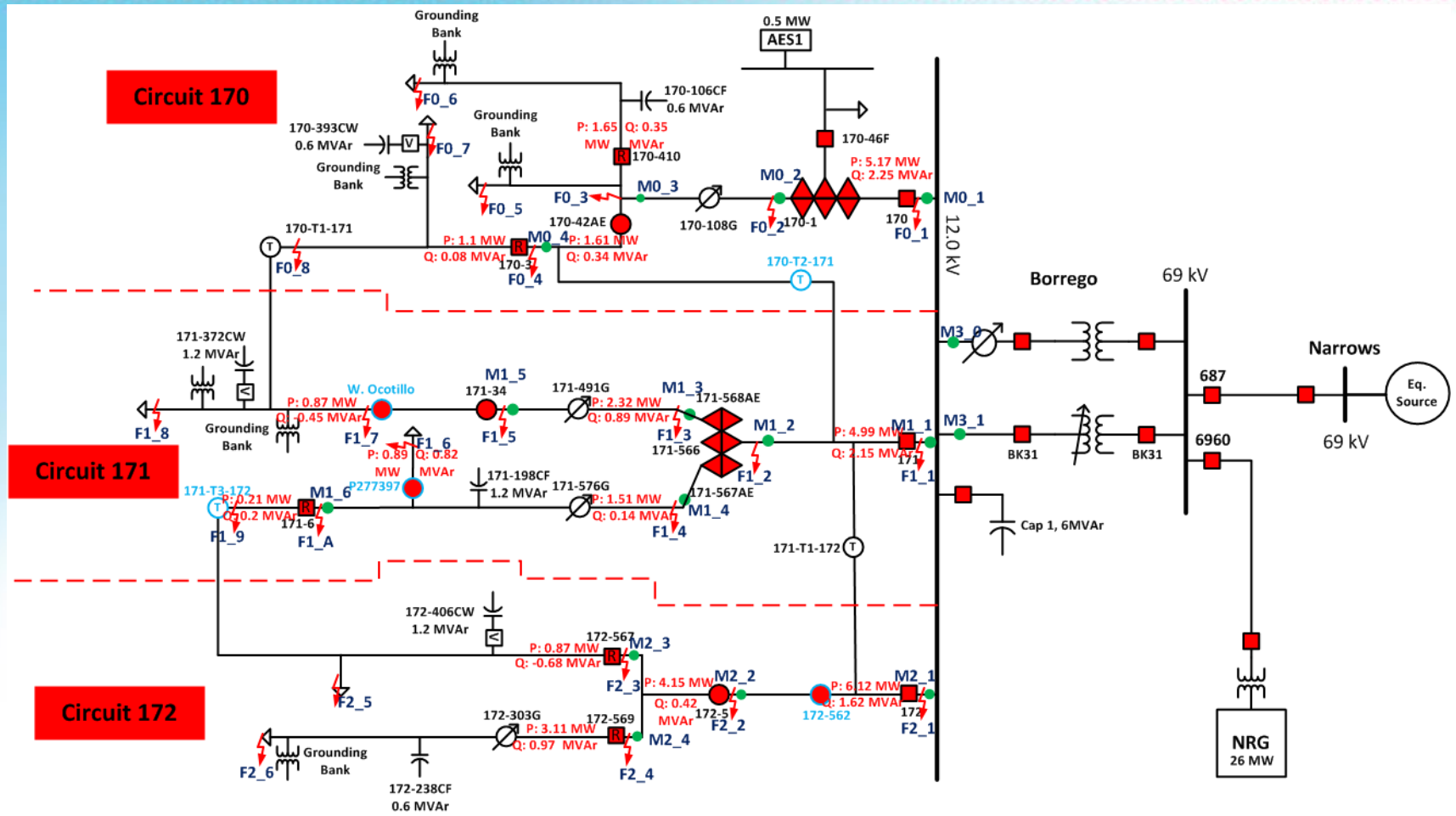
Modeling DER Integration



Modeling - Detailed PSCad Modeling

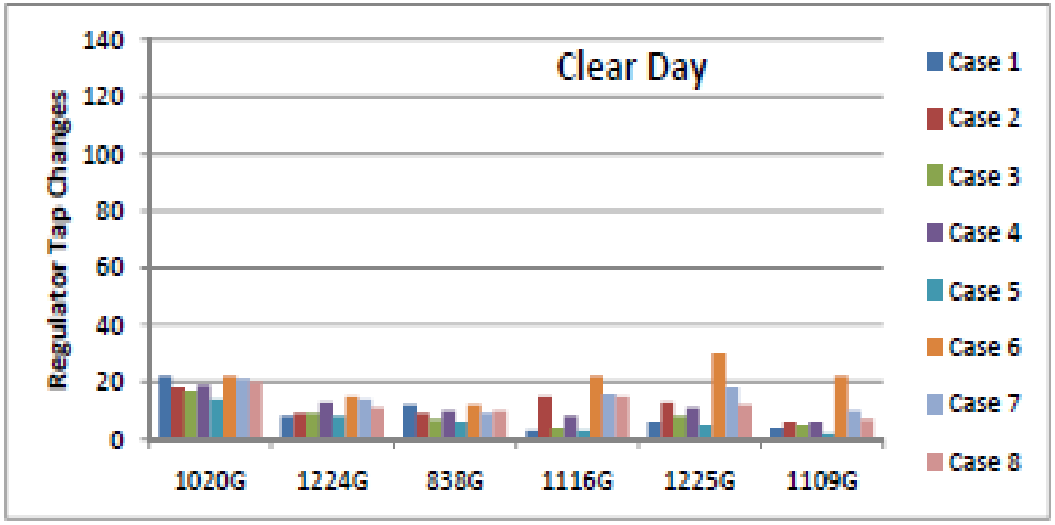


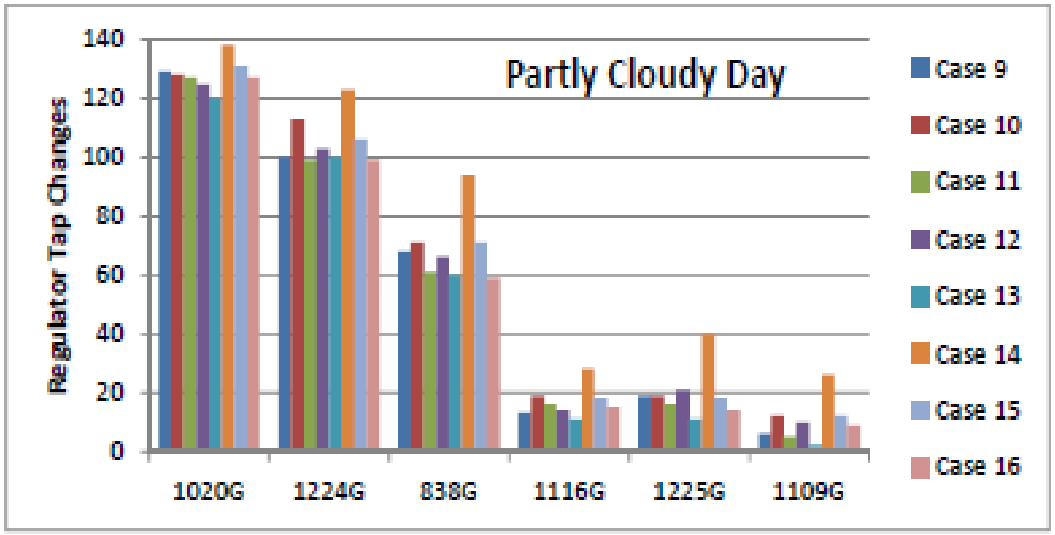
Modeling - RTDS



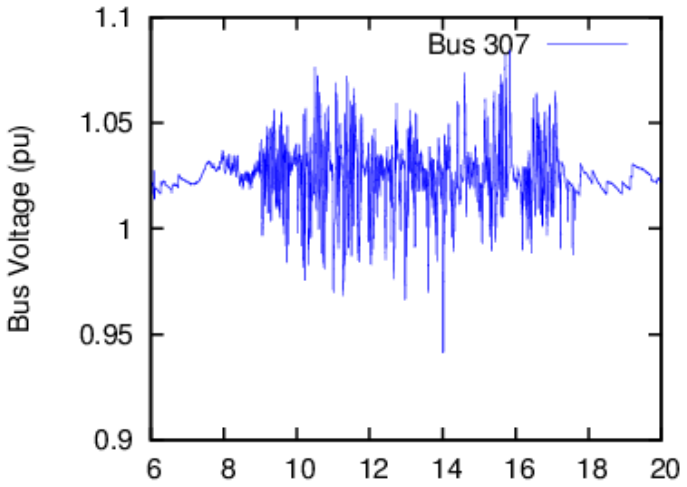
Scenario	Mode	Load (Serving)	Reserve Capacity	Generation			
				Diesels	AES 1	AES 2	NRG
1	Main Grid	6-12 MW	0	0	0.5 MW		26 MW

