Smart Grid in a Room (SGRS) Platform for Distributed Simulations

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9/10/2015

NIST – TE Challenge Workshop

Collaborative CMU-NIST effort

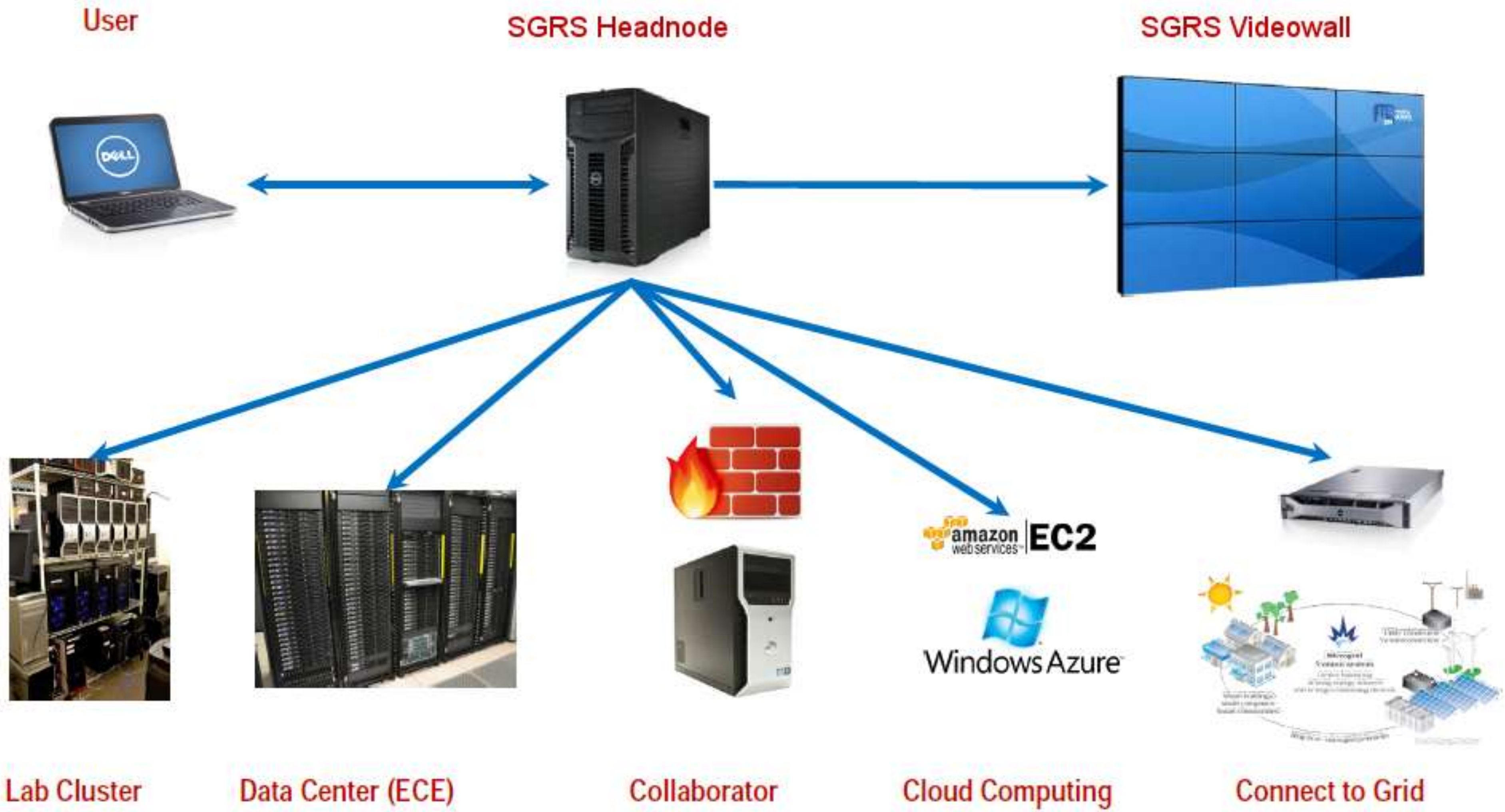
❖**SGRS –emulator platform** of

--**cyber algorithms** (1) energy market decision making by market participants; clearing process by the market; 2) retail market for differentiated reliability service; 3) smart wire grid algorithms; 4) primary control; protection; AGC; AVC; FACTS control logic)

--**physical power system processes**

-**inter-dependencies of cyber– and physical processes (prototype CPS emulator)**

SGRS Framework Overview



User

SGRS Headnode

SGRS Videowall

Lab Cluster

Data Center (ECE)

