



# Power Management in the Smart Grid

Gregory T. Smedley, Ph.D.

Taotao Jin, Ph.D.

Tong Chen, M.Sc.

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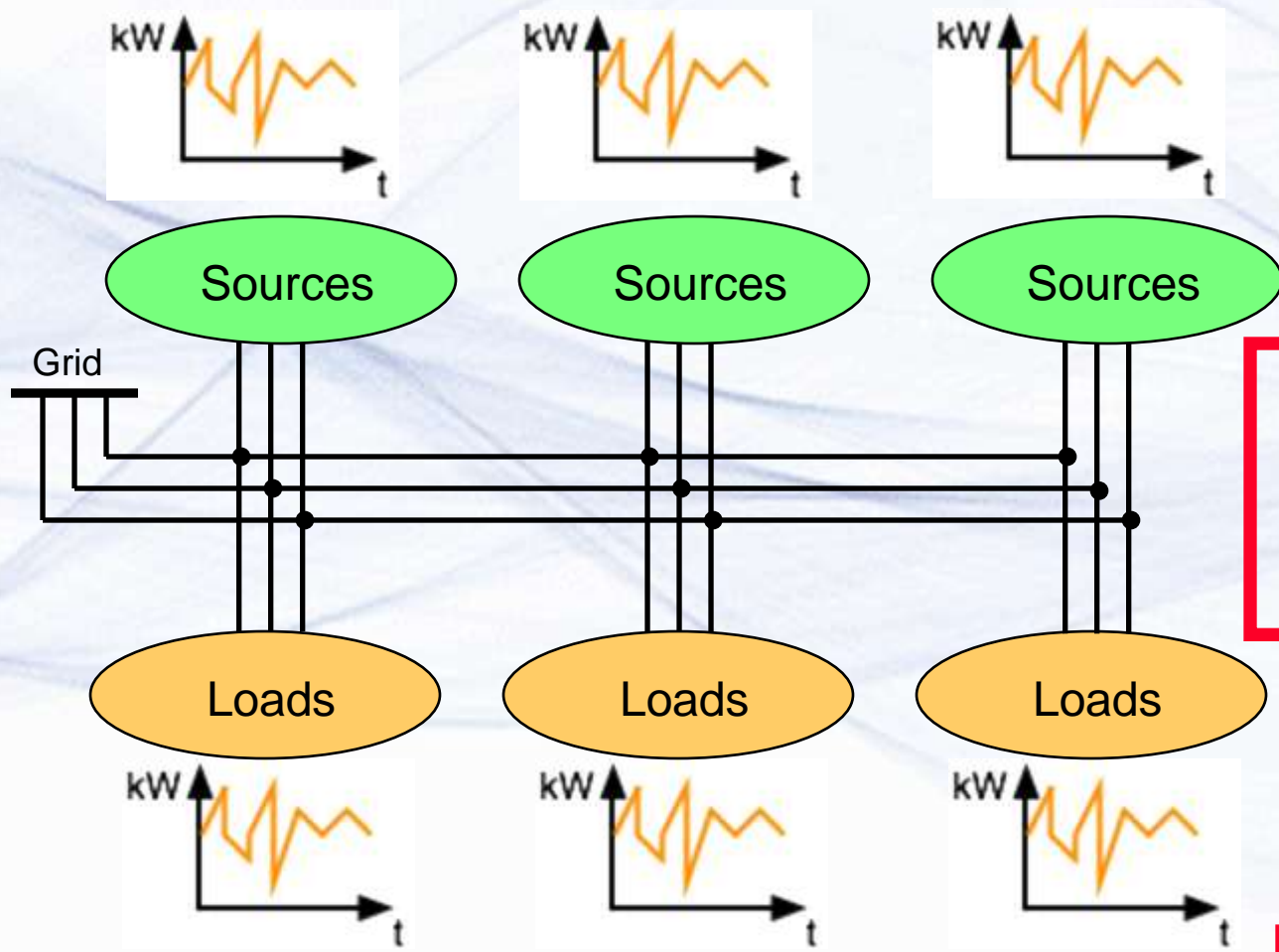
**Power Management, Cell Phones to the Grid**

