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The Power of Data

UCSD Microgrid Demand Response Dynamics

Presented by

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OSIsoft, LLC & UC San Diego

Outline

- UCSD Microgrid
  - Architecture
- PMU Data Analysis
  - Angle Unwrapping
- Building Modeling
  - PI AF Model
  - Naming Convention
- System Scalability
  - PI AF
  - PI AF Parameter Substitution

UCSD Microgrid

- Largest known microgrid in the world
  - 45,000 students and 45,000 faculty and staff
    - Rated 8th best public University in USA
    - Jacobs School of Engineering 5th in Bio Engineering
  - Peak load ~42 MW
  - Self Generation 30 MW
  - Solar PV ~1.5 MW
    - Soitec CPV (27.5 kW)
  - Fuel Cell 2.8 MW
  - Battery systems
    - Second life (60 kWh)
    - Peak shifting(30 kW/30 kWh)
    - 3.5 MW/7 MWH under construction

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UCSD Microgrid (continued)

- 12 PMUs
  - Six installed
    - 2 SEL 351a
    - 3 Arbiter 1133a
    - 1 FNET (UT)
  - Six under contract to be installed this fall
- Over 125 buildings
  - > 57,000 assignable rooms
  - HVAC system by Johnson Controls
  - Additional metering by Schneider Electric
  - ~ 45,000 PI tags (18 months of data, 32 TB of disk)
- Over ~900 electric vehicles on campus
  - 26 new charging stations being installed (RWE).
    - Fast chargers

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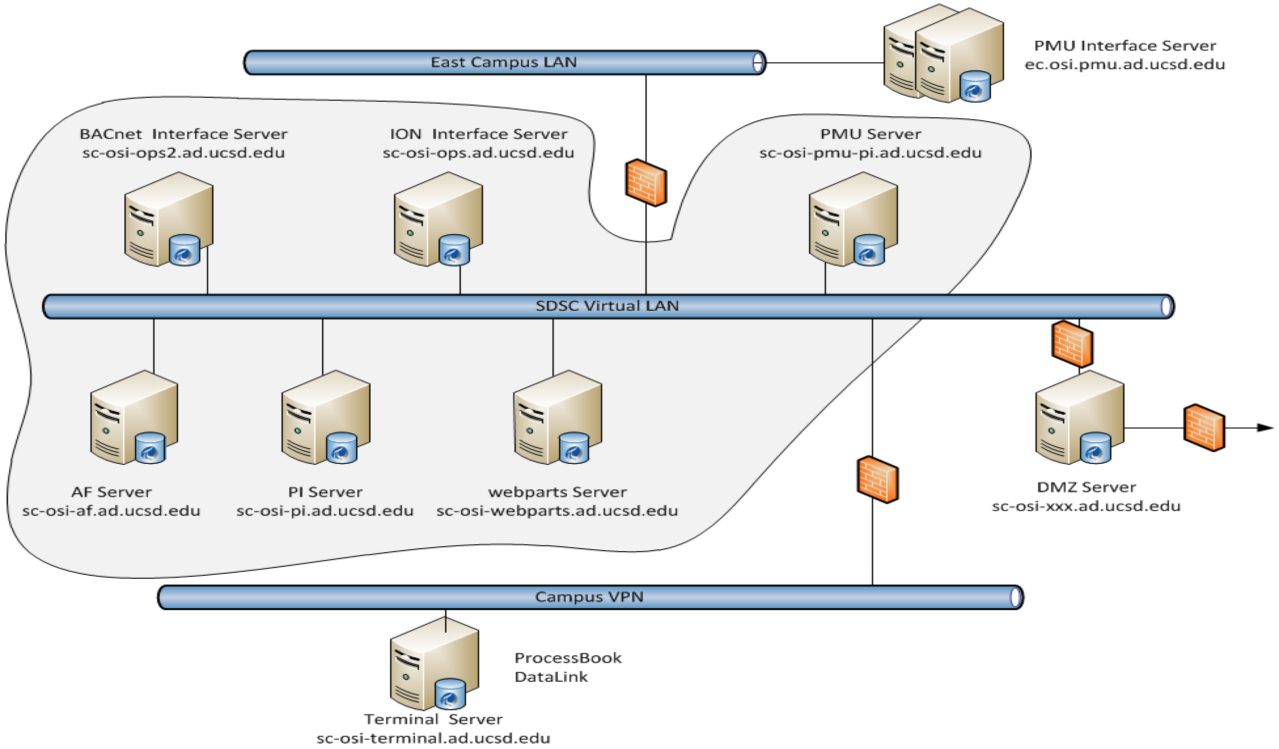
PI System installations at UCSD

- Main campus PI System
- Jacobs School of Engineering
- SDSC CSSP System

Architecture Overview



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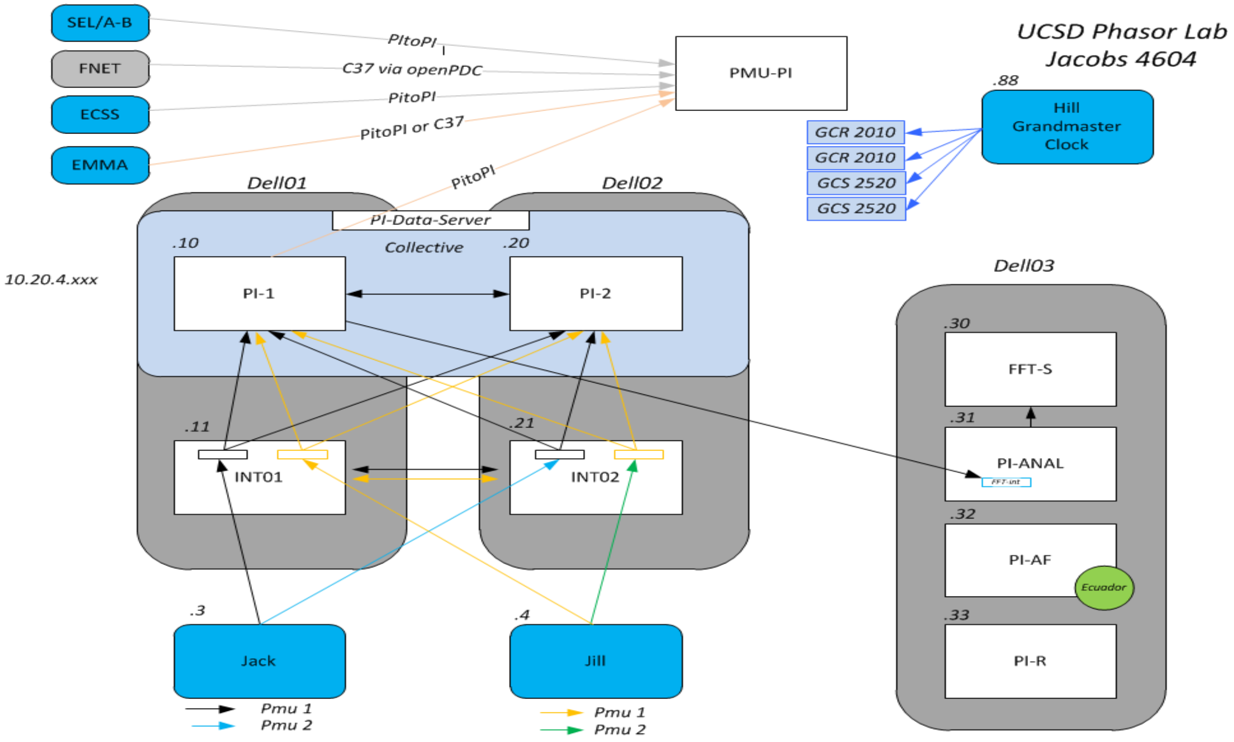
Jacobs Architecture Overview