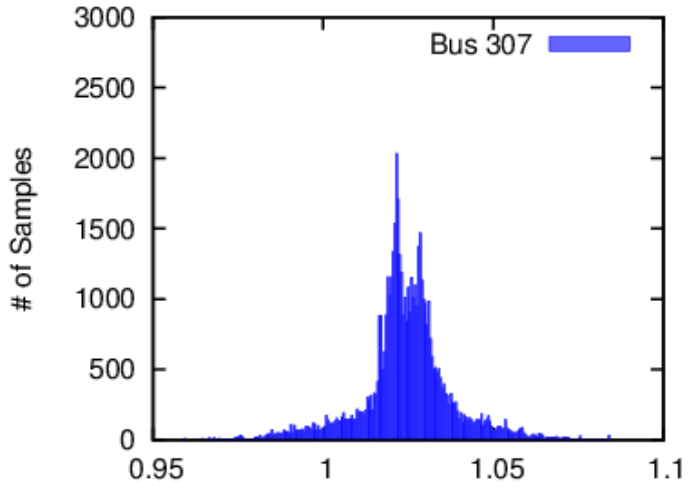
Modeling - Results

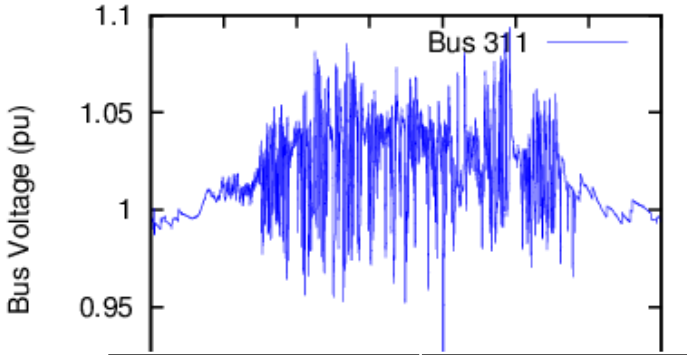


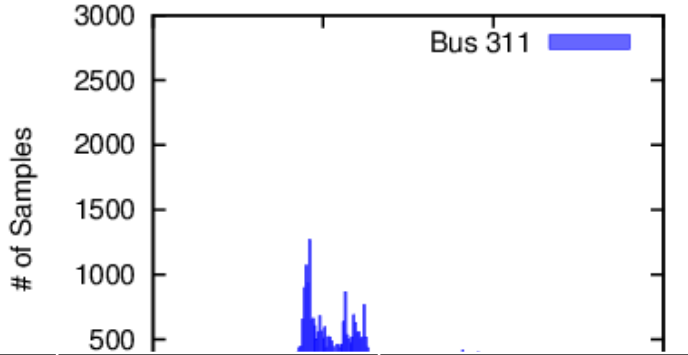


Modeling - Baseline



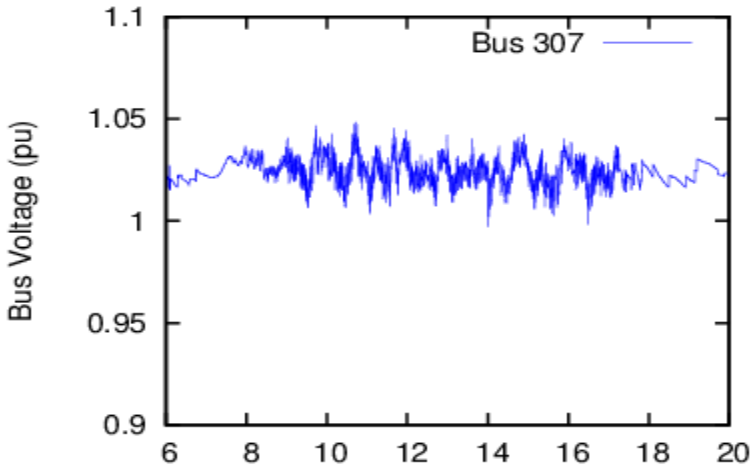


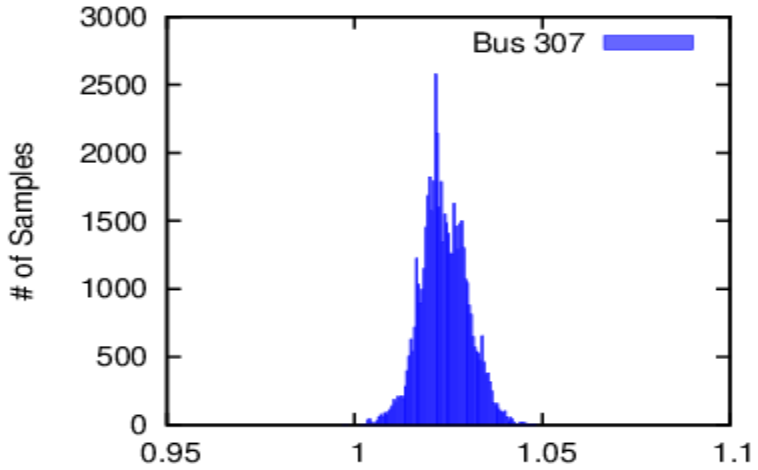


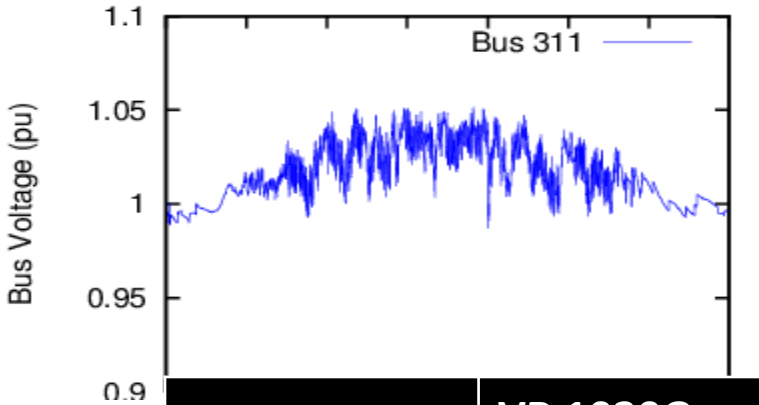


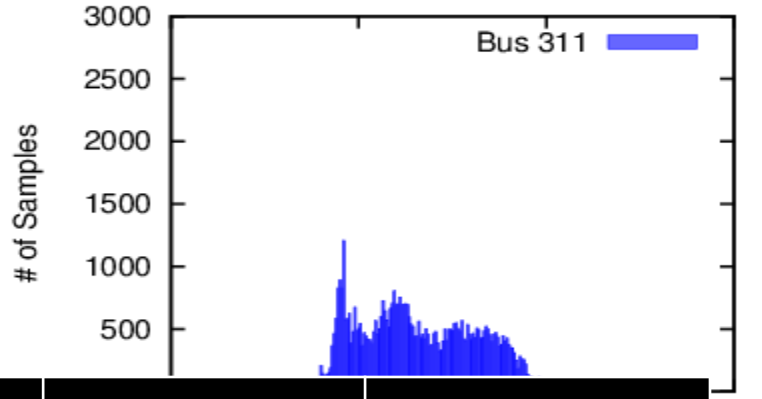
	VR 1020G	VR 1024G	VR 838G
Tap Changes	125	85	31

Modeling - Dynamic Voltage Control



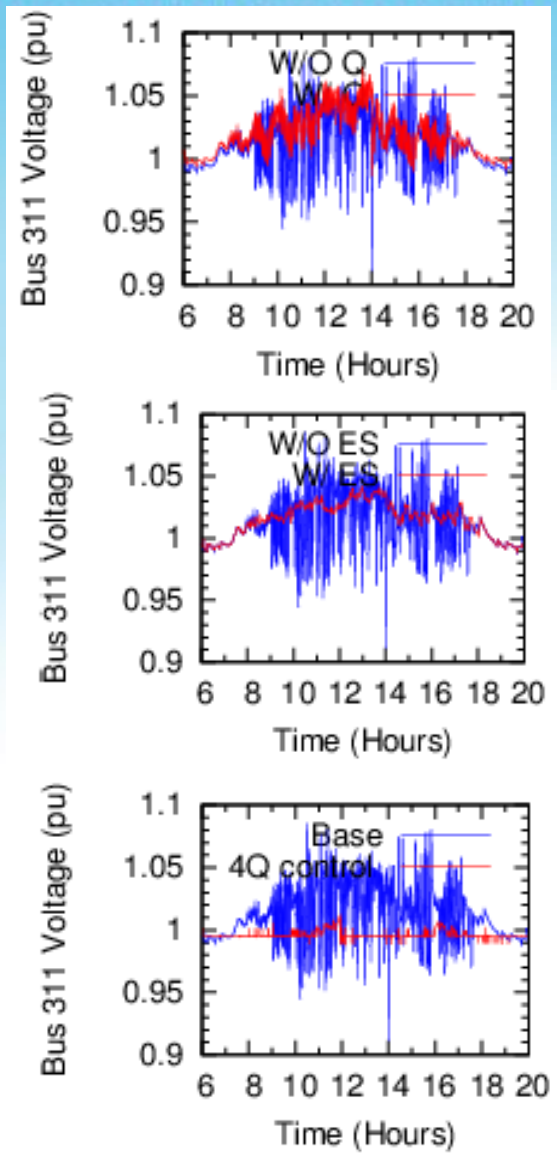






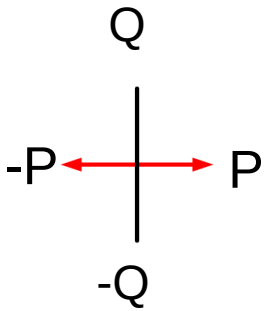
	VR 1020G	VR 1024G	VR 838G
Tap Changes	45	77	121

