



# CPES

*Center for Power Electronics Systems*

The Bradley Department of Electrical and Computer Engineering



College of Engineering

Virginia Tech, Blacksburg, Virginia, USA

## DC Nanogrids

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*Presentation at:*

**10<sup>TH</sup>**  
ANNUAL  
PITT



**ELECTRIC POWER**  
INDUSTRY CONFERENCE

Presented by the Swanson School of Engineering & the Center for Energy



University of Pittsburgh

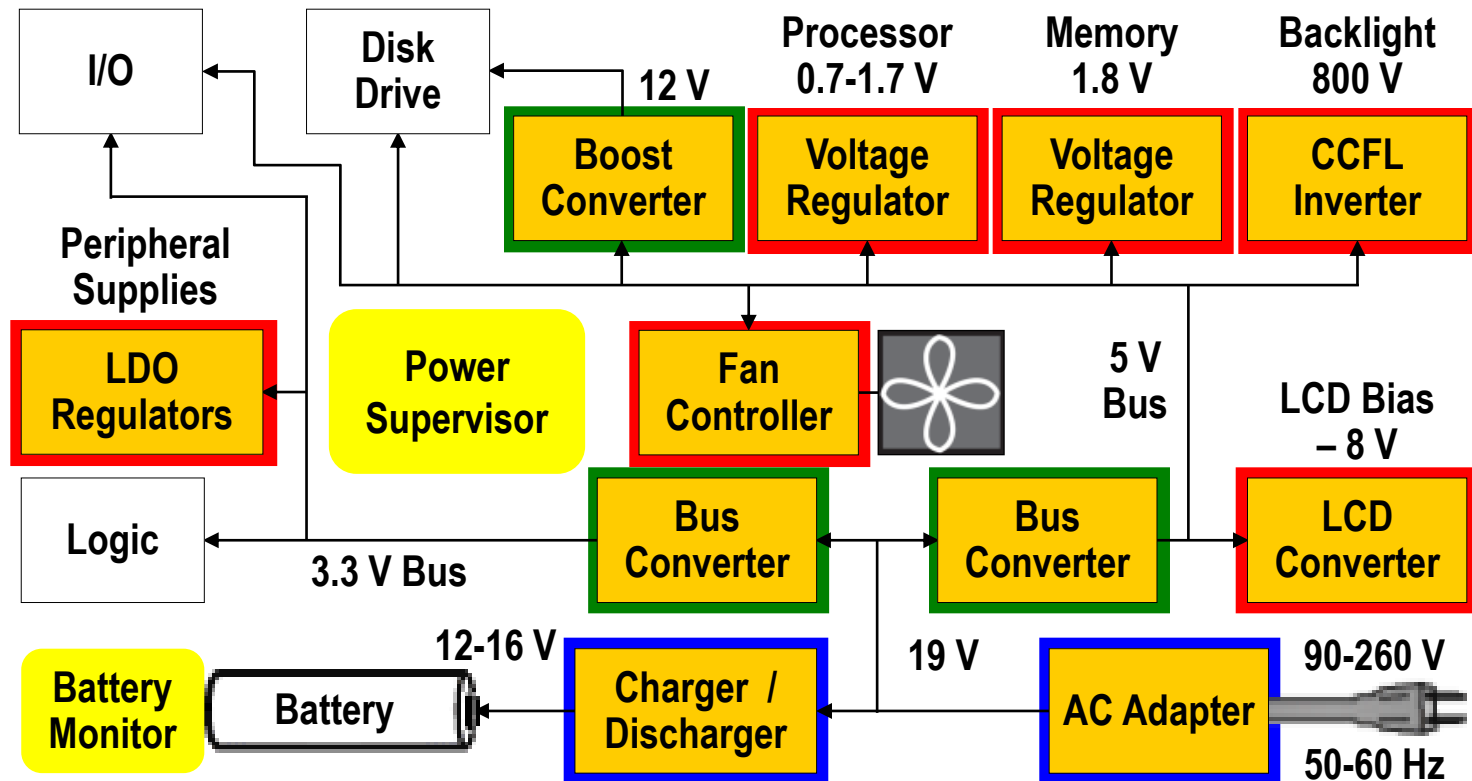
# Electronic Power Distribution System: A Notebook PC

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- Improved battery technology?
- High density packaging?
- Smaller electronic components?
- Better power management?

# Electronic Power Distribution System: A Notebook PC



- **Load converters:** Meet dynamic energy requirements of the loads
- **Source converters:** Meet ac line standards; improve battery utilization
- **Power Distribution Converters:**
  - Increase peak-power efficiency  $\Leftrightarrow$  Improve power density
  - Increase light-load efficiency  $\Leftrightarrow$  Improve energy efficiency

**REDUCE  
COST !**

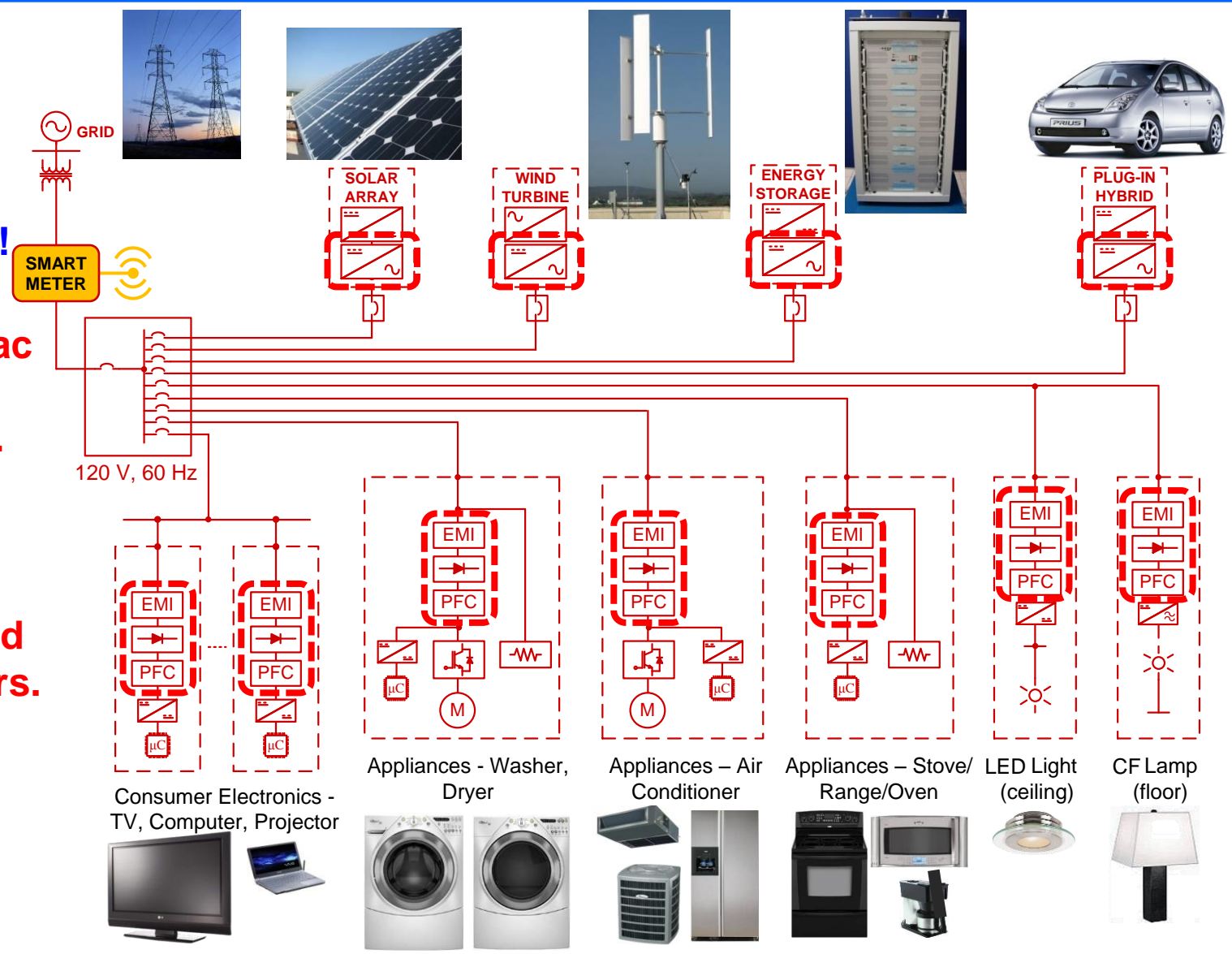
# Patching-up the 20<sup>th</sup> Century Technology

Integration of grid, renewables, and storage saves money!