**March 20, 2013**

# The Grid

## Big Passive Dynamically Stressed

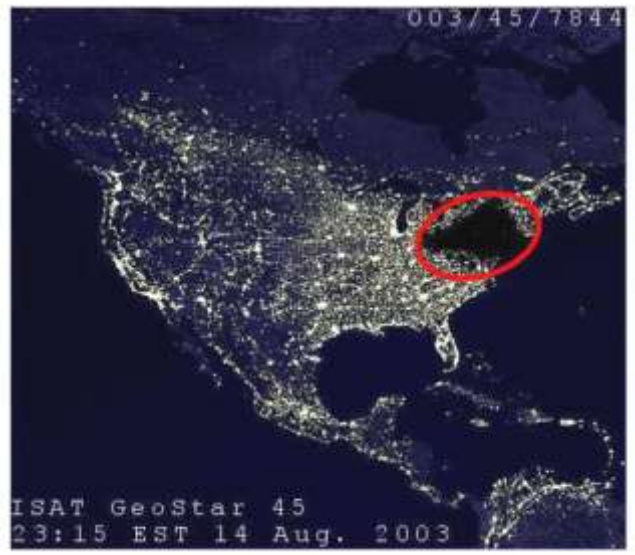
# Dynamic Sources & Loads ?



**Problem:**  
Dynamic  
Voltage &  
Frequency

Micro-Grid ?

# Problem: Cascading Outages



Eastern USA - 08/2003



Got Power ?



San Diego - 09/2011

02/2011 (TX)	1 M
02/2011 (Brazil)	53 M
09/2011 (CA)	5 M
09/2011 (Chile)	9 M
10/2011 (E. US)	2 M
01/2012 (Turkey)	20 M
04/2012 (Cyprus)	1 M
06/2012 (E. US)	3.8 M
07/2012 (India)	400 M
10/2012 (E. US)	8.2 M
02/2013 (E. US)	0.7 M