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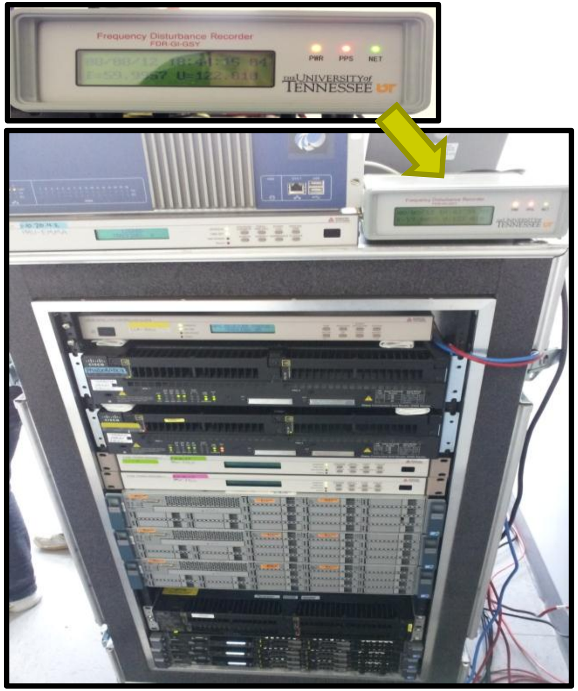
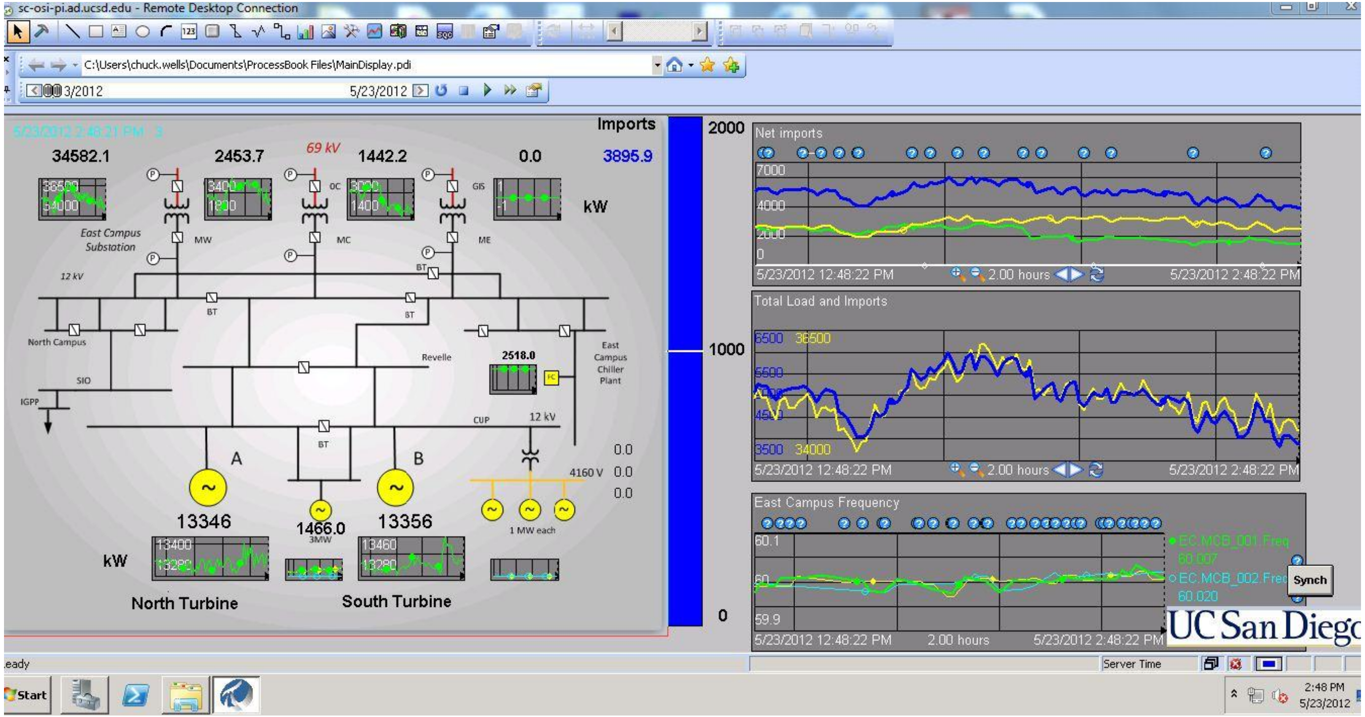
Hardware Photo