Requires dc-ac inverters for every source.

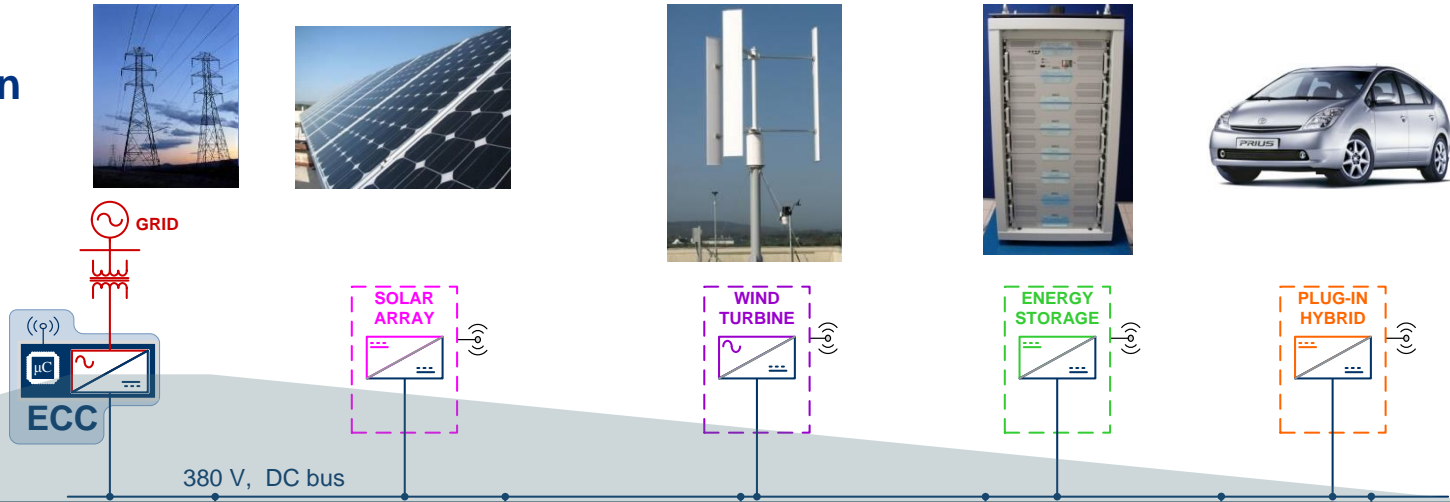
All electrical appliances have front-end ac-dc rectifiers.

“Smart” appliances save energy!

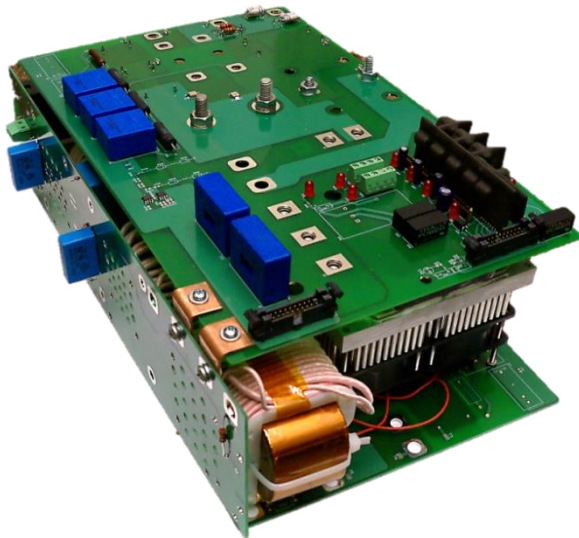


# 21<sup>st</sup> Century Electronic Power Distribution System: DC Nanogrid with Bus Architecture

- Bidirectional power conversion
- Separation of dynamics
- Islanded operation
- Integrated protection



## Energy Control Center (ECC)

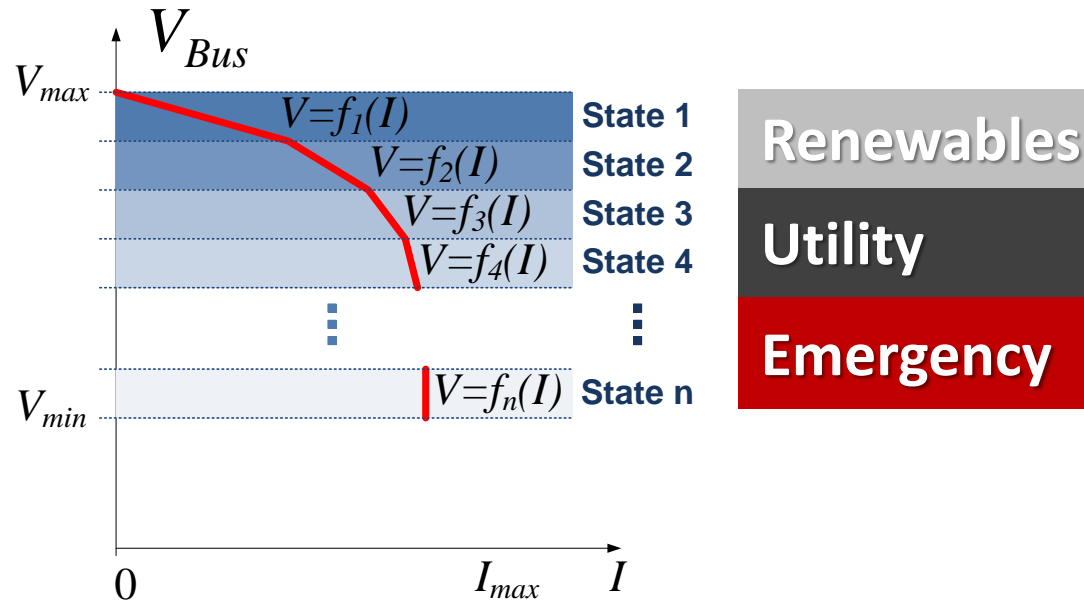
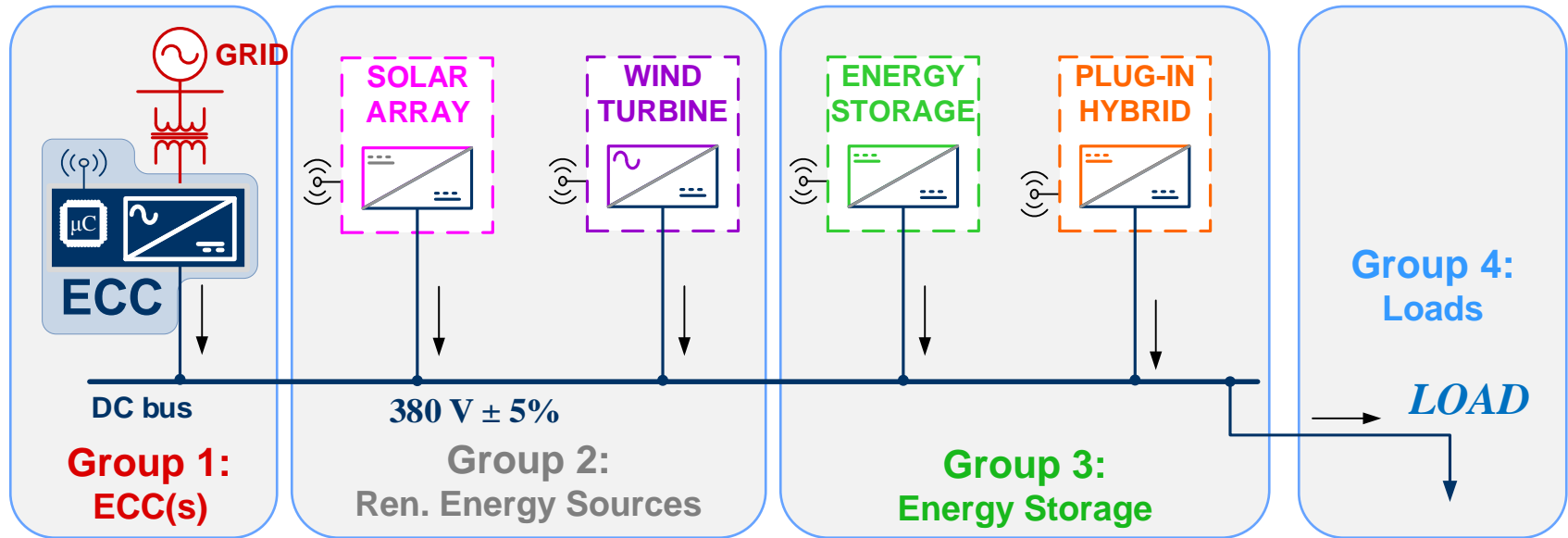