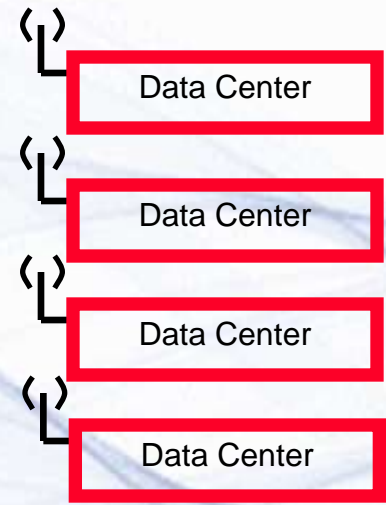
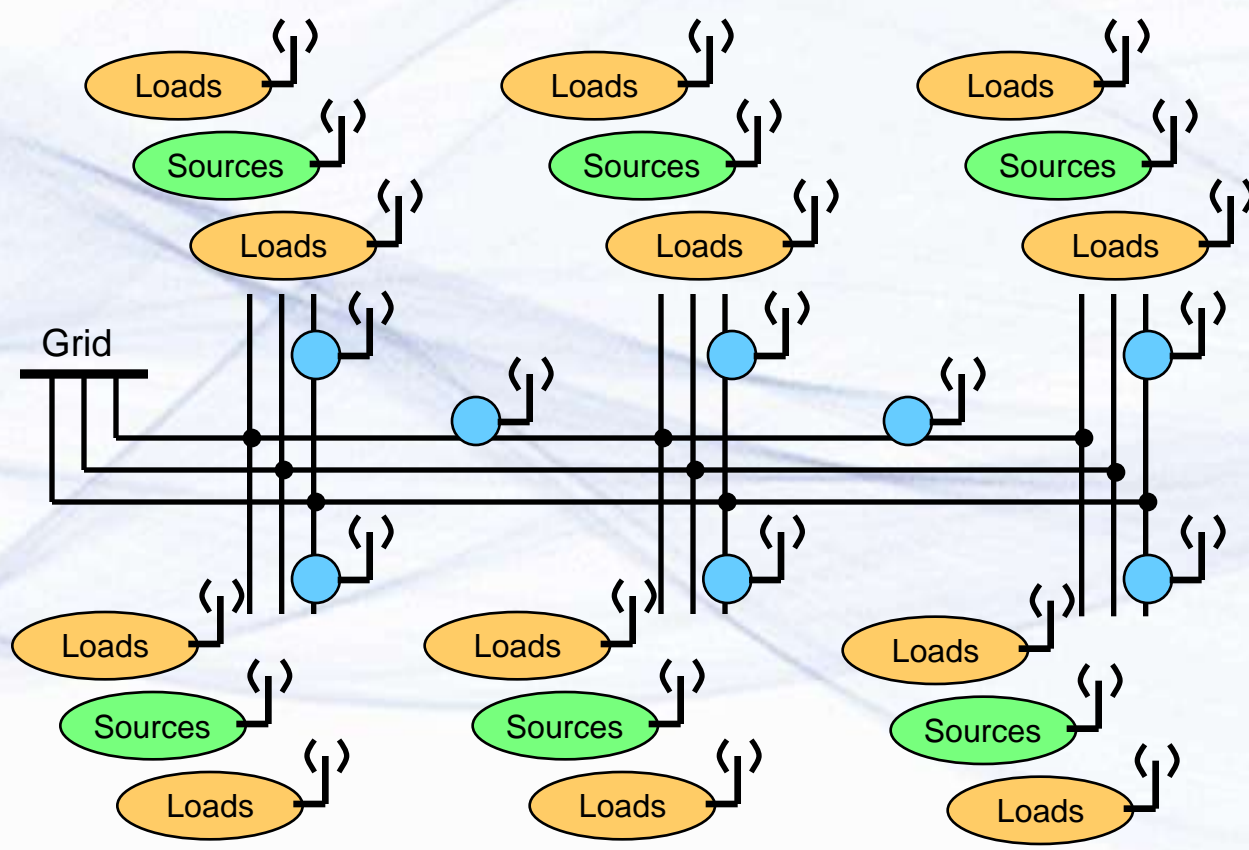
est. Loss ~ \$80B / year (USA)

# The Smart Grid

## Distributed Semi-Active Central Control

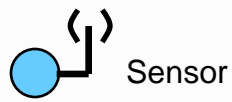
**Enabler: Datacom / Telecom**

# Sensors, Loads, Sources with Central Control



**Problems:**  
 “big brother”  
 $c = 3 \times 10^8 \text{ m/s}$

Actuators ?