The UCSD Microgrid



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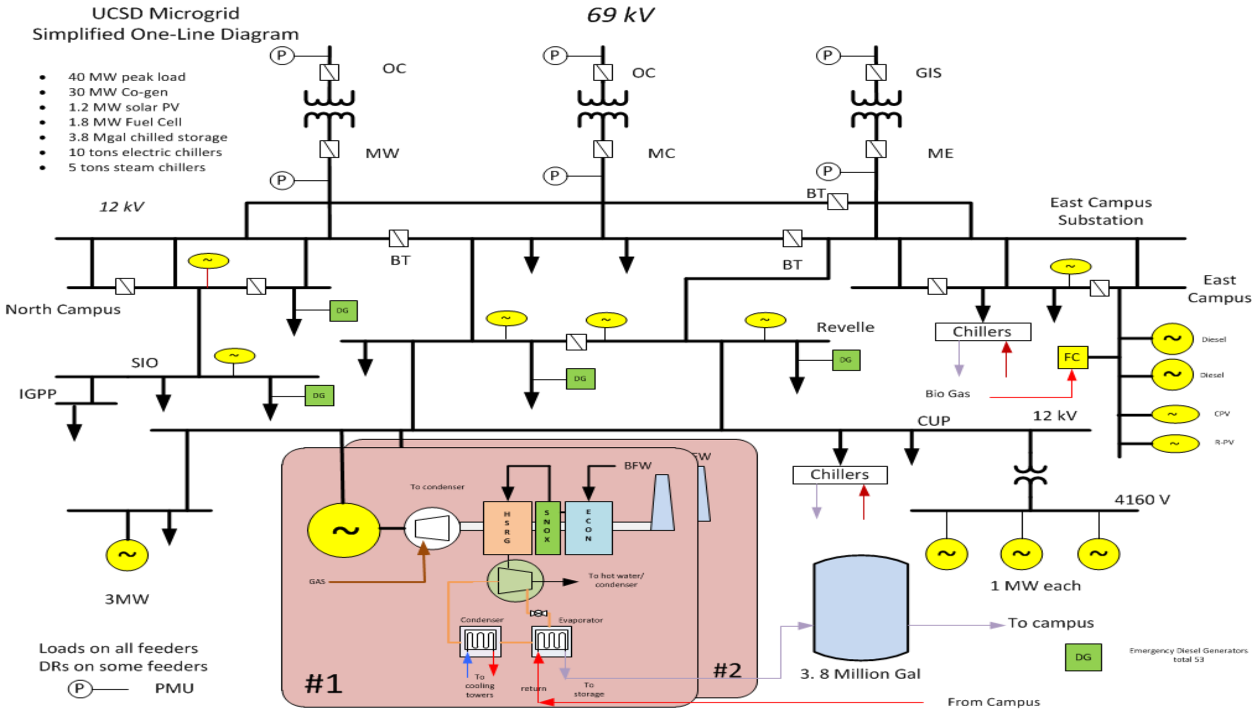
Electrical One Lines



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August 14 Demand Response

- “SDG&E has notified the campus that energy demand reduction is needed between 1 and 6 p.m. today due to continued high temperatures taxing regional power reserves. Without demand reduction, SDG&E may be required to take actions to stabilize the utility grid.

- Beginning at 1 p.m. today, Facilities Management will automatically reduce power demand by adjusting campus comfort cooling settings.
- Heating, ventilation and air conditioning in office areas will go into "unoccupied" mode and spaces will be warmer or cooler than normal, depending on the space. Temperature set points in lab areas will range between 68 and 76 degrees. Airflow will not be affected.”

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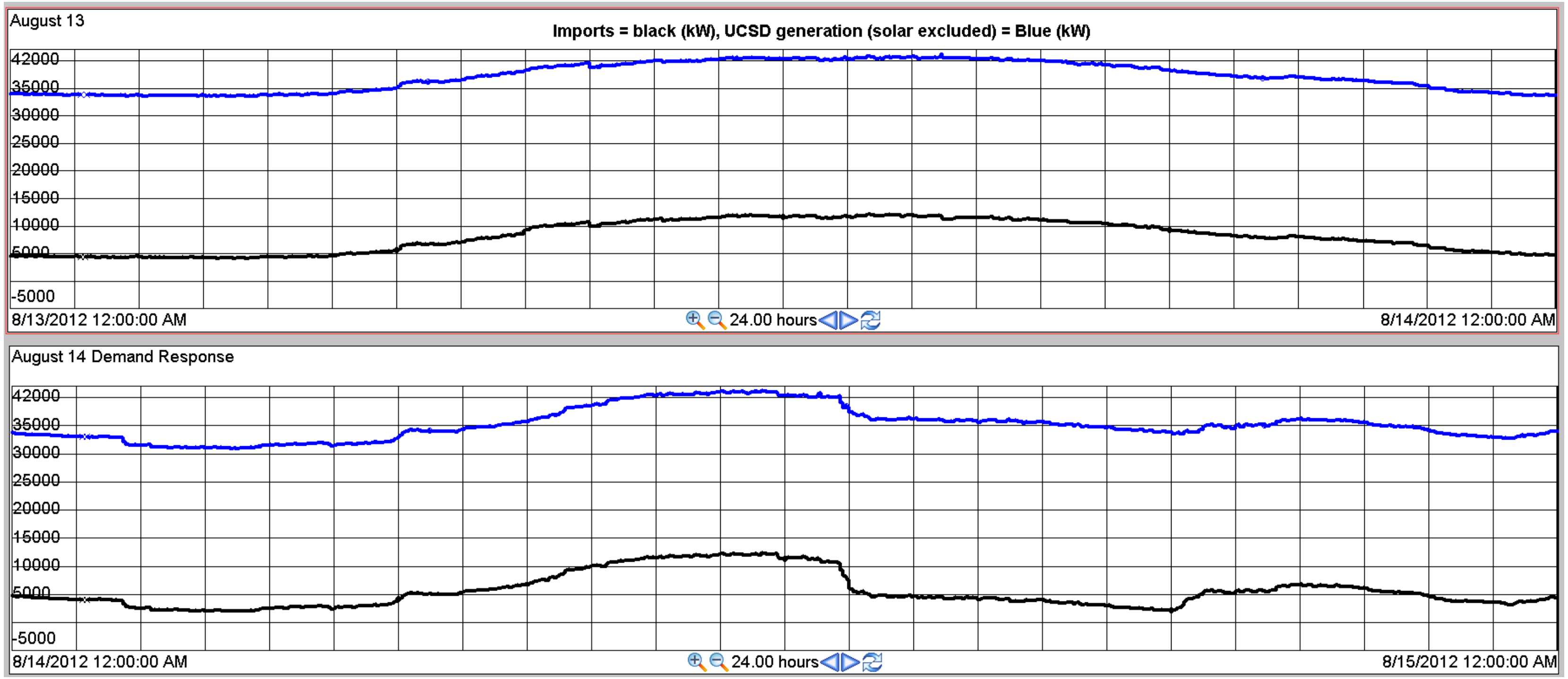
Comparison between August 13 and August 14