### Features:

- Bi-directional topology
- Bi-directional control system
- Bi-directional current limit
- Bi-directional decoupling due to dc-link
- Bi-directional EMI compatibility
- Low dc leakage current
- Low cost, high density

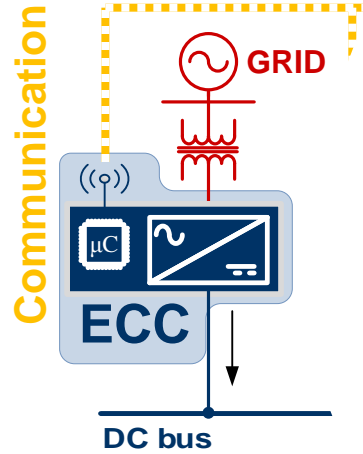
# Static Operation of the DC Nanogrid

(DC bus signaling)\*

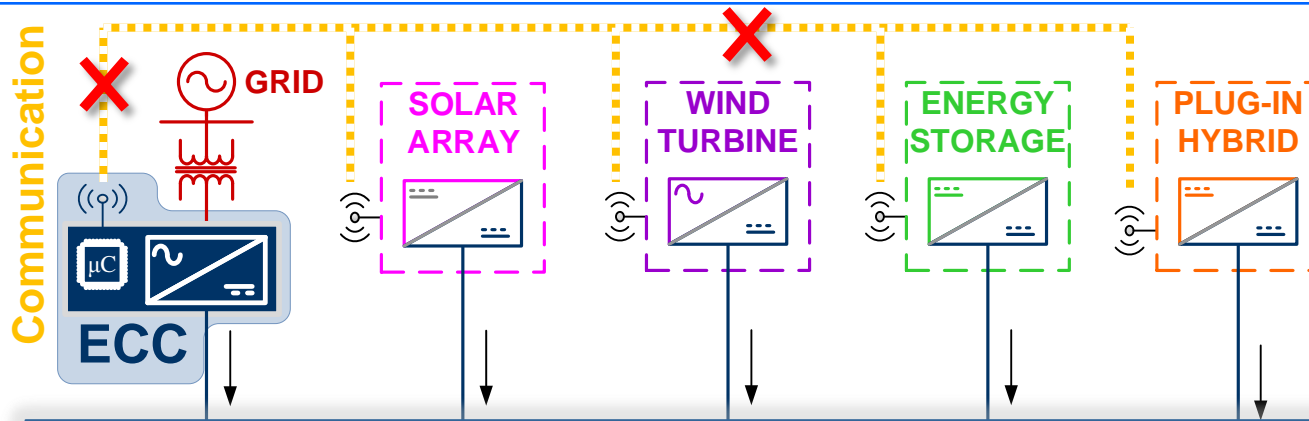


\* Bryan, Duke, 2004

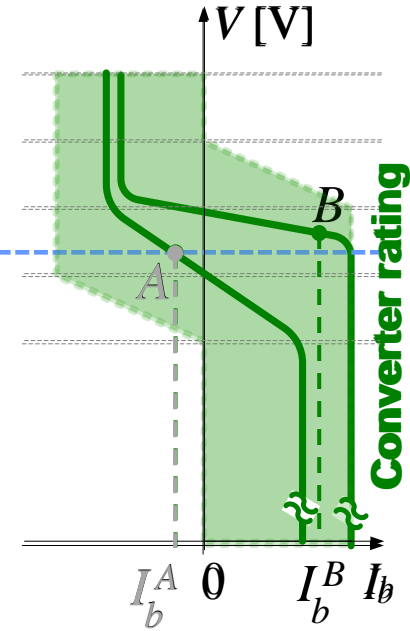
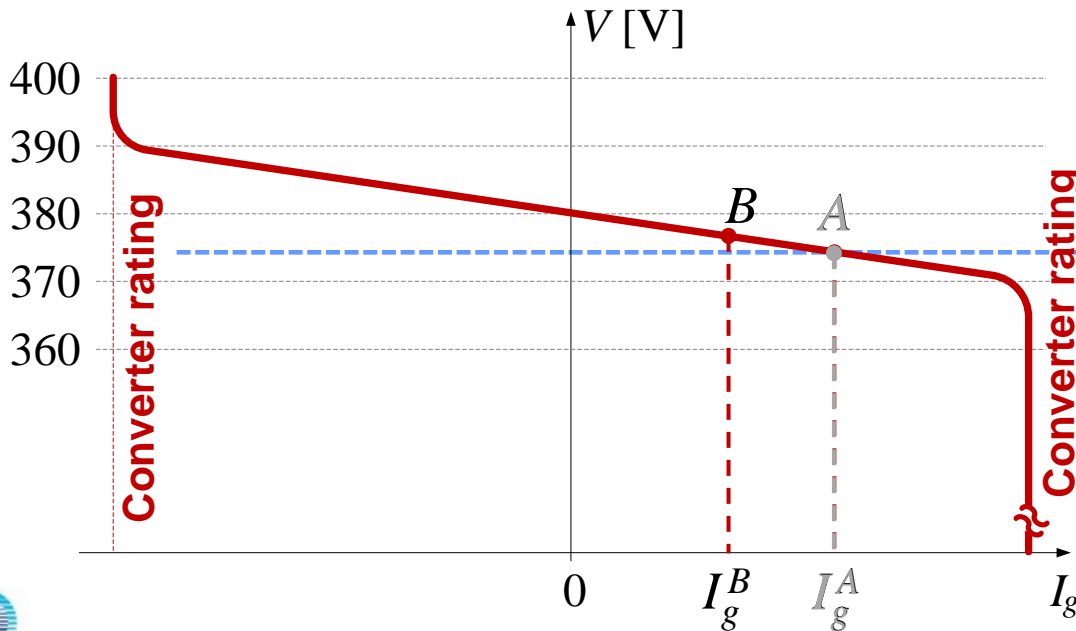
# Pre-programmed Static V-I Curves of the Nanogrid System Sources