Modeling - Solutions

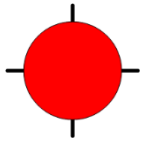


With and without dynamic VAr device

With and without energy storage

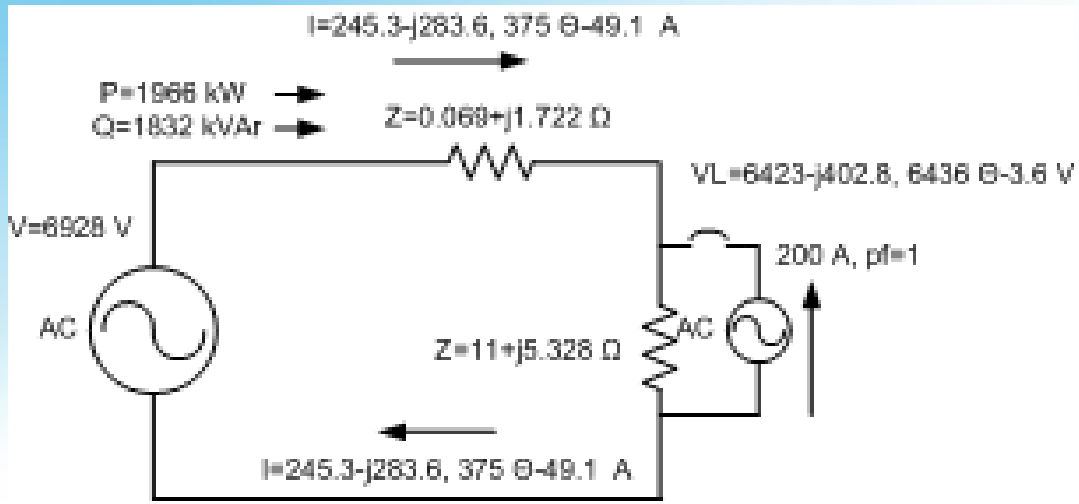


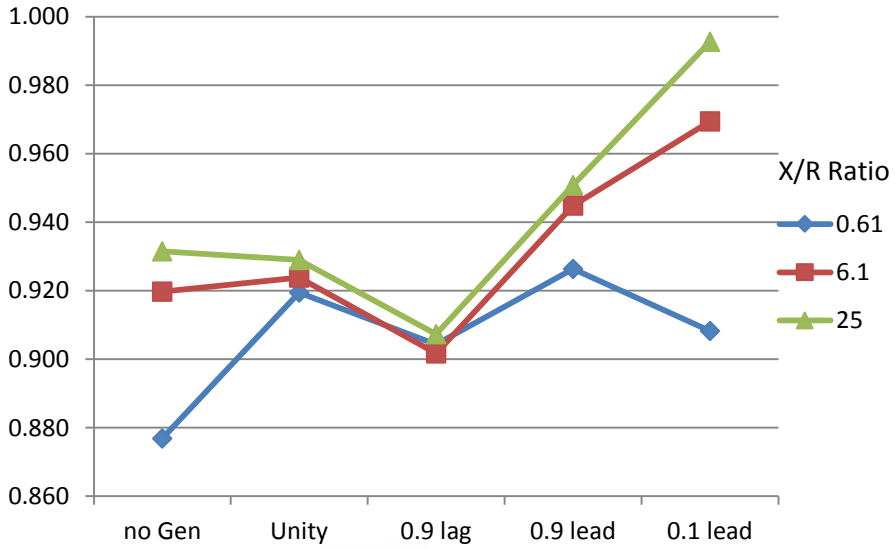
With and without storage and 4 quadrant control