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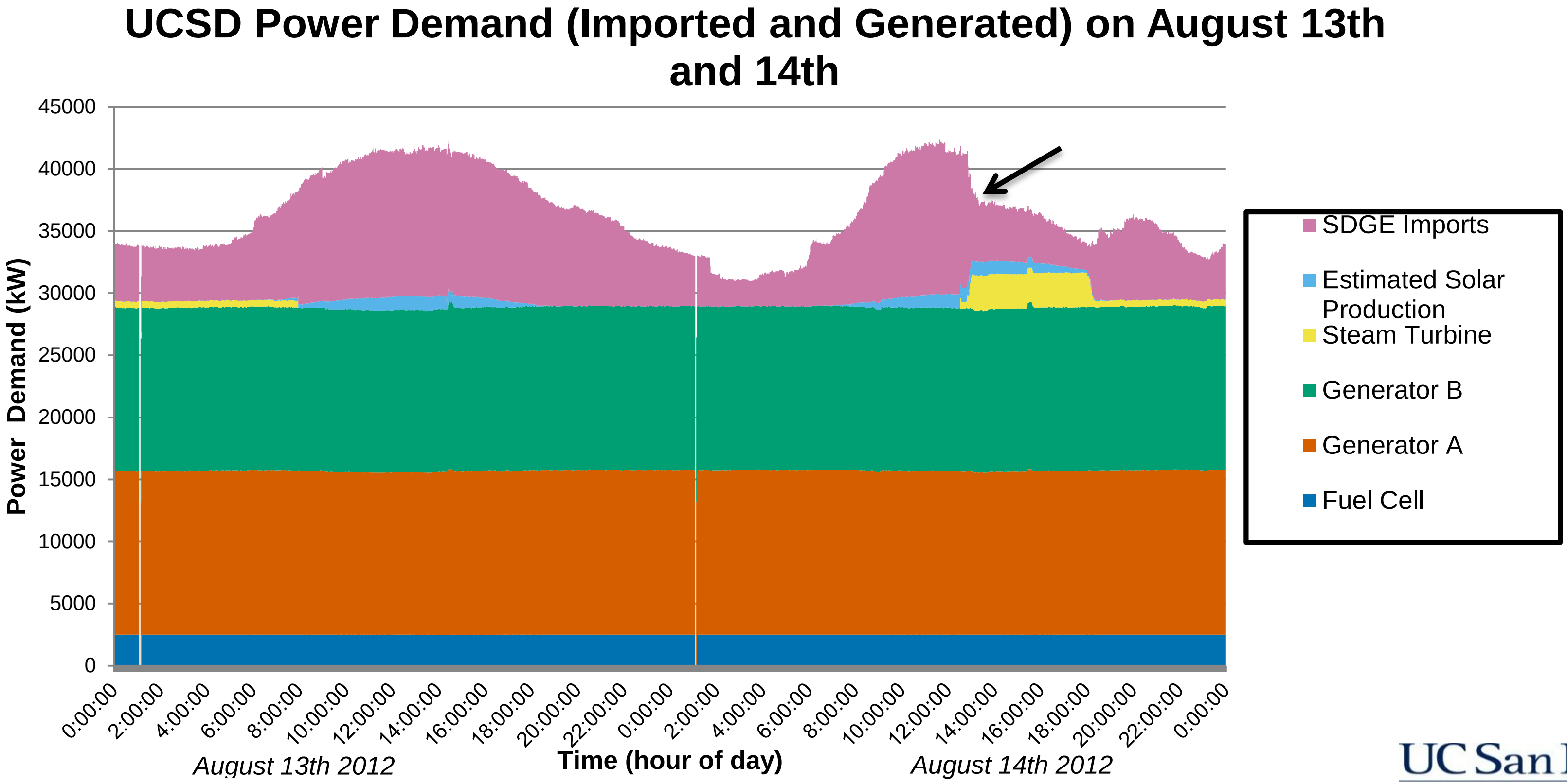
Stacked area chart



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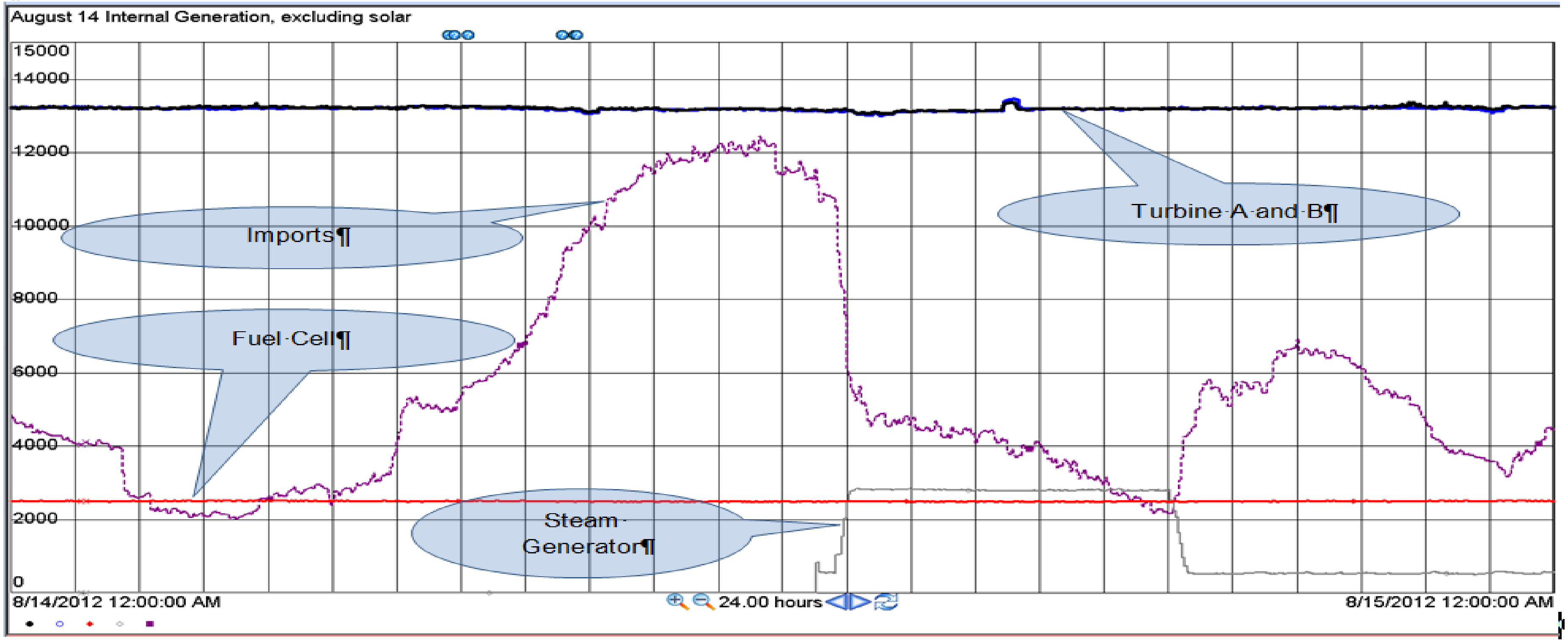
Dynamic response