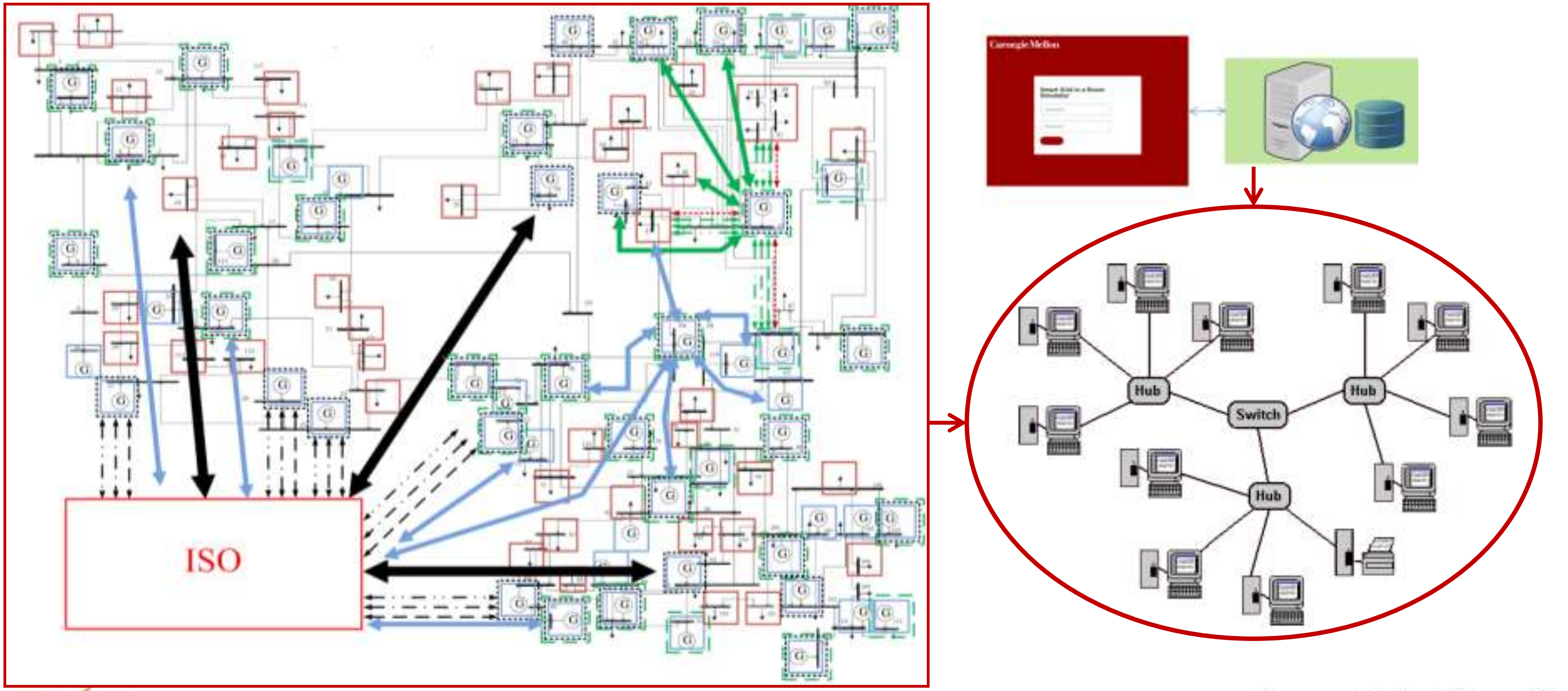
Collaborator

Cloud Computing

Connect to Grid

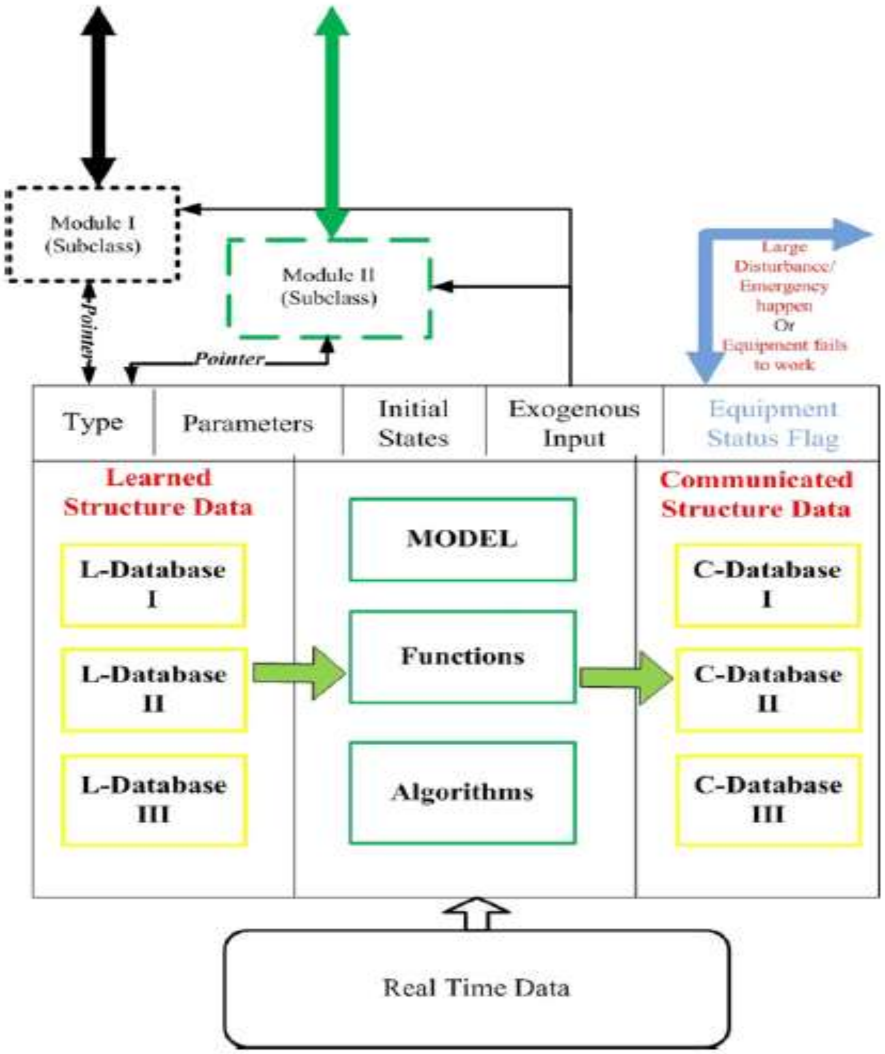
SGRS Framework Details

- Map power system to distributed simulation of power system modules
- Computational distribution abstracted away from user