Red = With Blue = Without

Modeling - X/R Voltage Impact

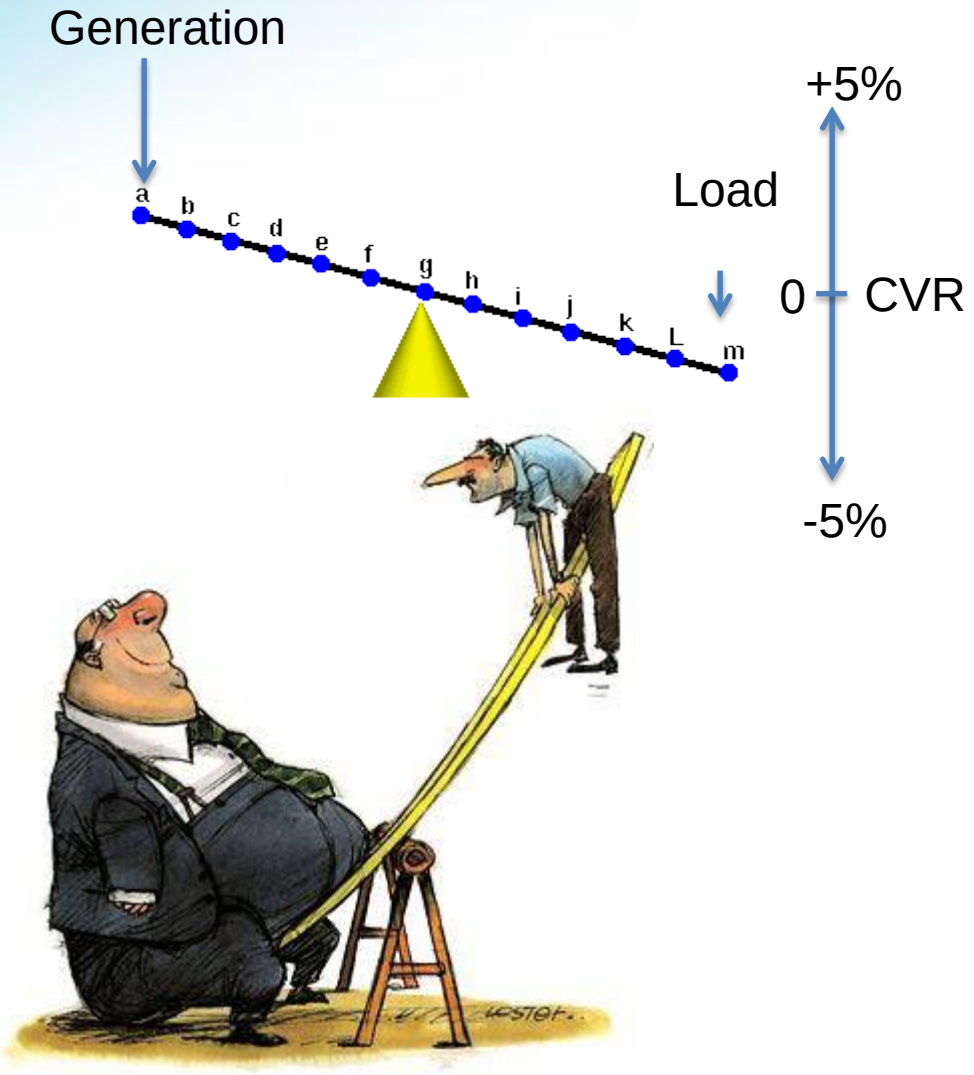




Lessons Learned

Factors Determining Impact

- **Location on the Circuit**
  - Near Substation vs End of Circuit
- **Circuit Rating**
  - 4 kV vs 12 kV
- **Type of Circuit**
  - Urban vs Rural
- **Circuit minimum loading**
  - High vs Low
- **Circuit X/R ratio at location**
  - High vs Low
- **Aggregate DG capacity**
  - Transmission issues
- **Voltage Regulation Equipment**