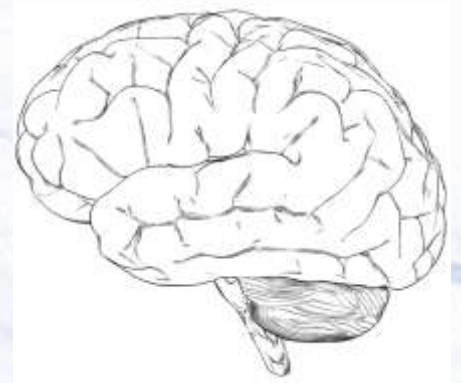
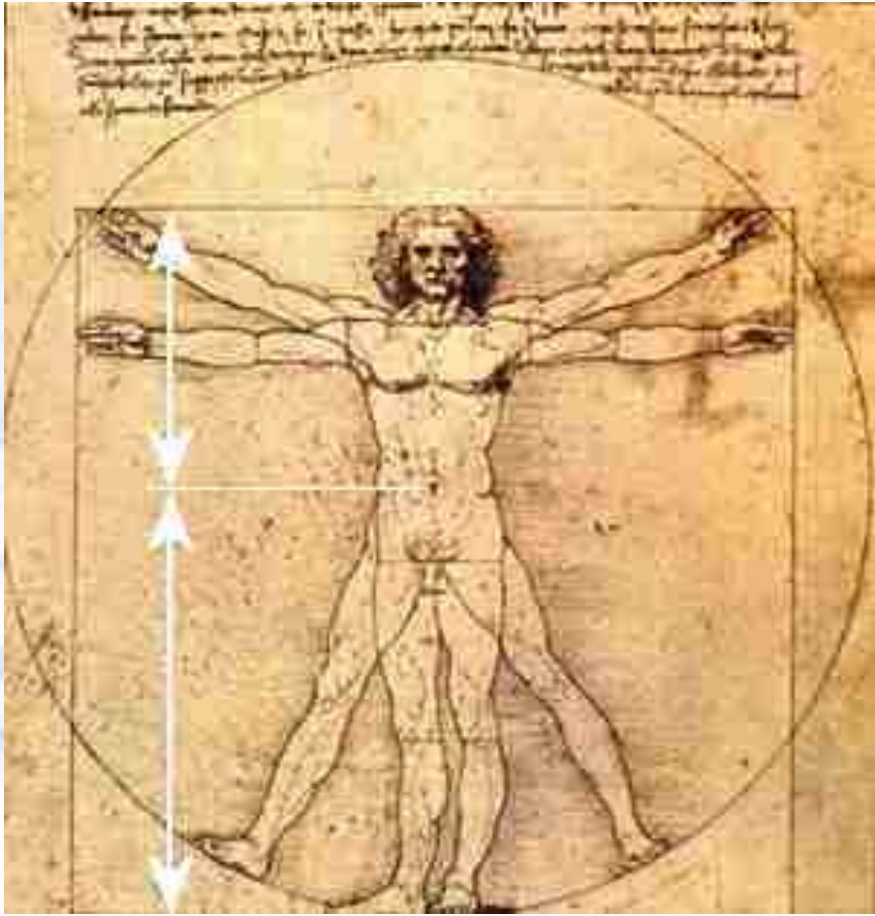


# Smart Grid Challenge

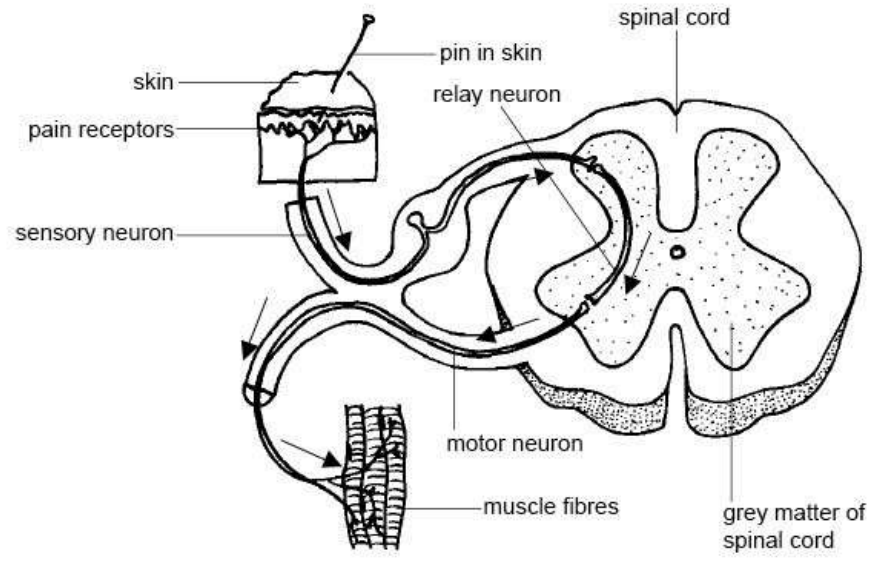
“One of the most daunting challenges facing utilities is the surge of data that will result as we modernize [the grid] .... managing thousands of times more data than you do today.”