through implementation of interfaces in modules
- Simulation cluster managed by broker and scheduler algorithms
- Access to framework via web interface and remote connection



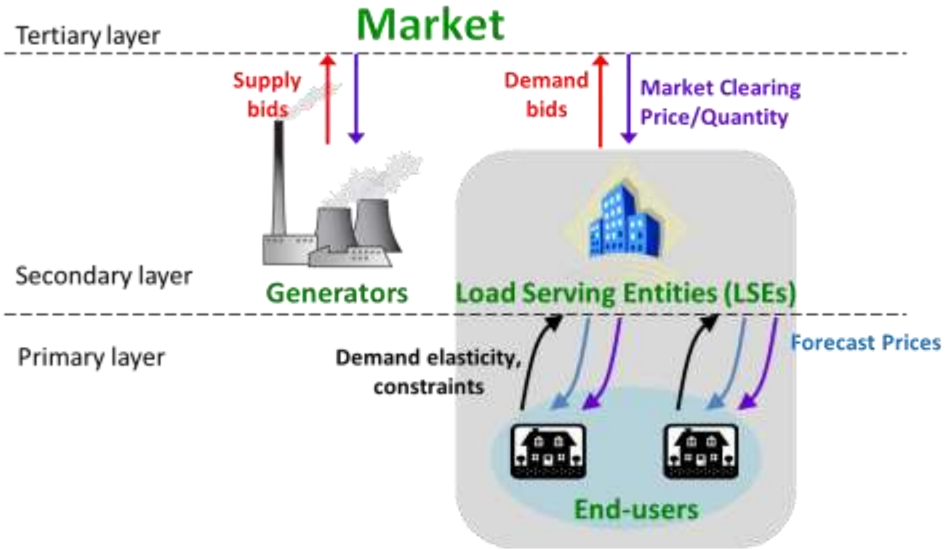
Dynamic Monitoring and Decision System (DyMonDS) –modular level