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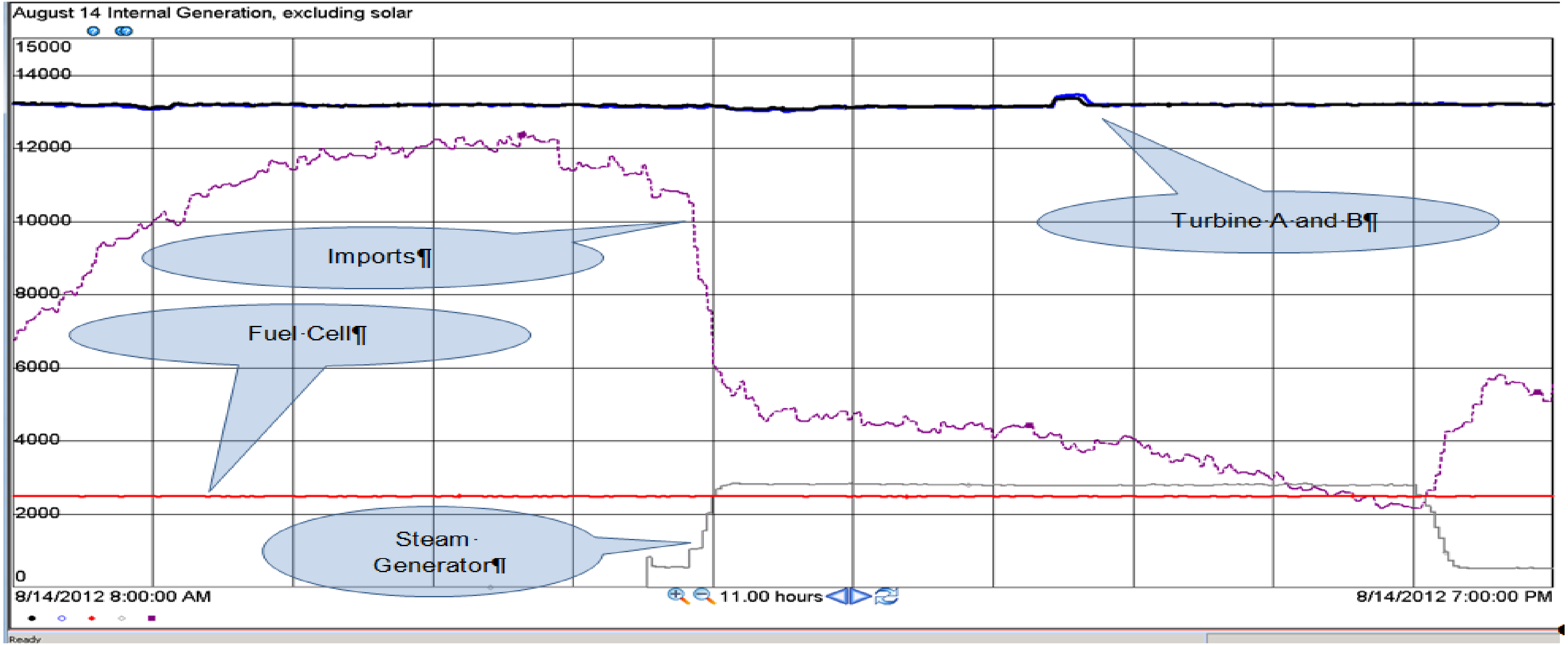
Zoomed in view



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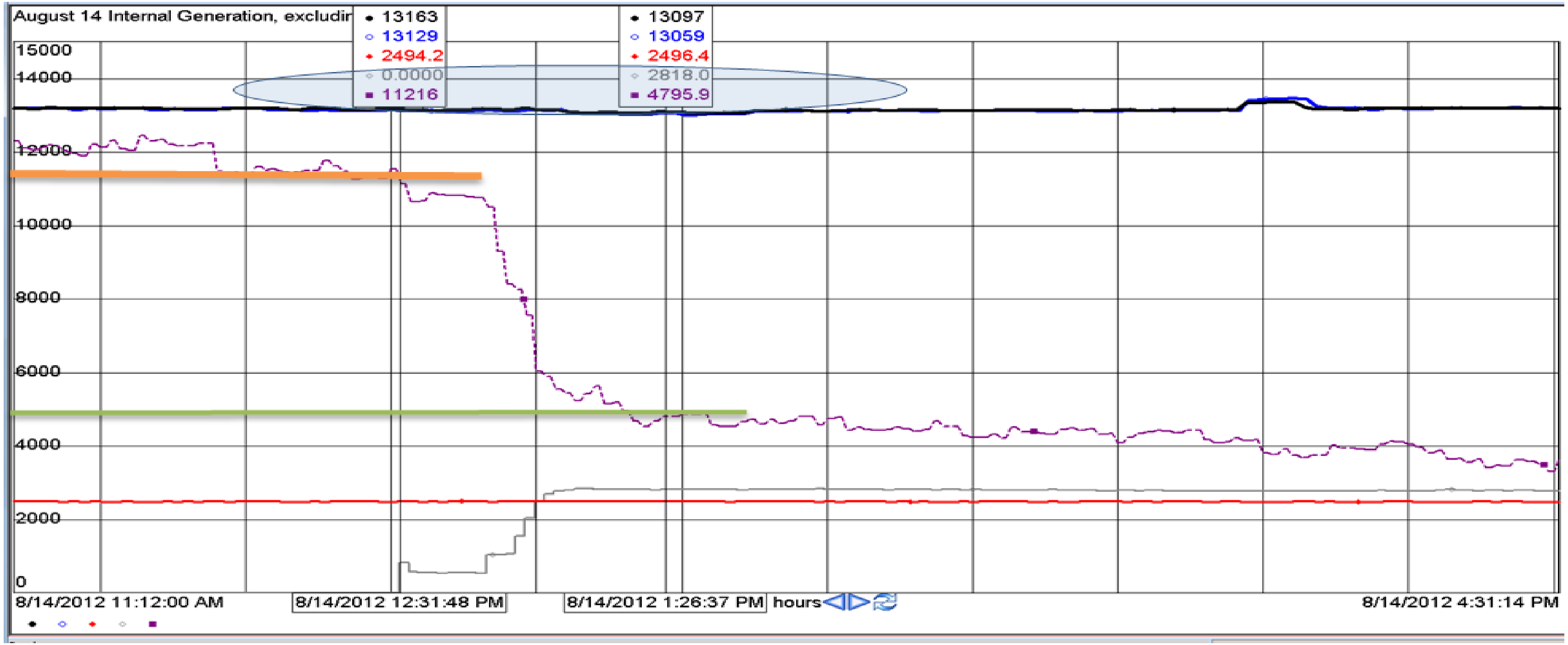
Estimating gain and time constant



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First order approximate response