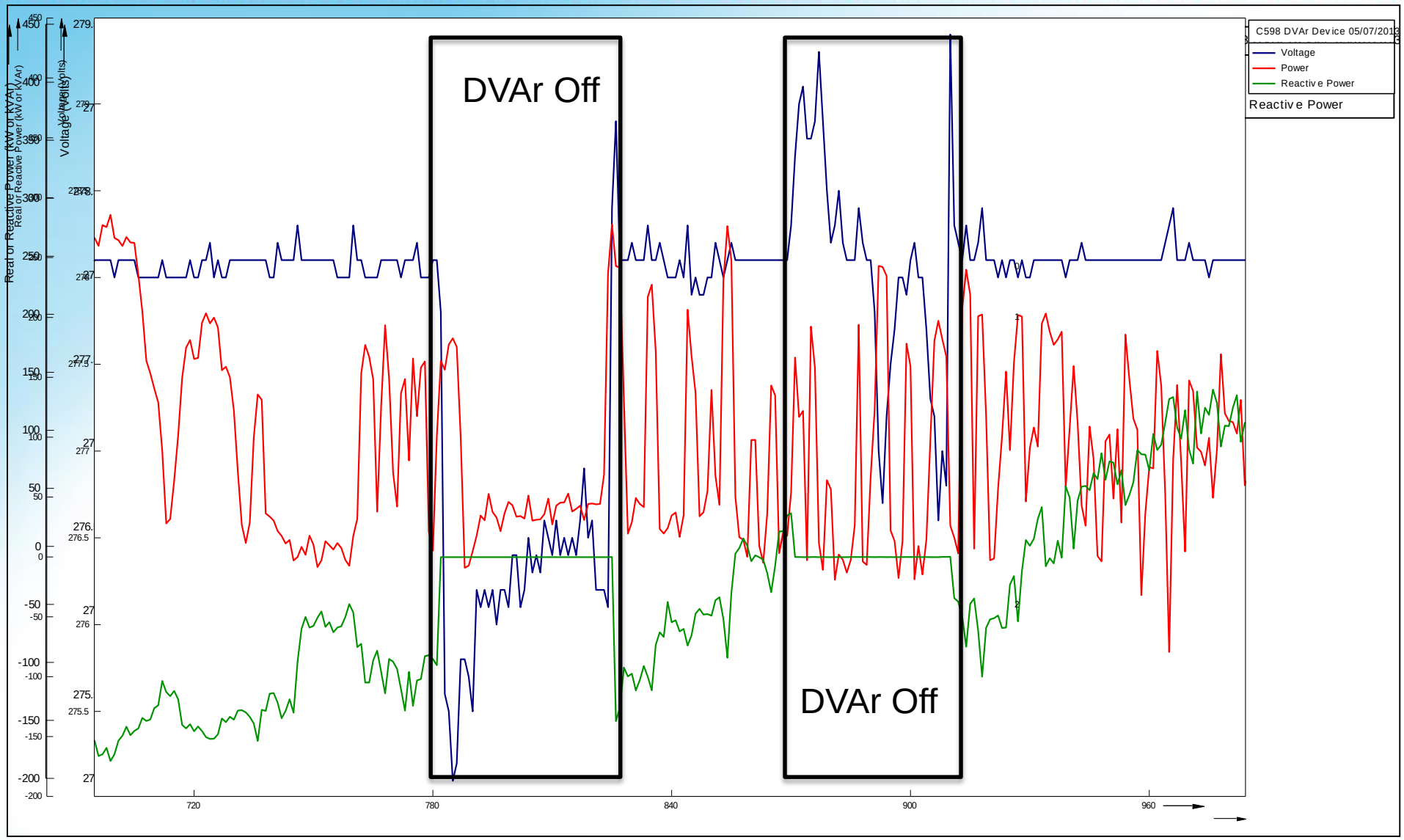


Lessons Learned

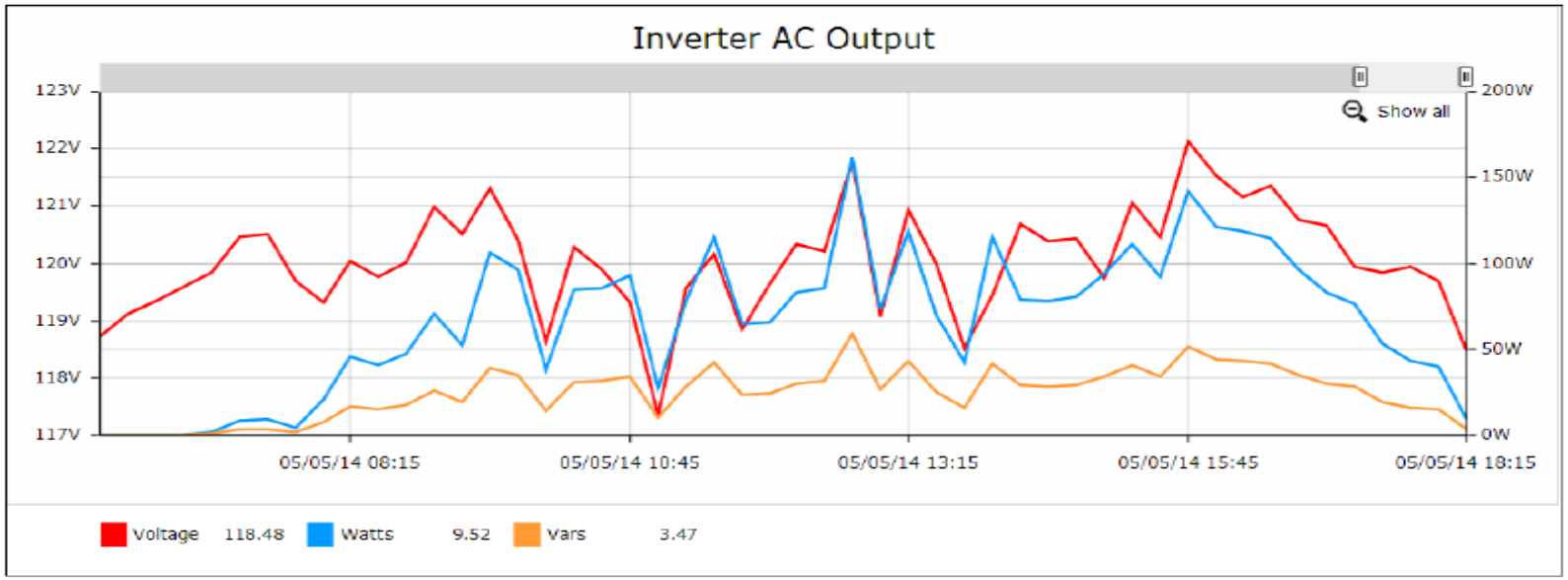
Solutions?

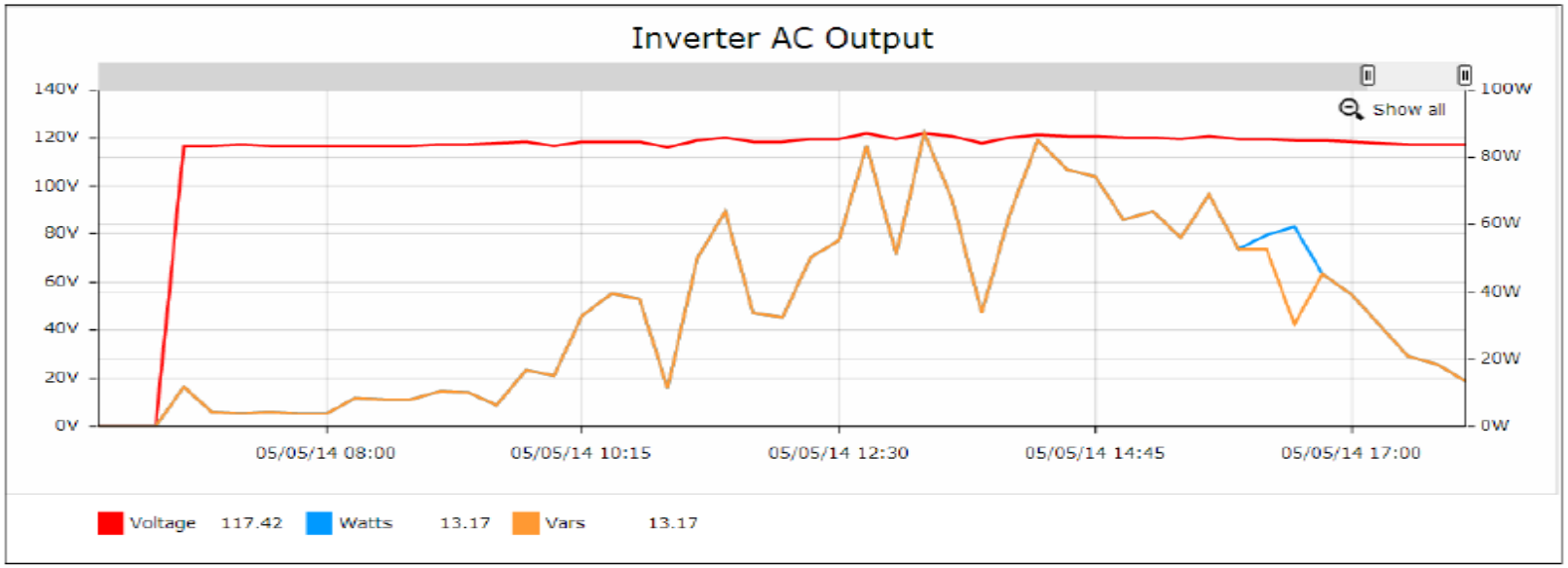
- **Circuit modifications**
  - Monitoring and ensuring resource adequacy
  - Voltage regulation
- **Demand response**
  - Slower dP/dt events?
- **4 quadrant control**
  - Utility dynamic VAR devices
  - Utility storage
  - Customers inverters/storage
- **Regulatory/Standards Changes**
  - Existing rules require modification to accommodate high PV penetration
    - CA SIWG advanced functionality