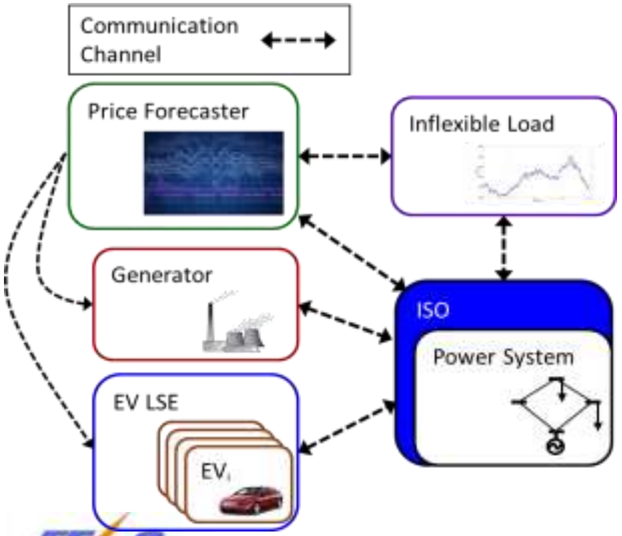
Year 1 Final Report



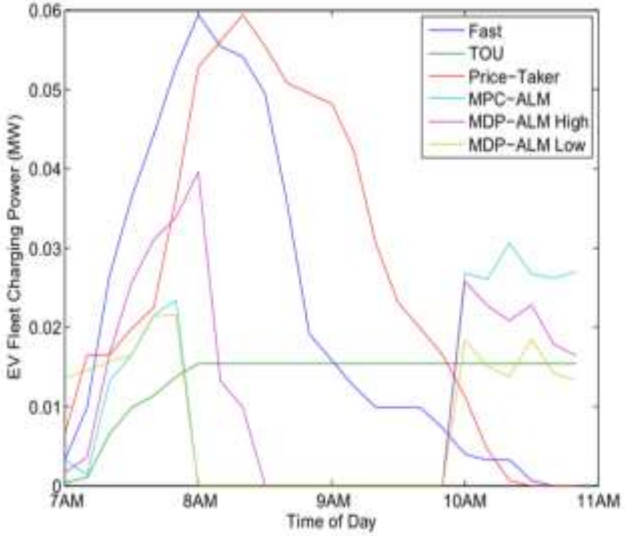
Example 1: Prototype TE – Market for EVs

- Simulation of charging strategies for electric vehicles
- Different methods for smart charging:
  - Fast charging
  - MPC based charging – price taker; time of use; ALM
  - MDP based charging – ALM
- Cost comparison