So the simple dynamic model of the campus could be as follows:

$$d(s) = \frac{K}{Ts + 1} u(s)$$

Where u(s) is the input function (the occupy command in percent of rooms set to “un-occupy” state), d(s) is the demand, K is the gain, and T is the time constant in seconds. For this test

$$u(s) = \frac{100}{s}$$

K = -36.02

T = 1800 seconds

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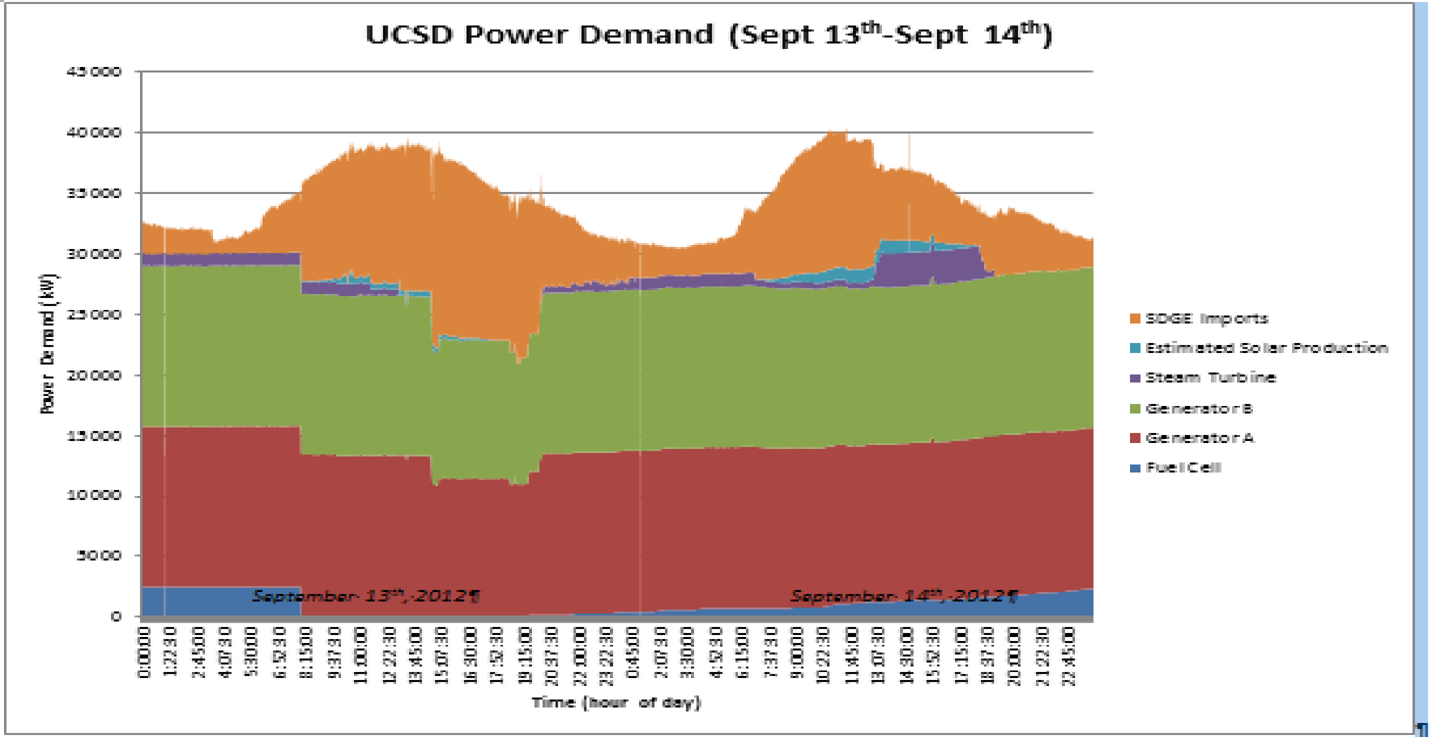
Comparison with September 14



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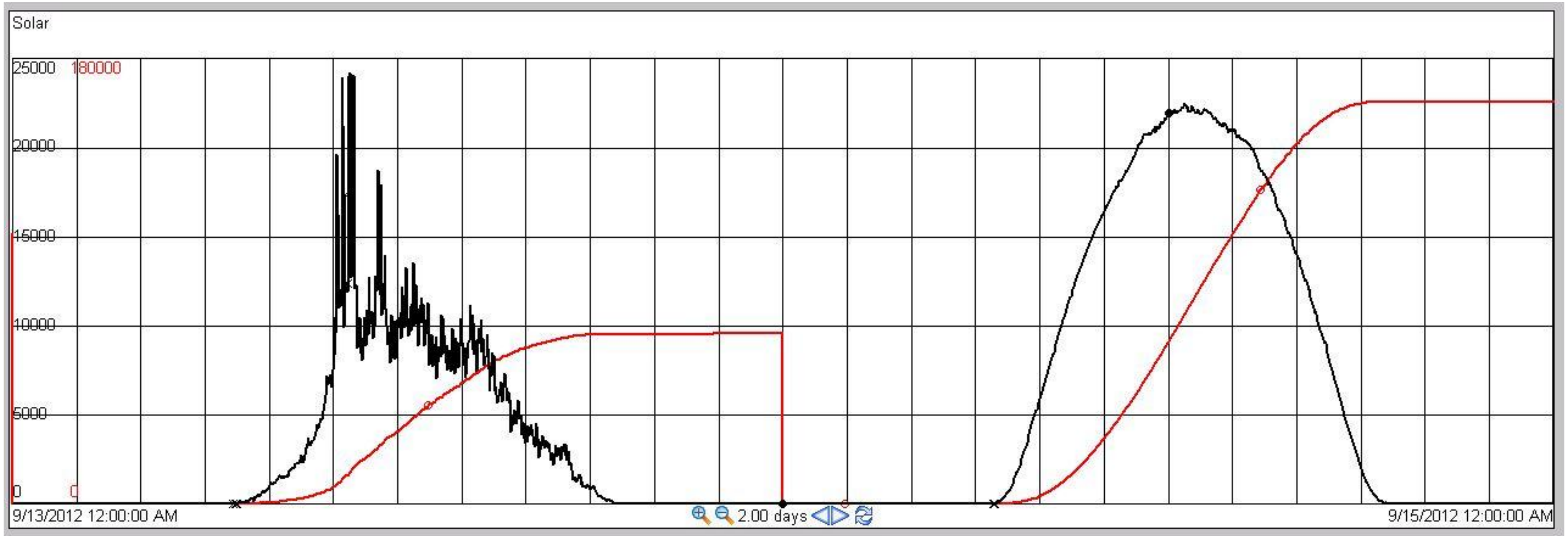
Solar output



Side by side

kW response	14-Aug	14-Sep	% Diff
Demand Response	6420	4433	-31.0%
STM generation increase	2818	2137	-24.2%
Building Reduction	3602	2296	-36.3%

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Significance

- UCSD can reliably reduce load by 6 MW in 54 minutes
- Sufficient chilled water must be available to allow converting the steam chiller to a steam generator.