Solutions - Dynamic VAr Device



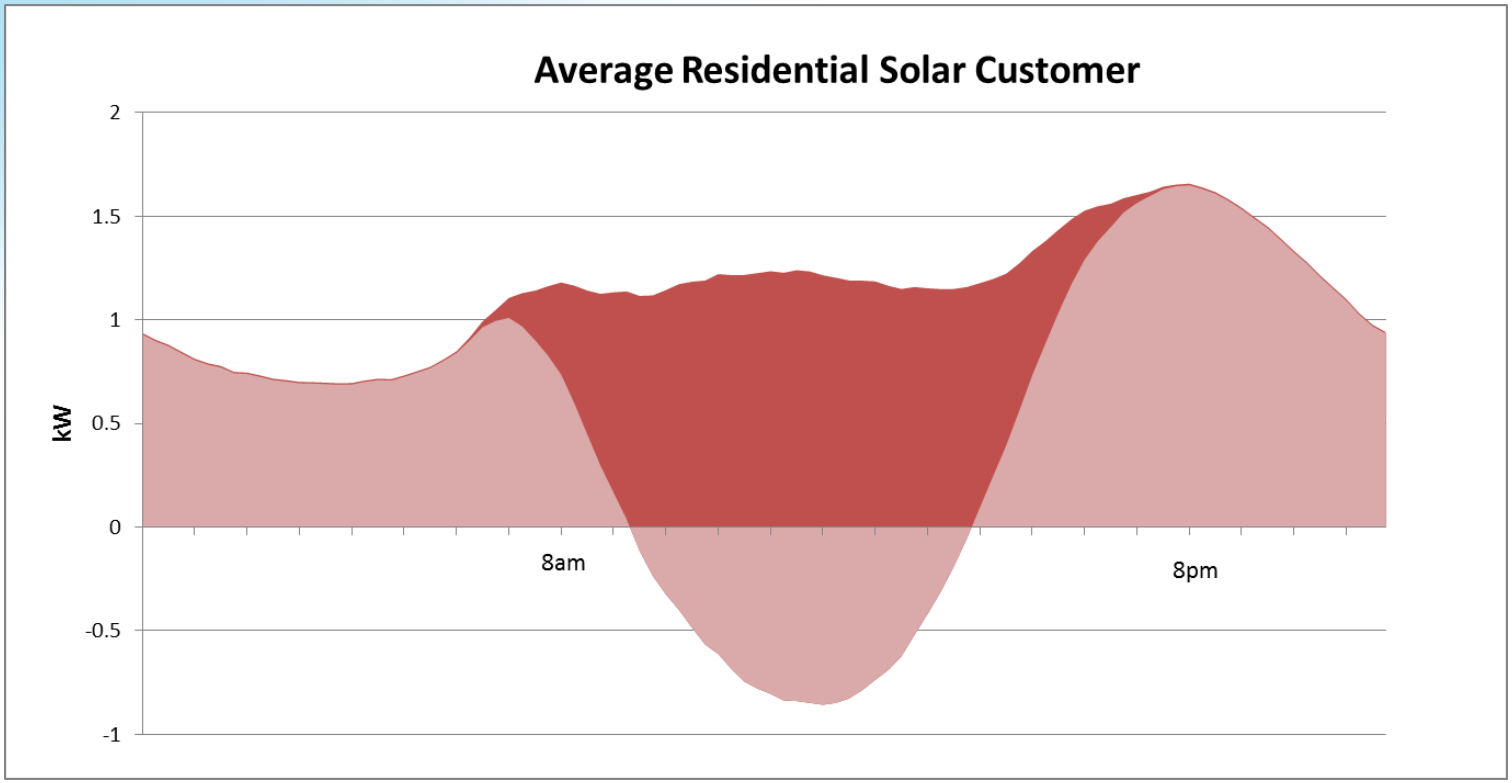
Solutions - PV with Smart Inverter



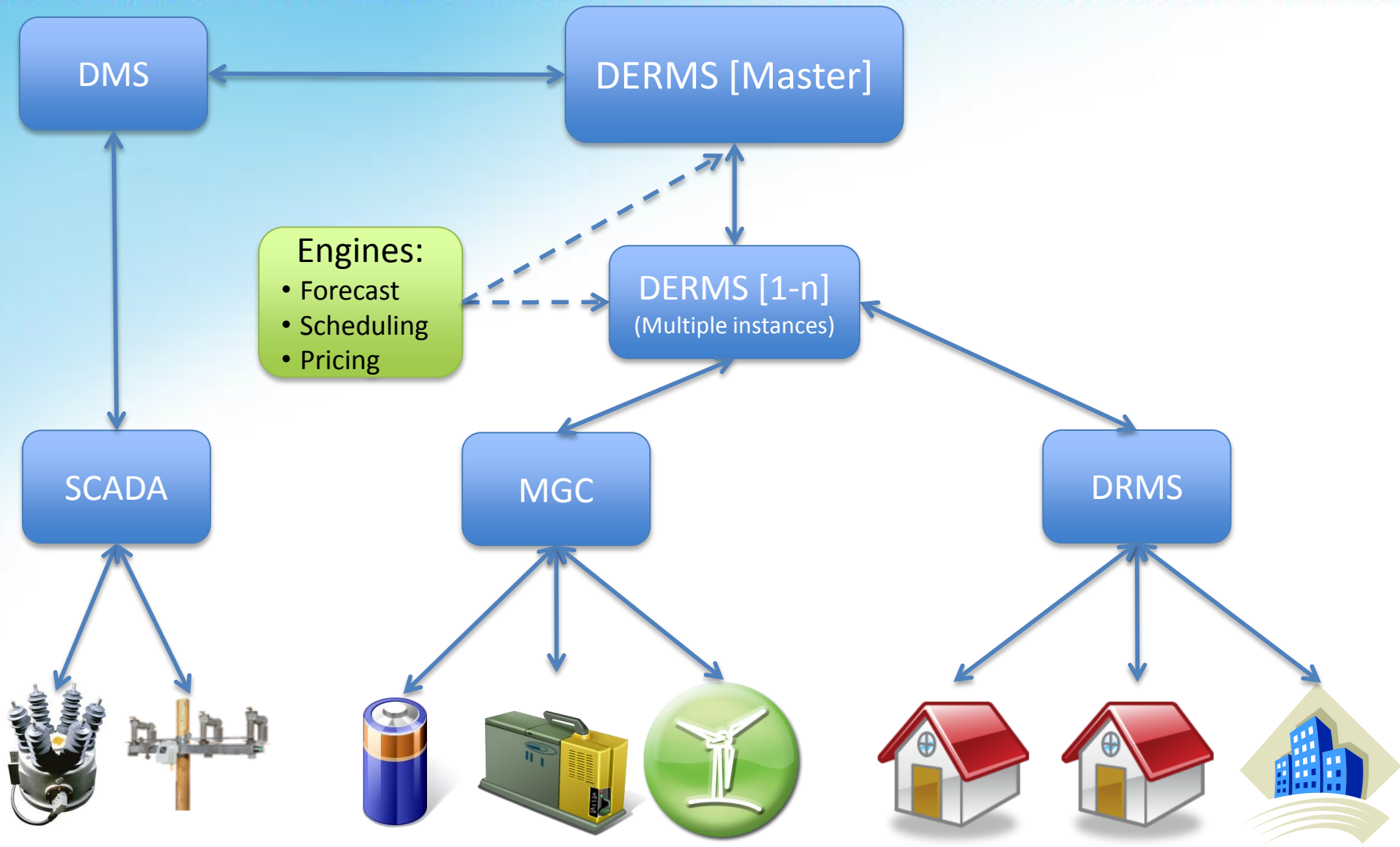


Solar PV Capacity Challenges

- Solar does not coincide with residential distribution system peaks
- Solar output curve does not match typical residential customer daily usage profile
- Opportunity for distribution and residential energy storage