Jesse Berst (Smart Grid News, Jan 2010)

# How can we simplify ?



Brain



Reflex

## Add Grid "Reflexes"

- "Reflexes" Mitigate Dynamics
- Autonomous => Reduces Data/Com burden



# **Future Grid**

**Distributed  
Active  
Autonomous**

**Enabler: Power Electronics**

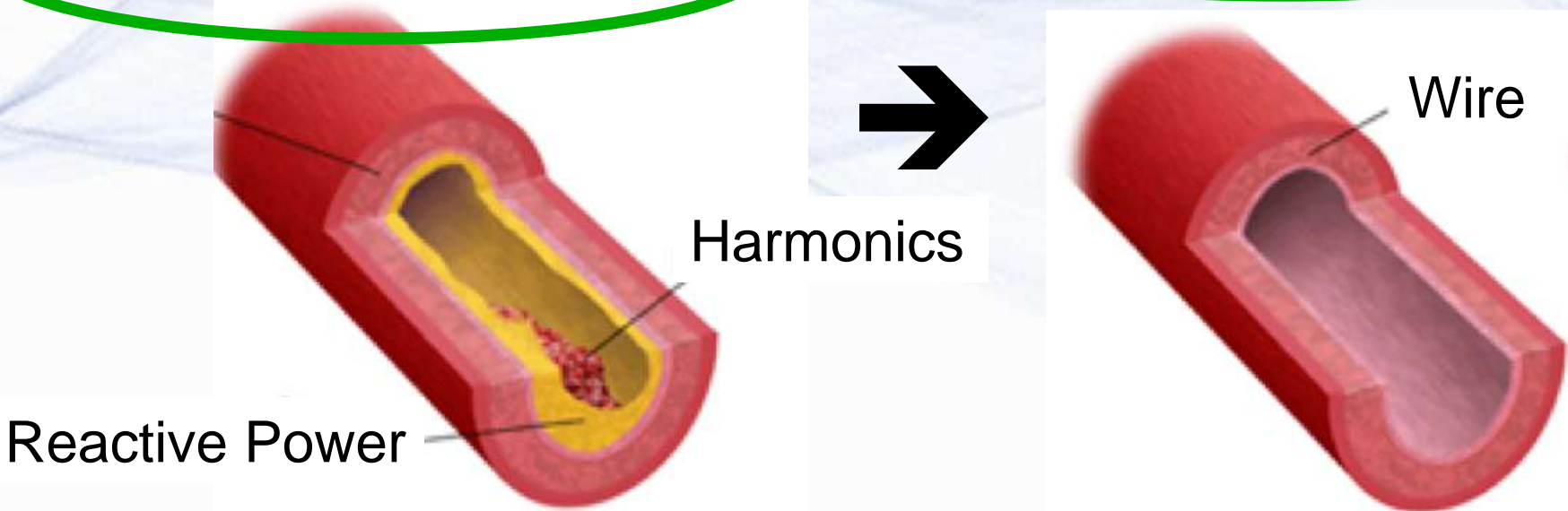
# Grid Solutions

## Increase Operating Margin

- More/Bigger Wires
- Eliminate Pollution

## Active Control

- Voltage
- Peak Load



# Power Electronic "Reflexes"

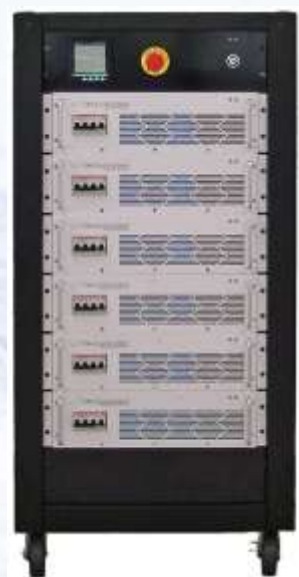


Eliminate Pollution



Active Power Filtering

Control Voltage



Dynamic VAR Compensation



Control Peak Load



Peak Load Regulation

Scalable: kW to MW

# Active Power Filtering

Eliminate Grid Pollution  
Boost Capacity & Efficiency

\* Grid Pollution Occupies ~20% of Grid Capacity

# APF Test Data

QuickTime™ and a decompressor are needed to see this picture.