- Can building energy response be improved by using existing HVAC data for efficiency

- Building KPI Intern program
  - Summer of 2012
  - Peggy Ip, John Lee, Yung Nguyen, Amy Chiang

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Why work on Building control systems

- As of 2010, the DoE reported that building energy consumption represents 41.1% of the U.S. Primary Energy Consumption which was greater than the industrial and transportation sectors
- A small improvement in building HVAC efficiency can result in large reduction in carbon emissions and lower costs of operations.
- Building might be useful “control” devices in local area power systems, especially to help compensate for solar PV and EV charging system intermittency

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Building KPI Project

- Original Tasks:
  1. ~~Survey Inventory of Buildings on Campus~~
  2. ~~Research and determine building KPIs~~
  3. Build 3-D model of campus on Google Buildings
  4. ~~Study existing PI database for global set of measurements~~
  5. ~~Determine other operational parameters that may influence behavior of building or room~~
  6. ~~Building model in AF~~
  7. ~~Build DOE model of energy consumption~~
  8. ~~Determine best set of names for objects~~
  9. ~~Select buildings on campus that have best set of data~~
  10. ~~Associate AF names with PI data stream names~~
  11. ~~Build web display~~
  12. Animate Google buildings with real-time data
  13. ~~Write Report on Findings~~

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Key Performance Indicators

- **Measures performance of a building**
- **Annual energy per square foot**
- Can include other variables:
  - Occupancy
  - Building type
  - Direction the windows face
  - Energy source
- Comfort KPI can include:
  - Amount of air flow
  - Zone temperature
  - Quality of air (CO_2)

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Results of the PI AF Building Model

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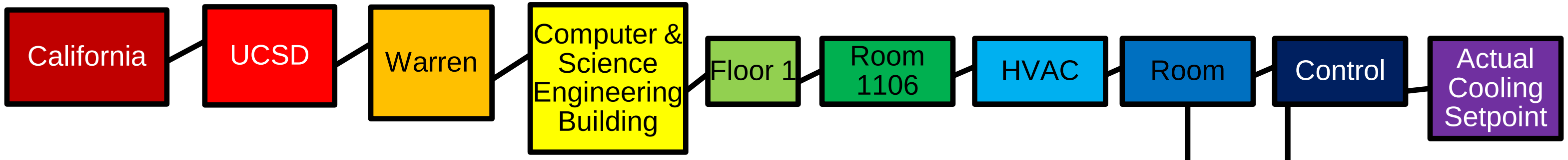
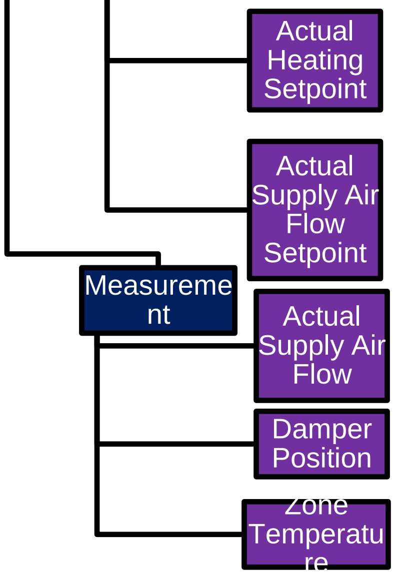
Tag naming issues and approach

- Problem
  - Legacy naming conventions not documented
  - Multiple names for same object begin measured
- Approach
  - Use object oriented design of naming structure
  - Use IEC 61850 recommended names for leaf objects
  - Use ISO 50001 Building Automation Standards
- Goals
  - Set foundation for auto discovery and naming of BACnet systems
  - Use PI AF data references to auto create PI System tags with rigid structure
  - Create PI AF names and tagnames with fixed width components

Naming Structure





Before

```
Modbus Hopkins Channel 1 Inverter Voltage
NAE-03_CALIT.N2-1.RM-2300.7-2VAV2-45.SUPFLOW.SUPPLY_AIR_FLOW
NAE-H02_HOUSING_AND_DINING.Field_Bus.SF-VFD1.SF-VFD1.AV-6.SUPPLY_FAN_VFD1_AV-6
NorthCamp.Rady_Main_7080_Power_kVA_c
REVELLE.Bonner_E1131.Energy.kVAh_del-rec
```

After

```
CA.UCSD~.ERC~.HOPPS.ROOF~.ENERP.PV~~~.INVRT.MEAS~.VOLT
CA.UCSD~.WARR.ATKIN.FLR2~.R2300.HVAC~.ROOM~.MEAS~.SAF
CA.UCSD~.REVE.HNDB~.MECHI.HVAC~.AHU#~.SF6~~.CTRL~.VFDCOMMAND
CA.UCSD~.NCAM.RADY2.FLR7~.R7080.OUTLT.3PO~~.MEAS~.kVA
CA.UCSD~.REVE.BONNH.FLR1~.R1131.OUTLT.3PO~~.MEAS~.kVAH
```

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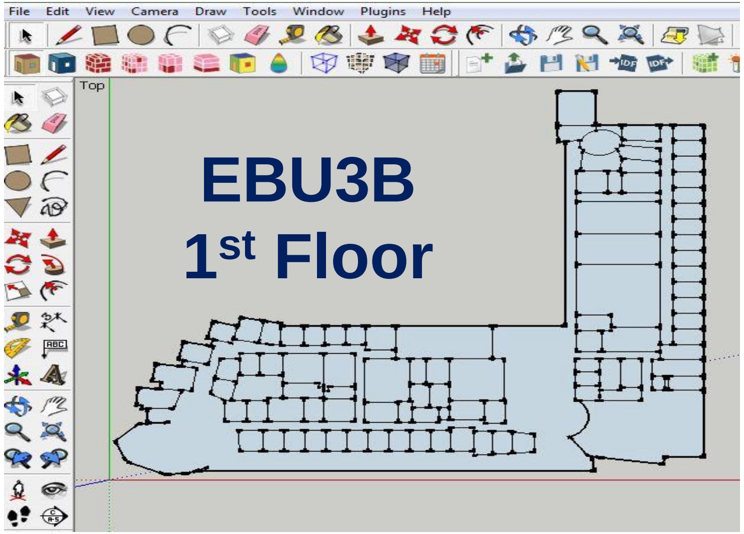
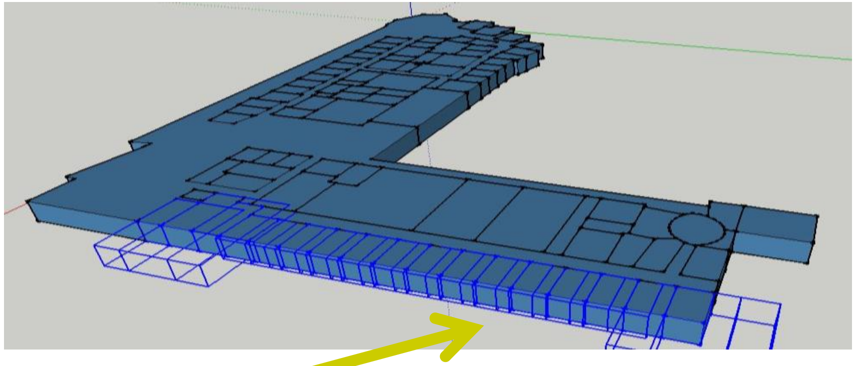
Baseline KPI