# Optimal Energy Utilization in the Nanogrid



**Nanogrid Can Operate Autonomously with Partial or Entire Communication Failure!**





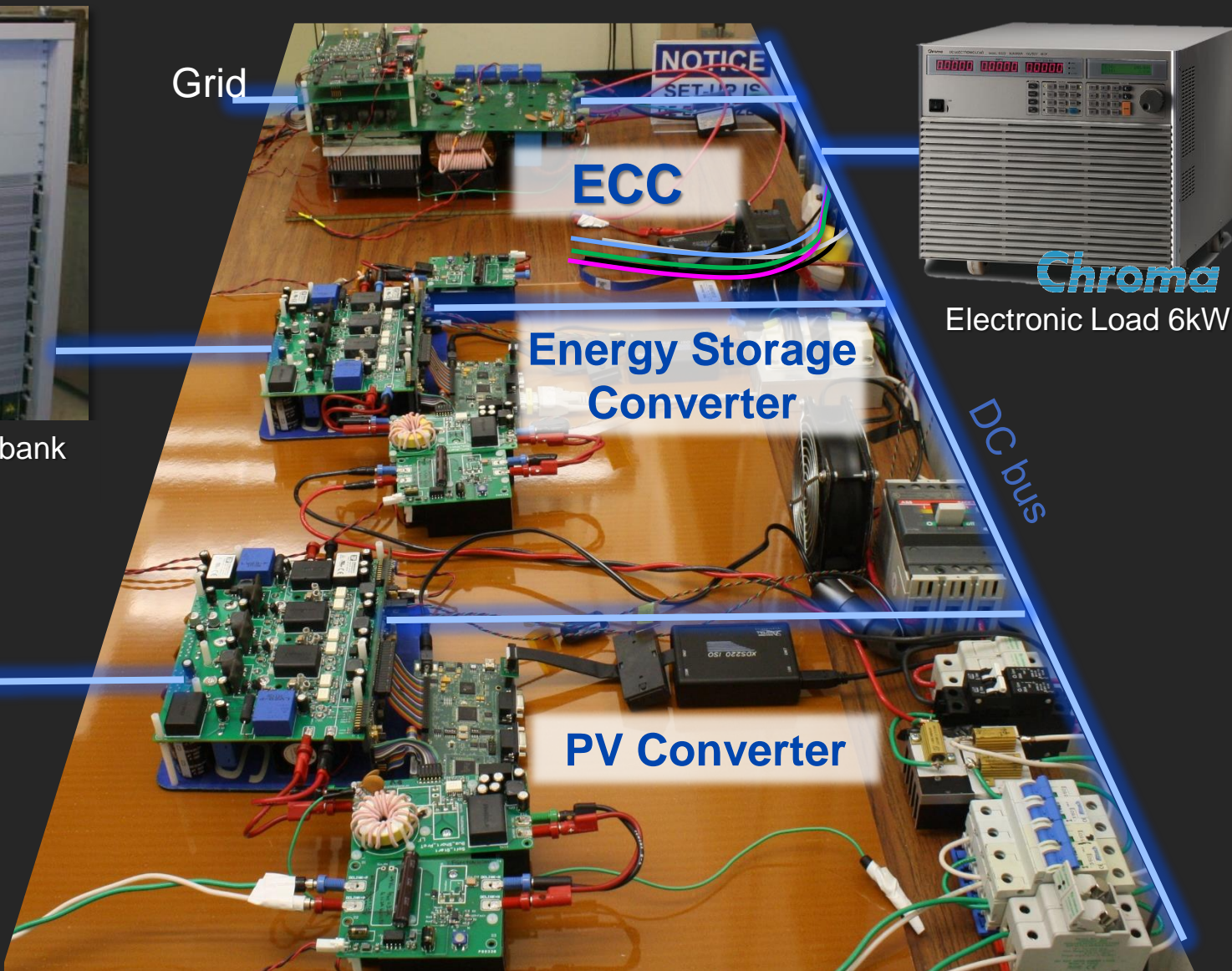
# CPES DC Nanogrid Testbed



Li-ion Battery bank  
(45Ah)



Solar Simulator  
(15kW)



Grid

ECC

Energy Storage  
Converter

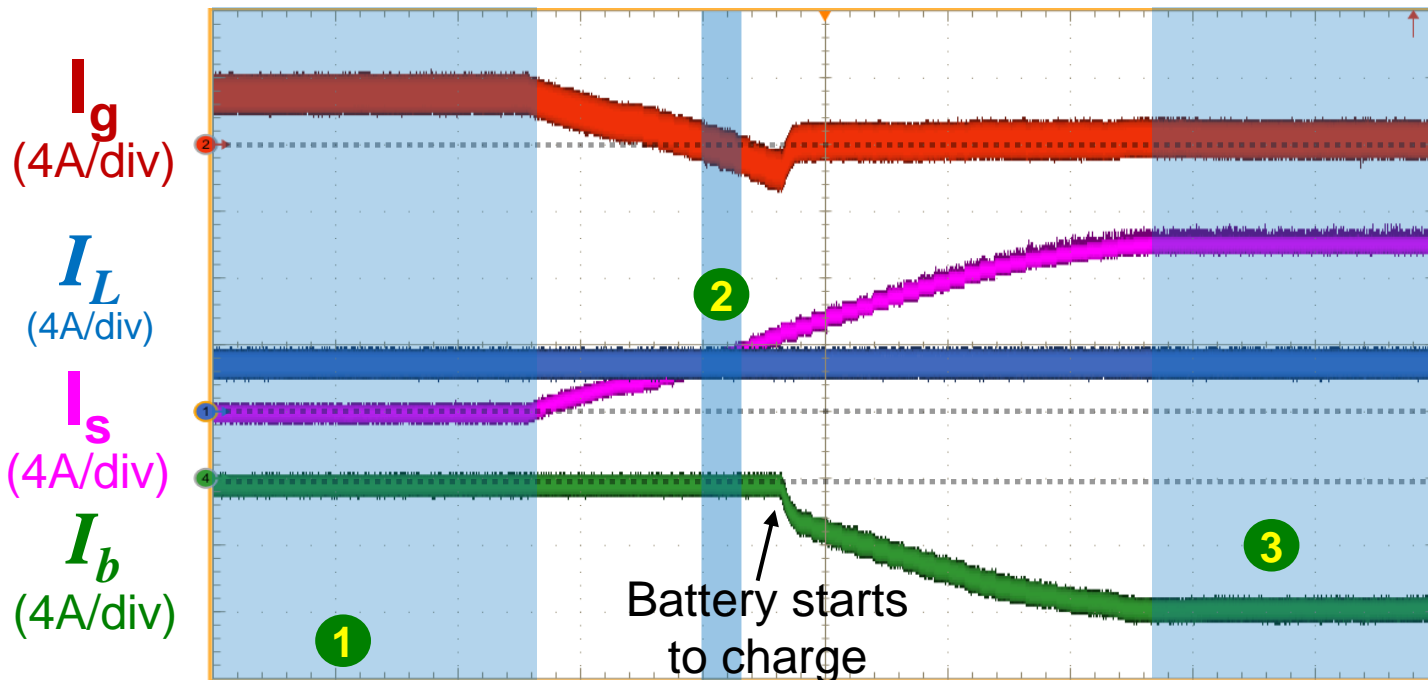
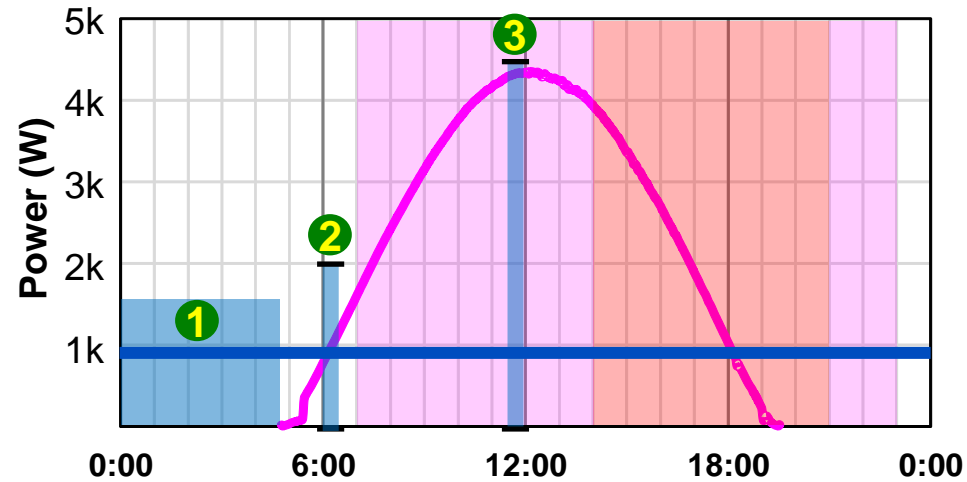
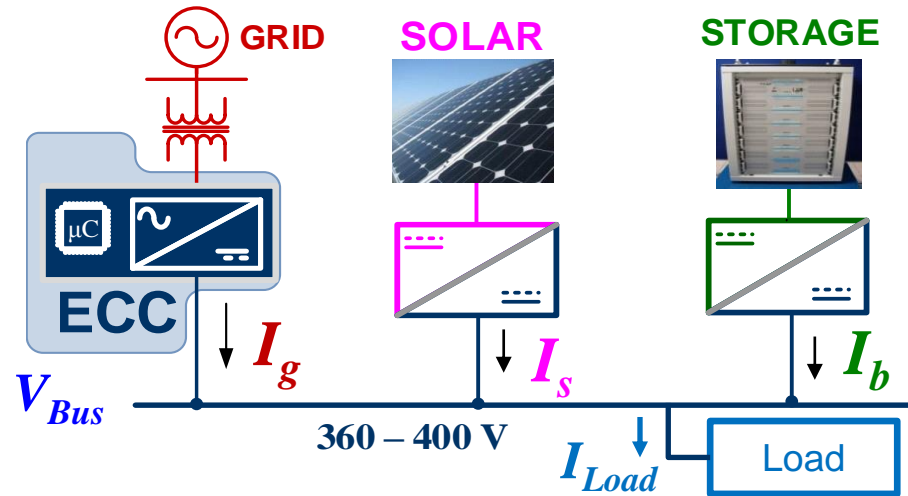
PV Converter