## OFF

PF=0.79



## ON

PF>0.99

V<sub>A</sub>  
I<sub>A</sub>  
I<sub>APF</sub>  
I<sub>LOAD</sub>

\* Boost Grid Capacity (~20%) & Efficiency in Real Time

# Dynamic VAR Compensation

Stabilize Grid Voltage  
Increase Renewables  
Boost Grid Resilience

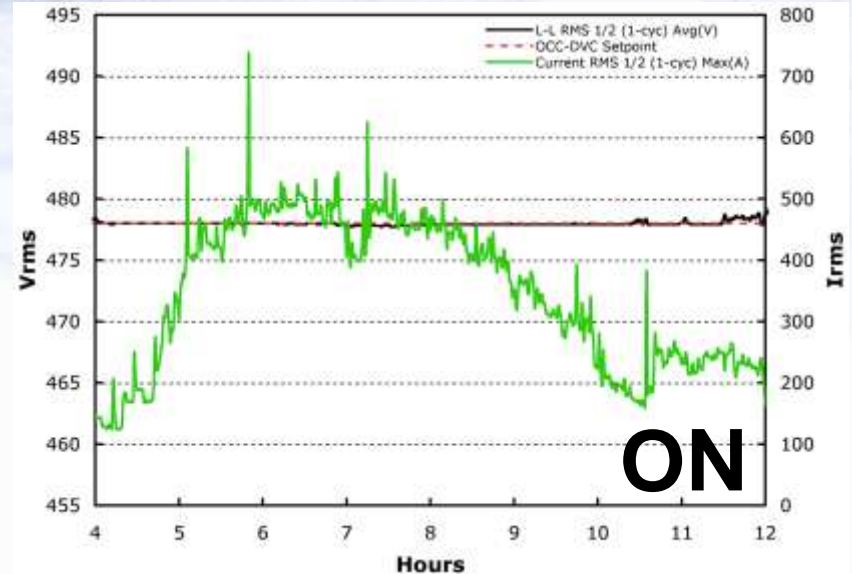
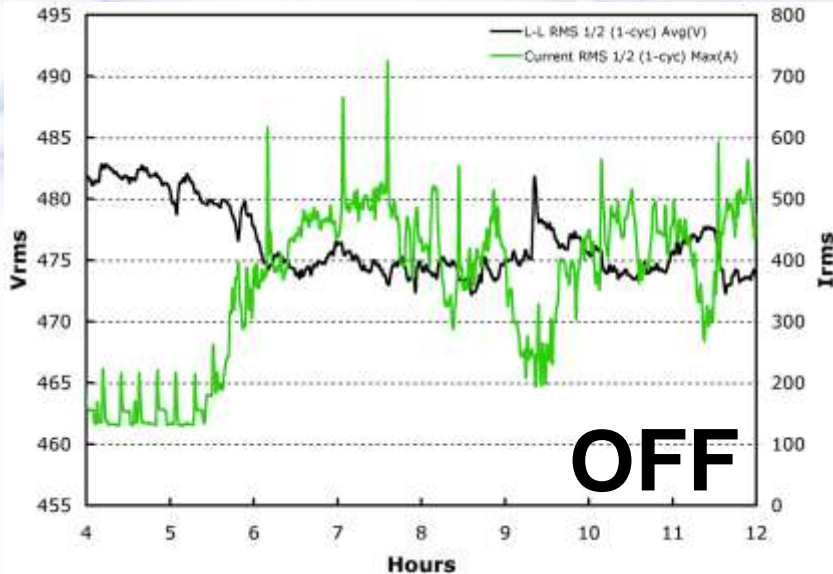
\* Grid Instability limits Renewable Generation to 15%

# DVC Field Data (240 kVAR)



QuickTime™ and a decompressor are needed to see this picture.

- Real Time Setpoint Control
- Voltage support ~ V
- Distributed, Small, Fast, Precise “Reflexes”
- Low V ride-through