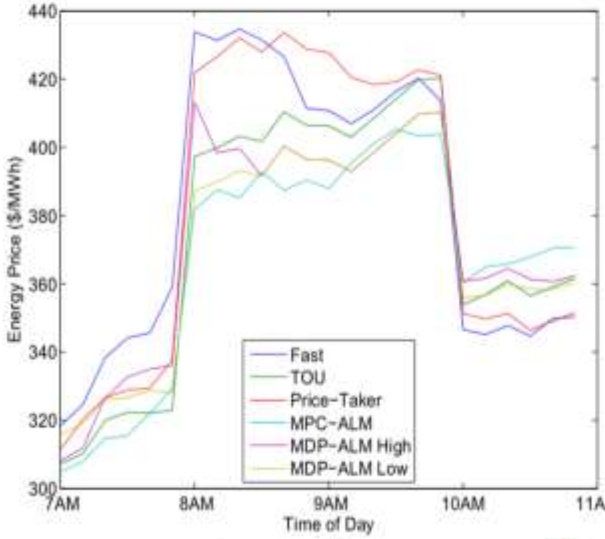




Charging power

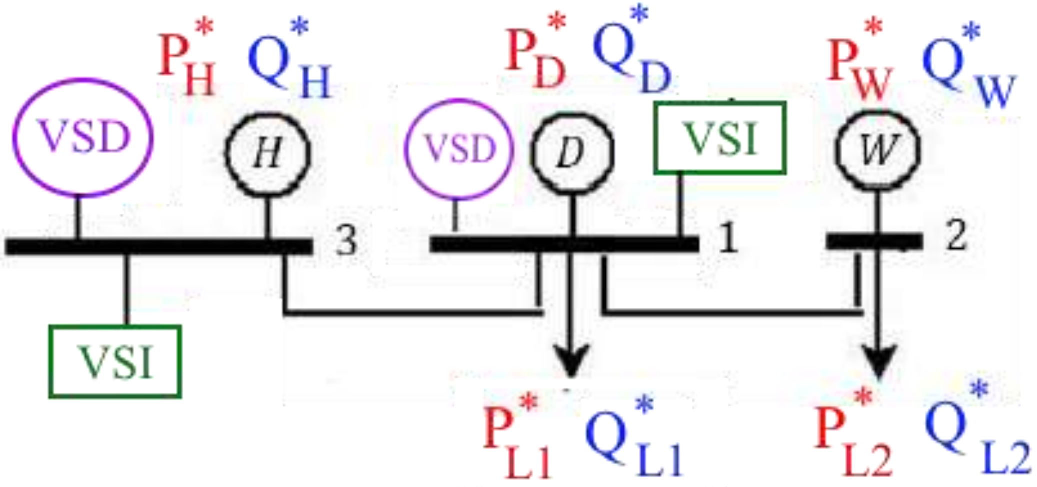


Energy prices



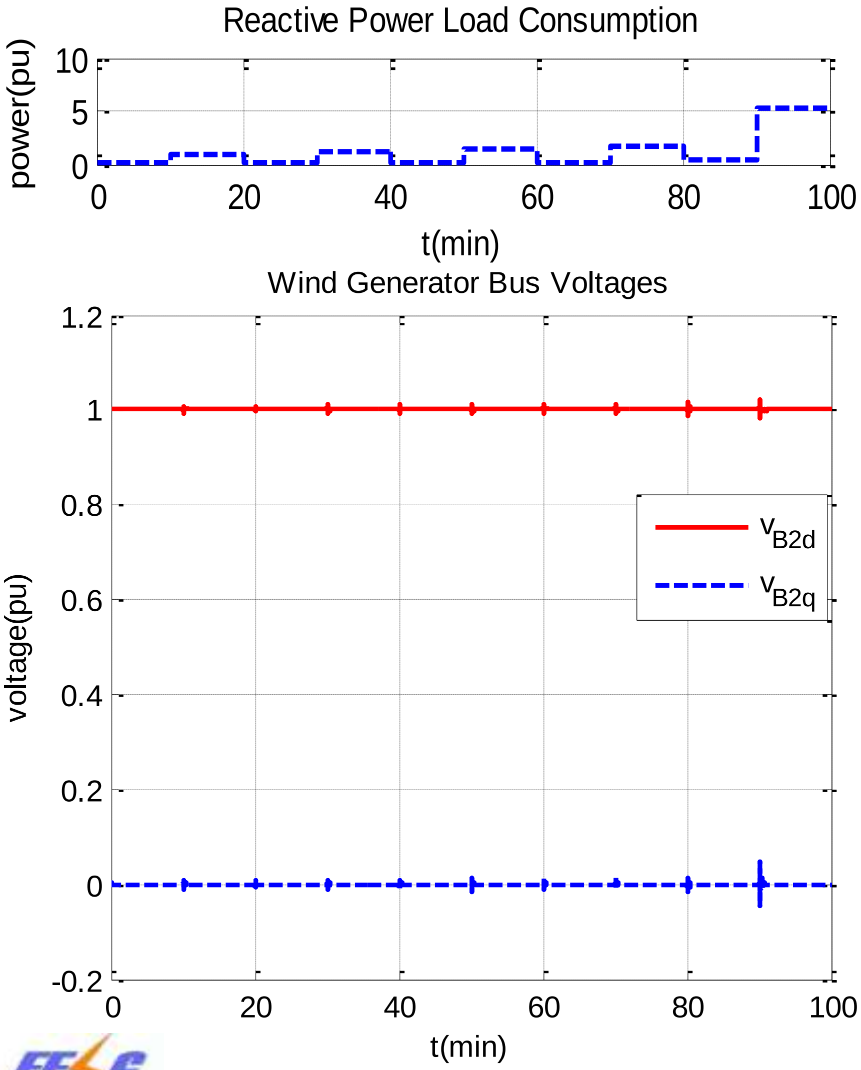
Example 2: Flores Island: Combining Dynamics and ALM

- Based on prices, market computes active power set points P* from each component
- Since currently the market does not specify reactive power set points Q*, data for Q* is randomly created
- Place a voltage source inverter and a flywheel variable speed drive controller on the hydro and diesel generator buses
- Control the sum of the power out of the hydro and diesel generators to match the active and reactive power set points