Chroma  
Electronic Load 6kW

DC bus

# Experiment Demonstrating One Case of DC Nanogrid Autonomous Operation

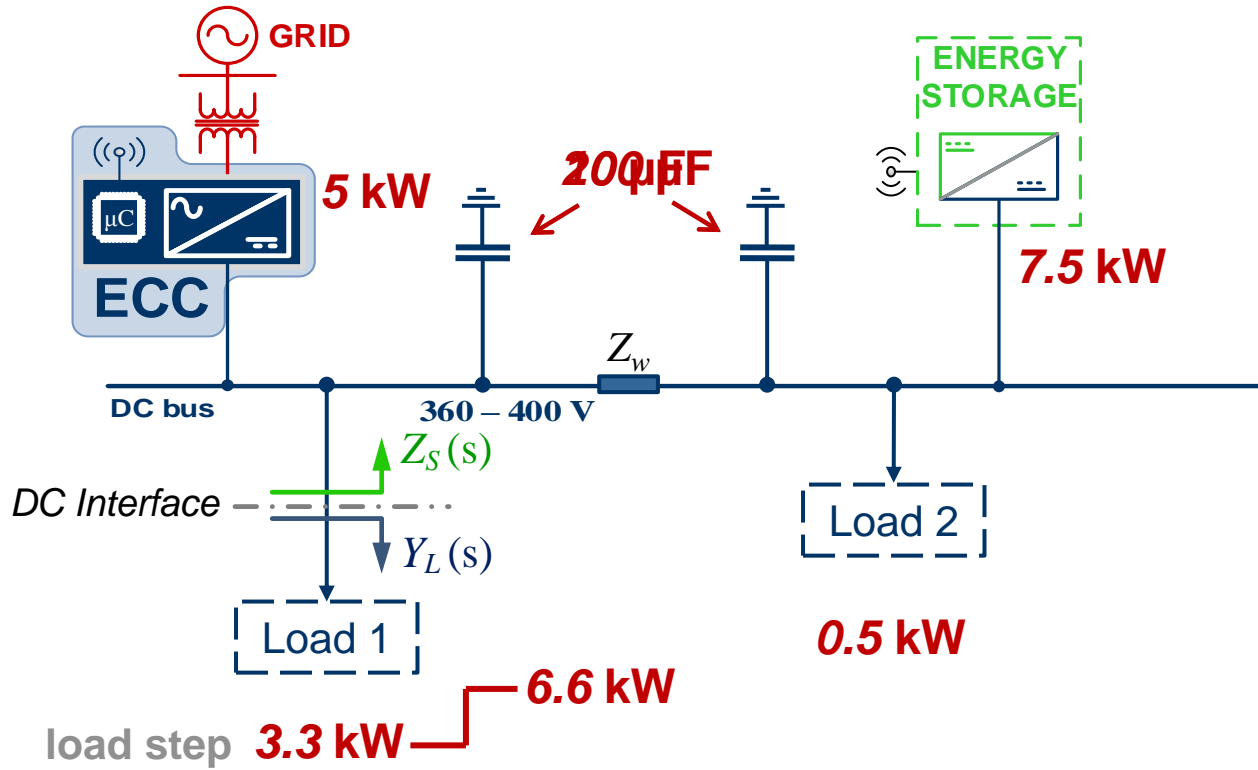


Load: 1kW  
Constant.

25kS/s  
40s/div

# Dynamic Interaction Example in dc-Nanogrid

(Minimum relevant system - two sources and two loads)

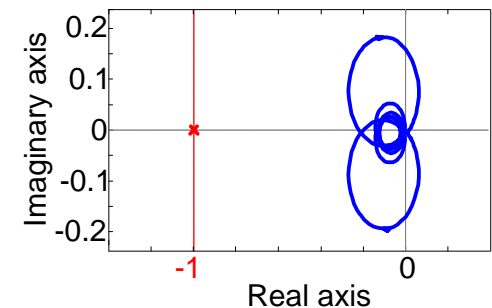
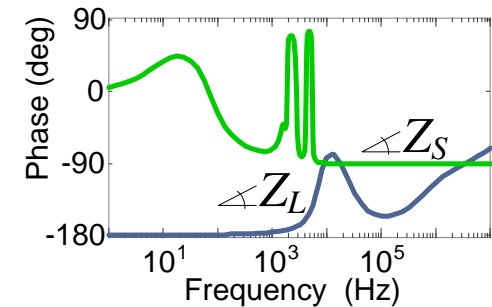
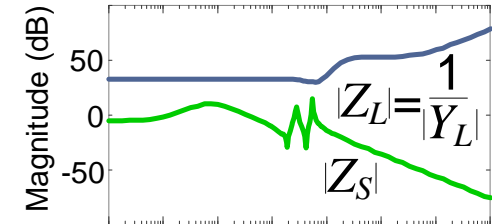
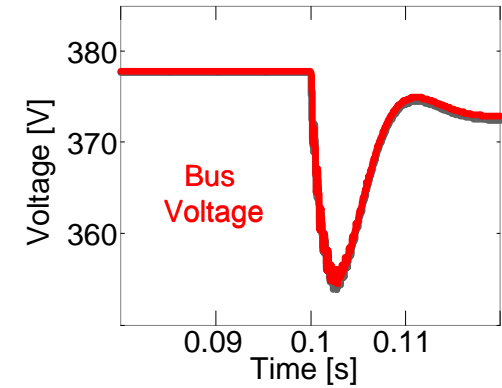