# Peak Load Regulation

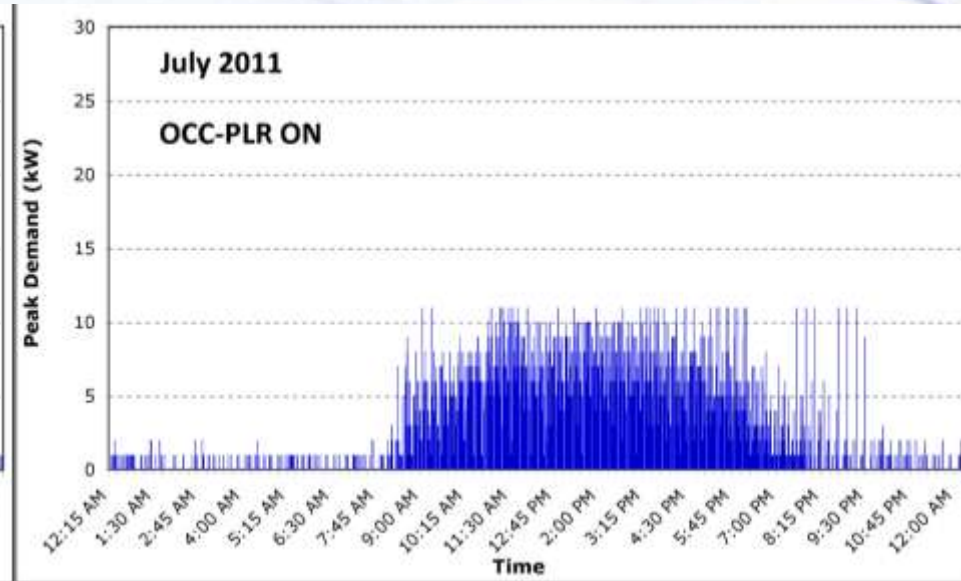
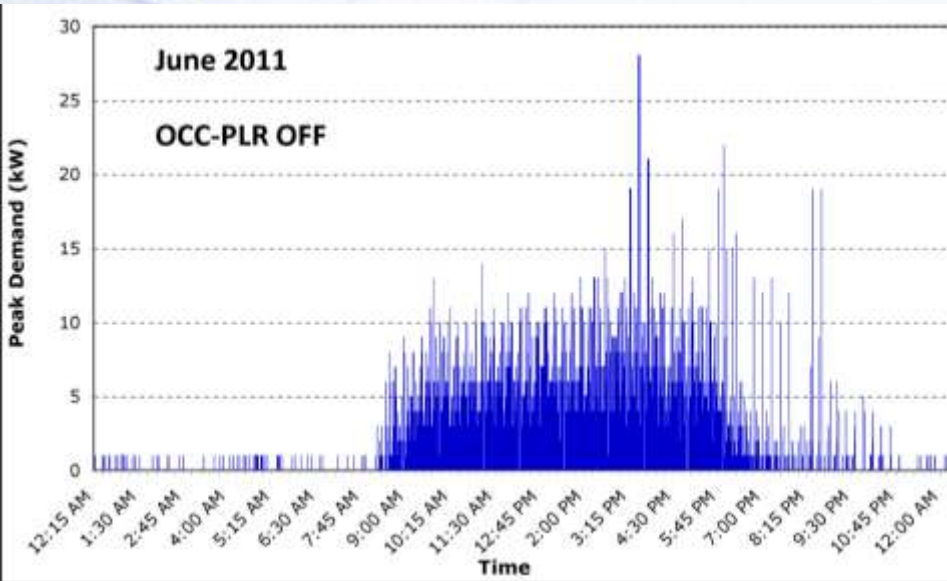
Reduce Peak Load  
Stabilize Grid  
Increase Renewables

- \* Peak Load forces Grid Over-Design
- \* Load Dynamics Destabilize Grid



# PLR Field Data

QuickTime™ and a decompressor are needed to see this picture.



## OFF

Spiky peak power

## ON

Flat peak power

\* Stabilize Grid Load in Real Time



# Autonomous Constellations APF, DVC, PLR

Stabilize Grid

Reduce Central Control Burden

Increase: Renewables, Grid Capacity, Grid Efficiency

Enabler: **Datacom / Telecom & Power Electronics**



*Greg Smedley*

# Thank you for your attention ... Questions ??

**address:** 12 Mauchly, Building P, Irvine, CA, 92618  
**phone:** (949) 727-0107 x01  
**email:** [gsmmedley@onecyclecontrol.com](mailto:gsmmedley@onecyclecontrol.com)