- Commercial load profile is more aligned to solar output

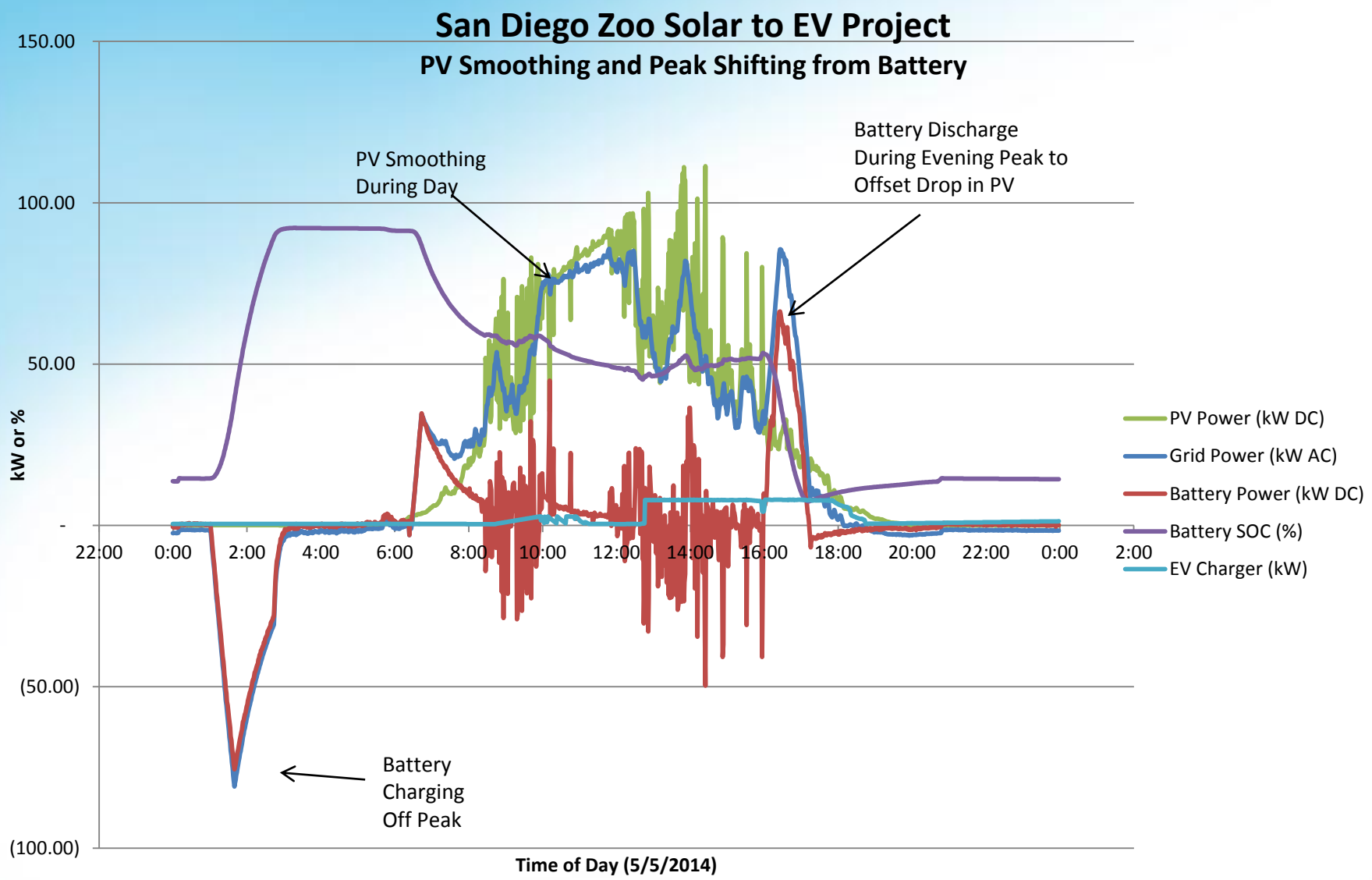


Control Hierarchy



The Possible: Peak Smoothing through Storage

San Diego Zoo - May 5, 2014



Questions?

SDGE
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Thank You

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www.sdge.com/smartgrid/