- To avoid instability, the *return ratio*:

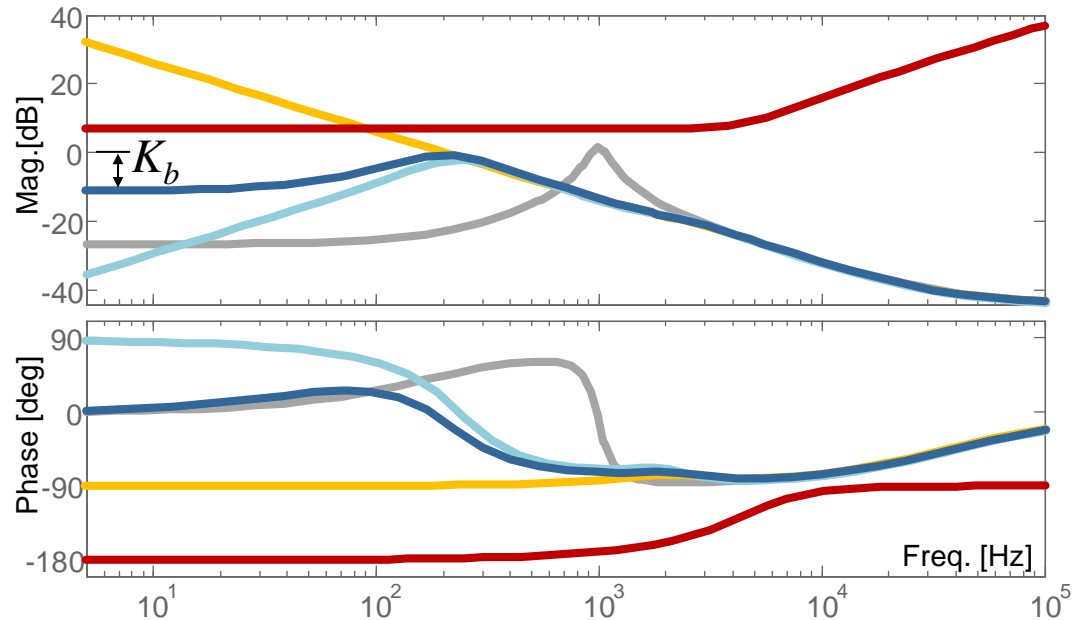
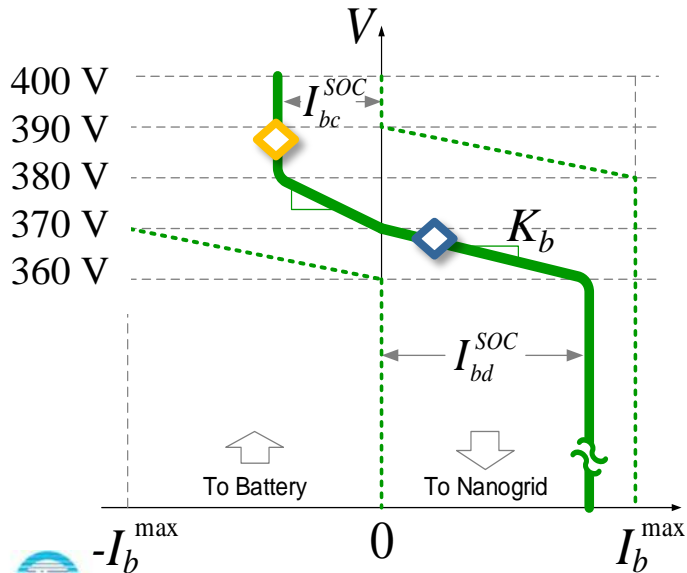
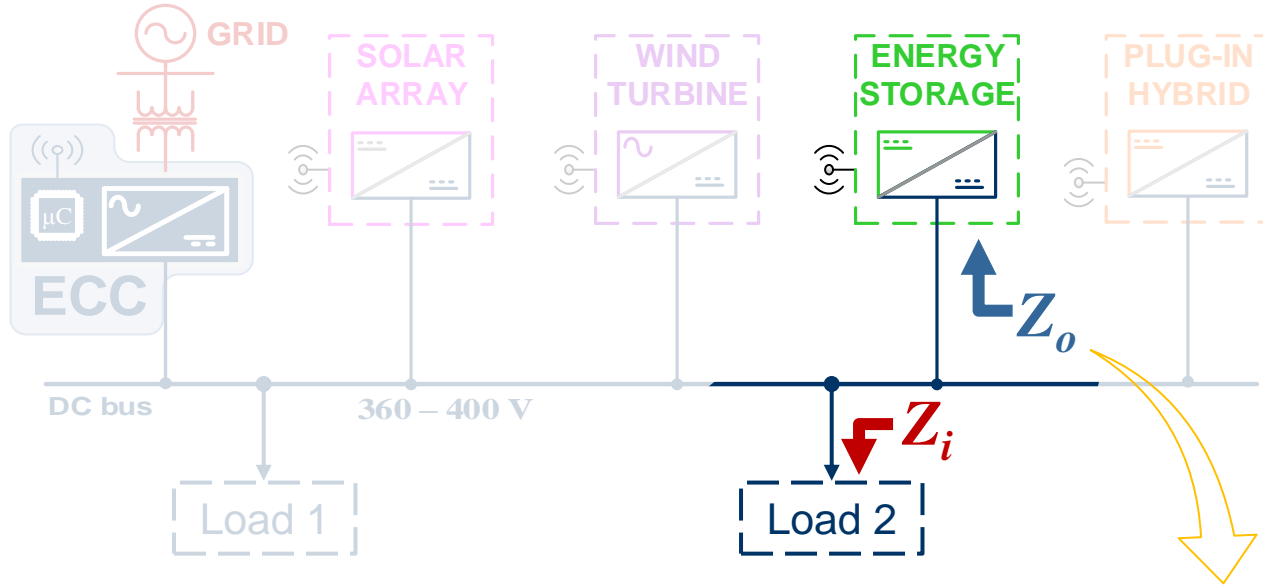
$$L \equiv Z_S / Z_L$$

must stay away from  $-1$  !