Energy simulation with ideal air load provides **baseline** for calculations

Google SketchUp

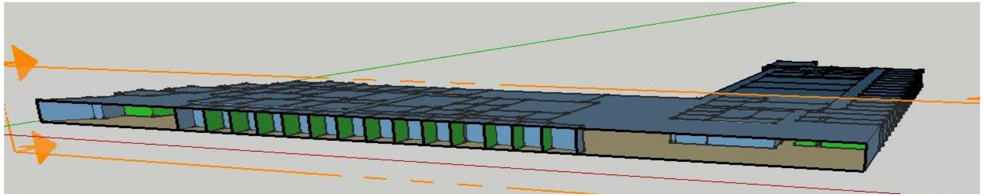


Defining Thermal Zones



West Side of Building

Defining Surfaces



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KPI Comparison with Baseline

DoE Model VS. Estimated KPI

- Let's take 3 rooms on the 1st floor in EBU3B…

	1106 Administrative	1107 Administrative	1113 Conference
DoE Model	9.01 $\frac{kWh}{ft^2}$	14.55 $\frac{kWh}{ft^2}$	14.09 $\frac{kWh}{ft^2}$
Estimated	10.95 $\frac{kWh}{ft^2}$	77.74 $\frac{kWh}{ft^2}$	9.20 $\frac{kWh}{ft^2}$
% Deviation	21.34%	432.30%	−34.72%

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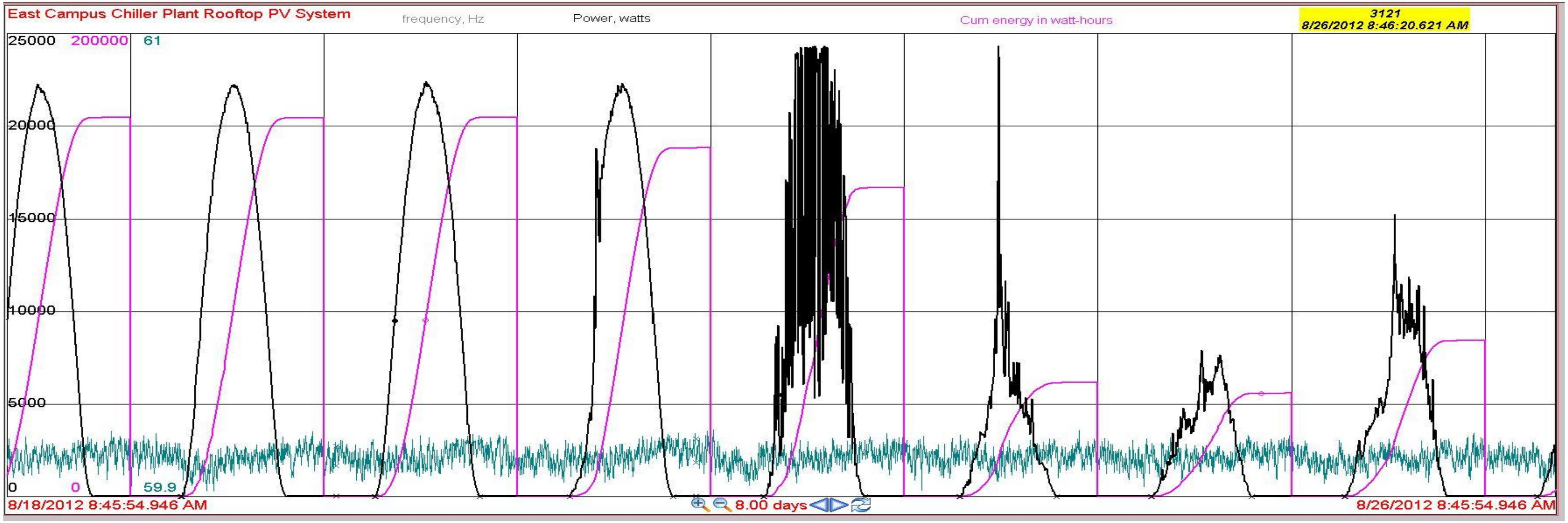
How can buildings be used as control variables

- We observed 3 MW demand response from buildings
- We observed 30 minute time constant from buildings
- We asked the question
  - Can buildings be used for microgrid control?
- What effect will solar PV have on grid stability?
- What effect will fast EV charging have on grid stability?
- Can the microgrid deliver ancillary services to the area power system?

Besides demand response, what other control issues?



Proposed Control system

- Hierarchical building controls based on "room agent"
- "Agent" implemented as PI AF template
- Room PI AF template includes:
  - PI Notifications object issuing SMS messages to Facilities
  - PI SQC object issues SQC alarms to Facilities
  - Room KPI includes comfort as well as energy
  - PI AF analytics used to communicate to parent object
  - Decoupling air flow control and temperature control
- Floor PI AF template communicates to building
- Building PI AF template communicates to College
- College PI AF template communicates to University

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Others working in this field of agent based controls

- IBM
- Five significant papers on this subject

- UCSD KPI team filed Invention disclosure on this approach to agent based controls
- Key innovations include:
  - Template based room object
  - SQC function inside the room object
  - Notifications inside the room object
  - Decoupling air flow and temperature

Goals towards scalability and auto discovery

- Developed common naming system with dictionary
- Examined PI AF syntax for parameter substitution to create tag names
- Worked with SDSC to crack BACnet names using Levenshtein distance algorithm (Jo Frabetti)
- Legacy tagnames can be automatically renamed to new PI System tags that match the PI AF names

Suggested follow on work

- Build the PI AF naming structure for entire campus
- Implement room agent Notifications and SQC
- Implement decoupling analytics in room template
- Implement hierarchical control system
- Determine time constant of new building controls
- Use local microgrid frequency as building control signal
  - Frequency decrease → load reduction

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THANK YOU

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