~~Stable~~ **Stable**

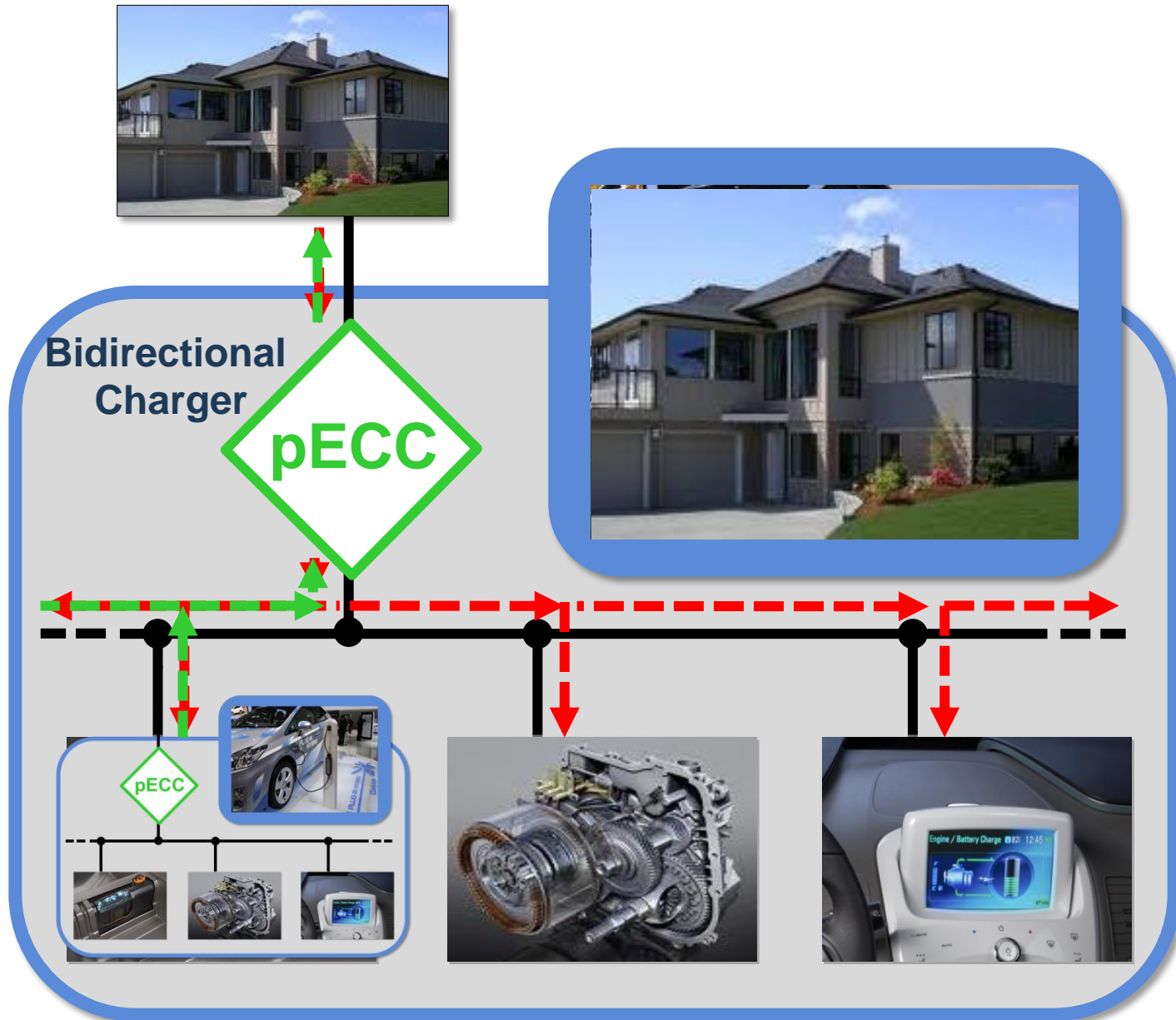


# Output / Input Impedances of the DC Nanogrid System Sources / Loads

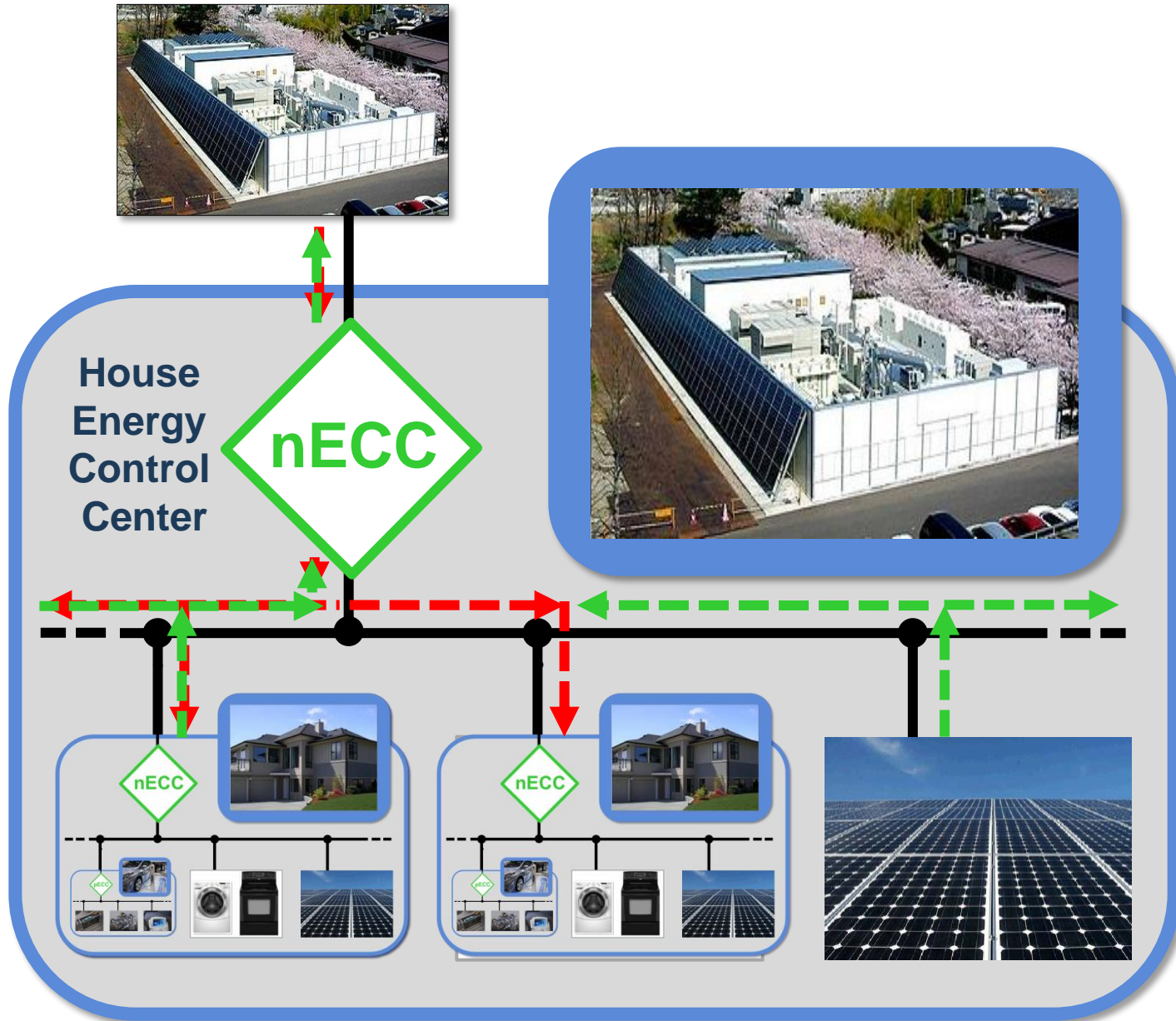




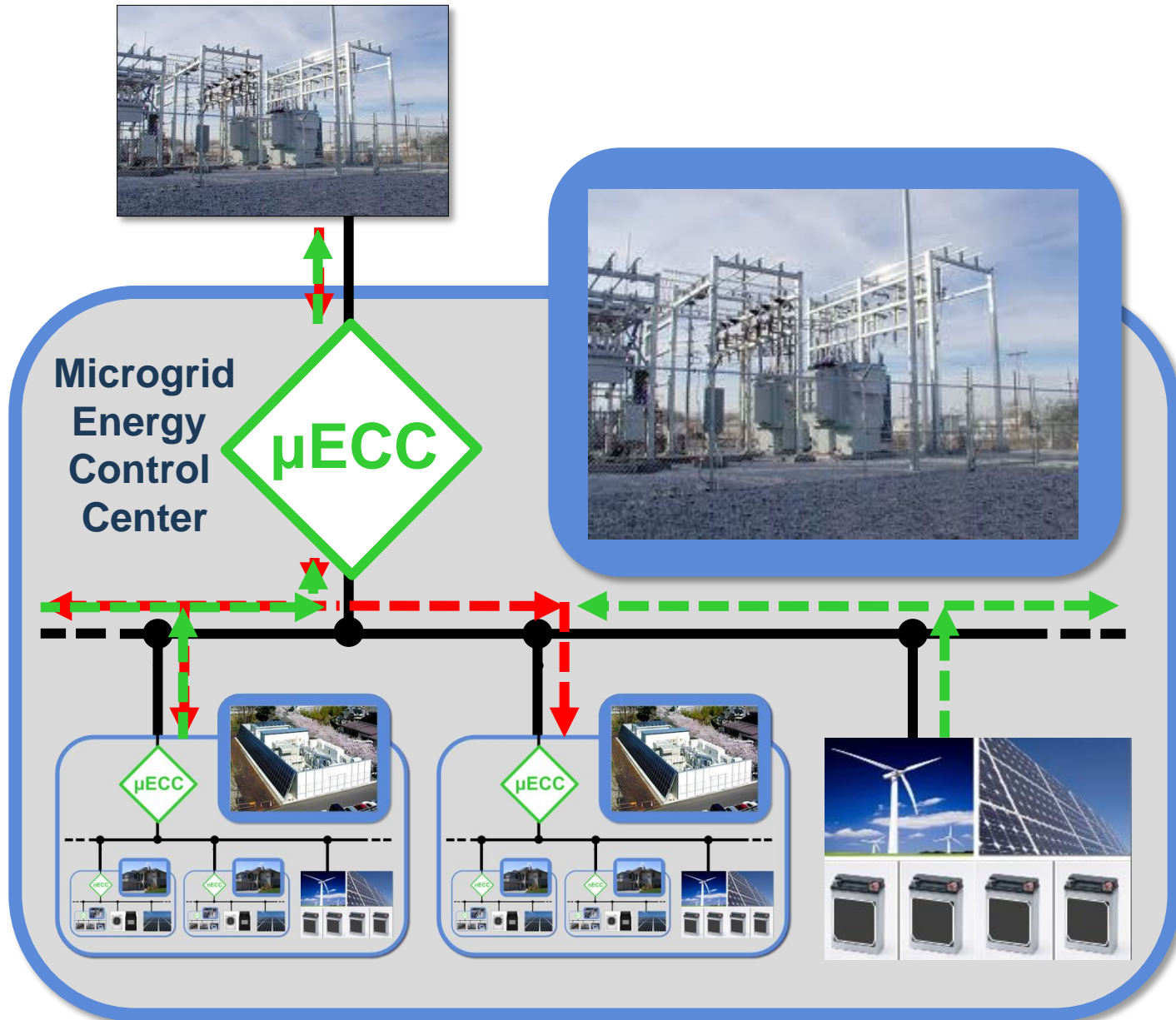
# Plug-in Hybrid Fleet (Navajo) ( Picogrid )



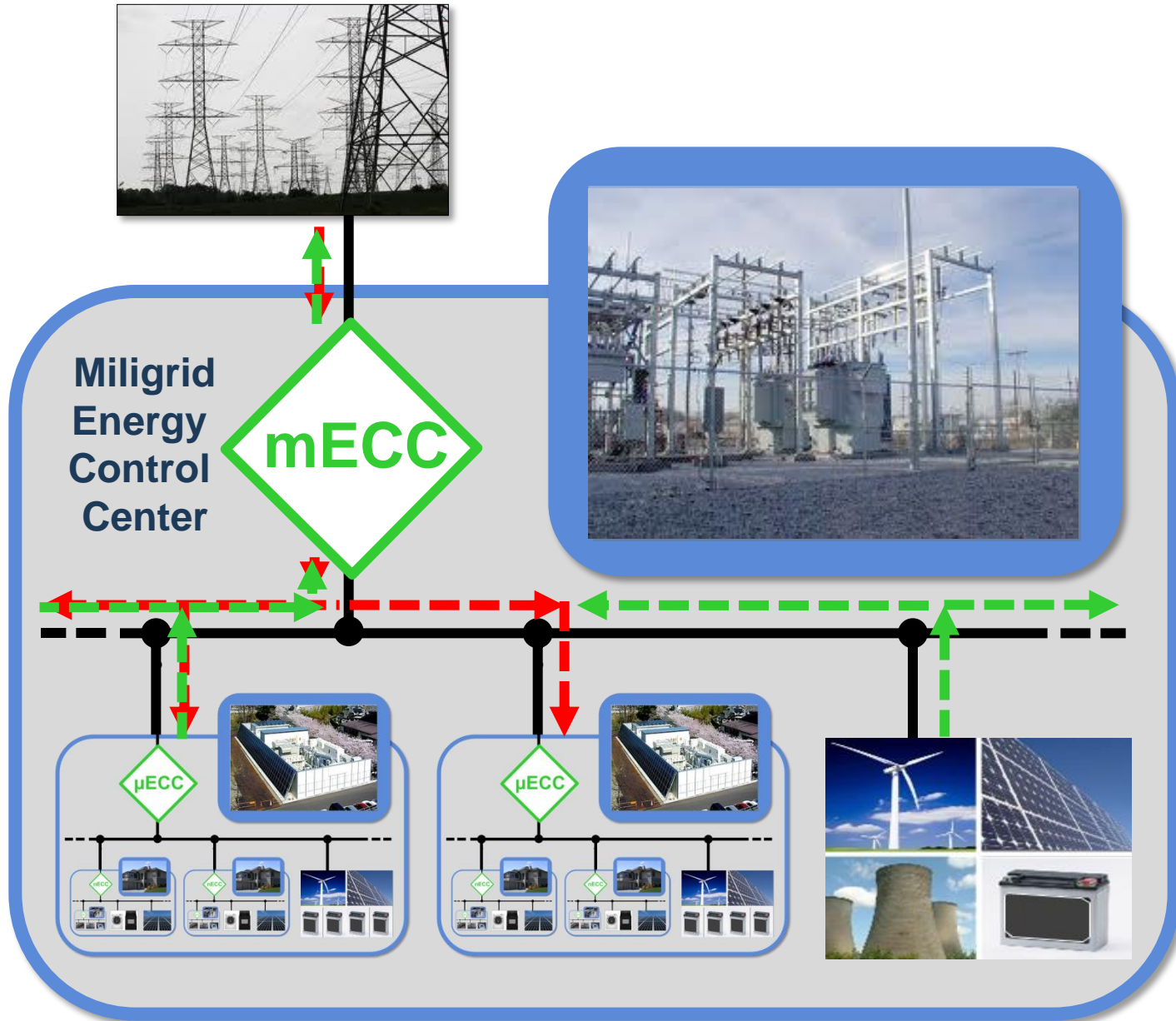
# A house (Hybrid)



# Microgrid



# Miligrad





# Expanding DC Nanogrid Concept to:

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**Hierarchical Network  
of Dynamically Decoupled  
Electronically Interconnected  
Sub-networks**

**Intergrid**



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## Thank you!

### Questions/ Comments / Suggestions ?



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