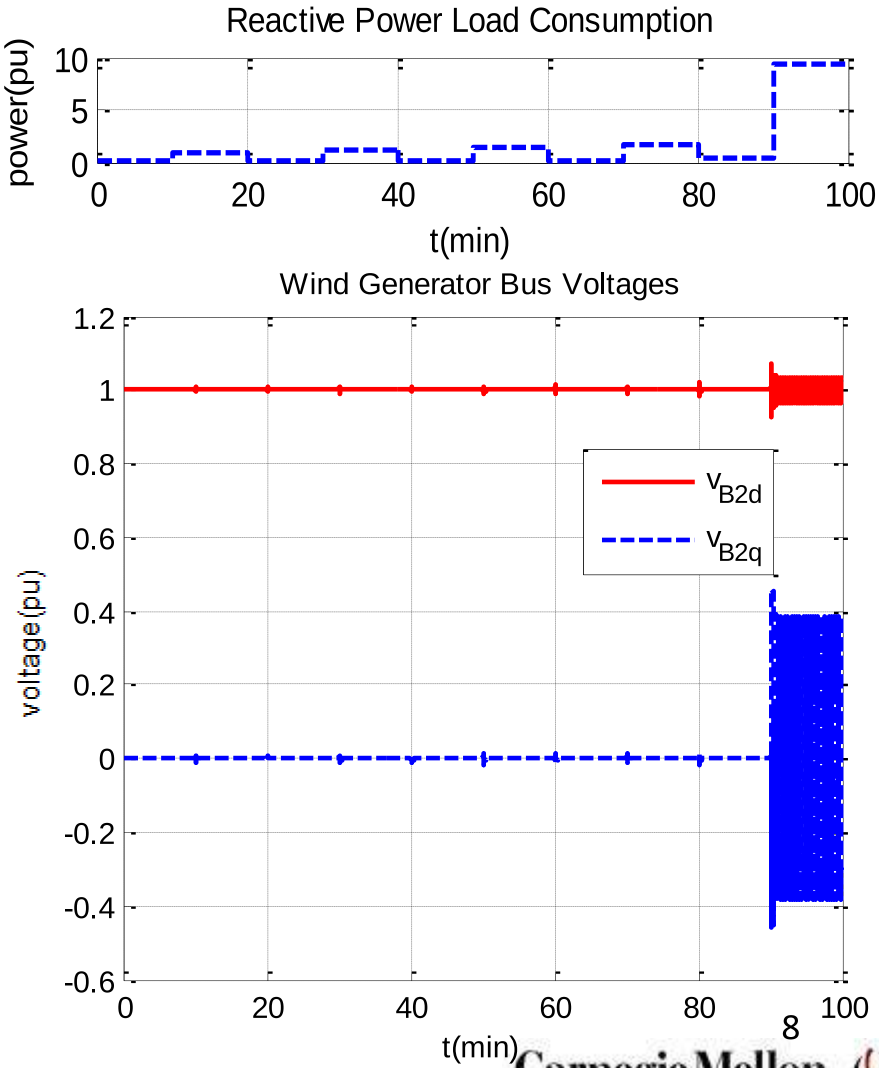


Example 2: Simulation Results – Wind Generator Bus

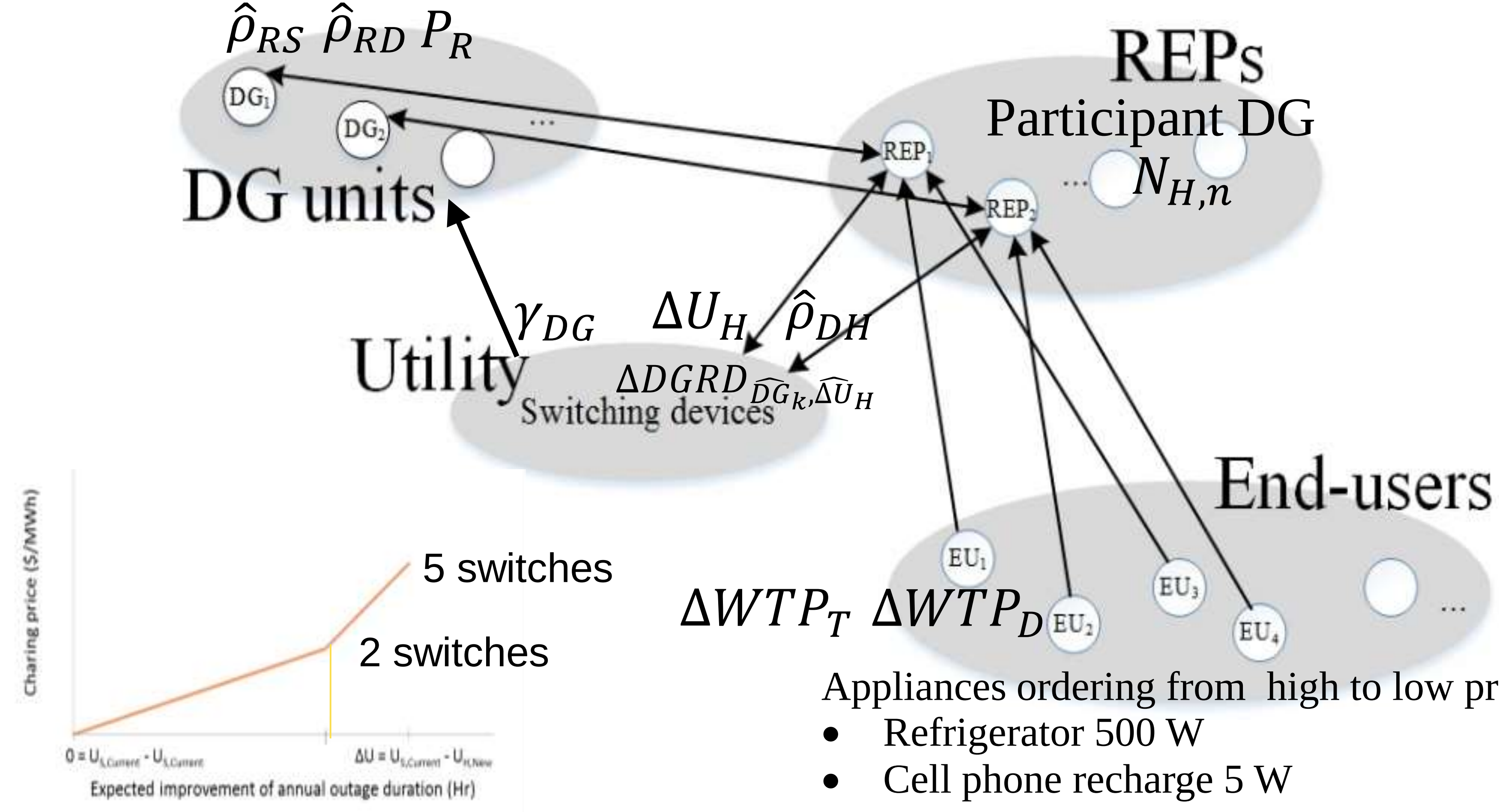
Stable Case:



Unstable Case:



Example 3: Retail reliability market—SGRS prototype (Siripha Julakarn, EPP PhD, 2015)



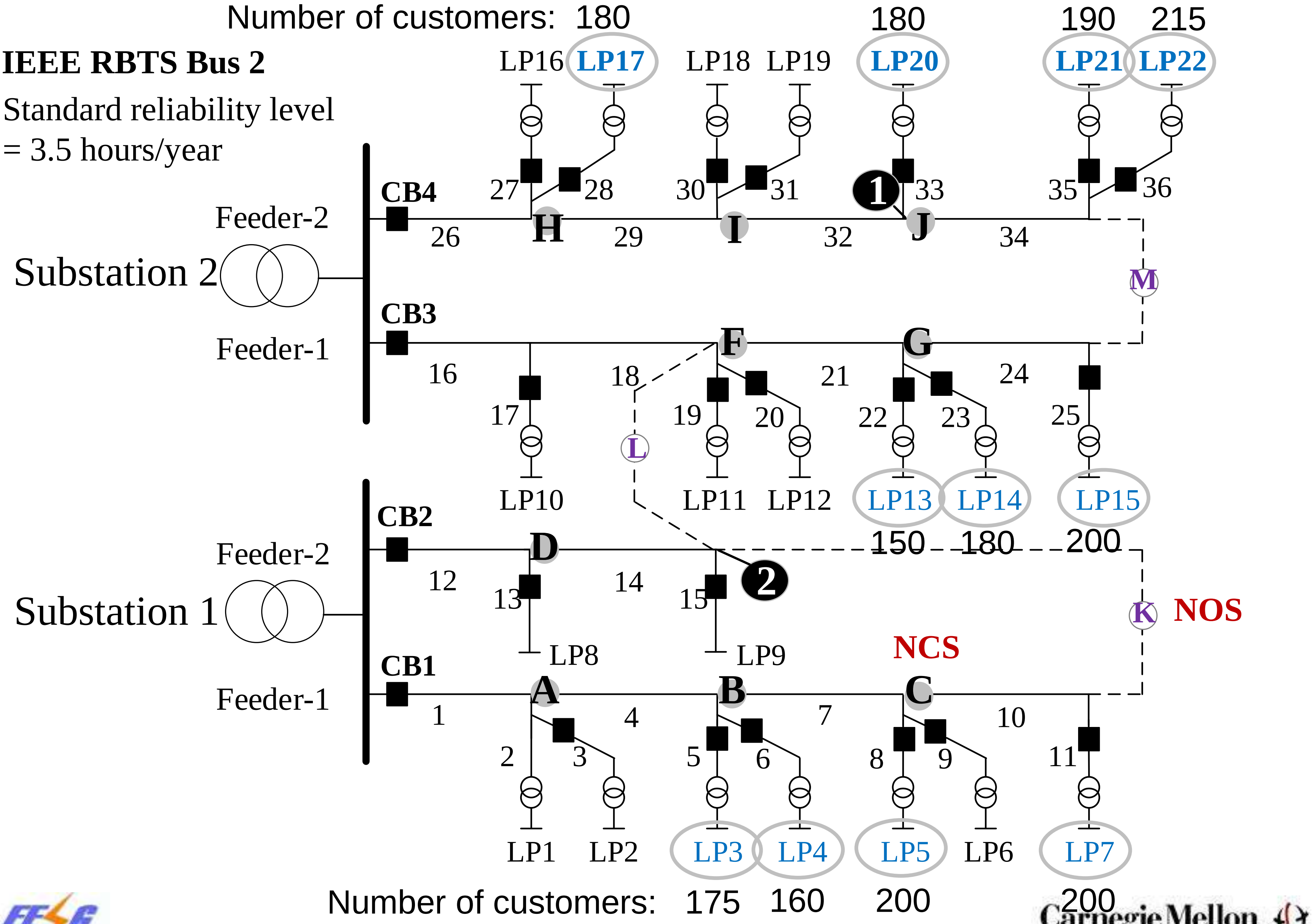
Appliances ordering from high to low priority:

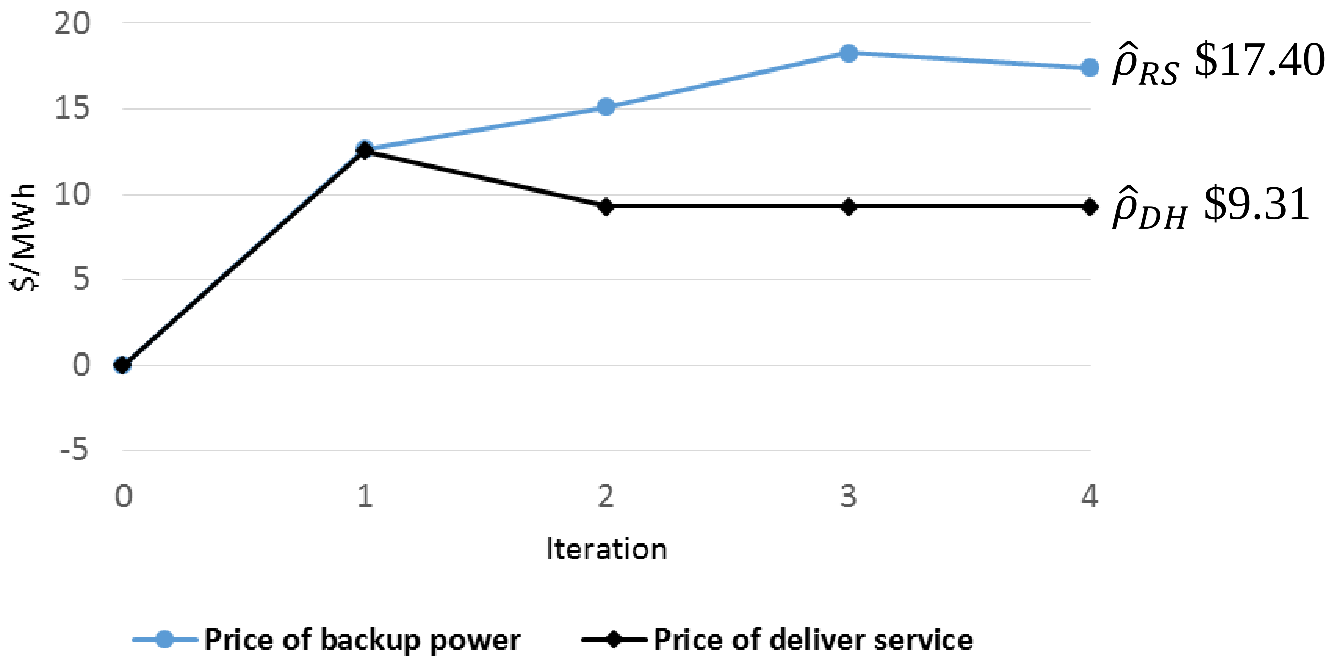
- Refrigerator 500 W
- Cell phone recharge 5 W
- TV 250 W
- Light 30 W

Minimum power needed: Refrigerator 500 W

IEEE RBTS Bus 2

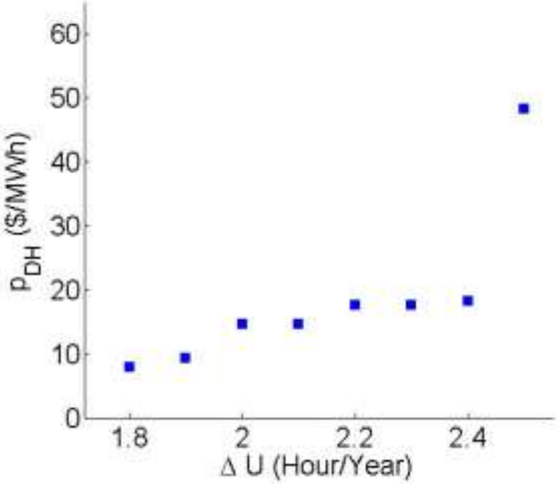
Standard reliability level
= 3.5 hours/year

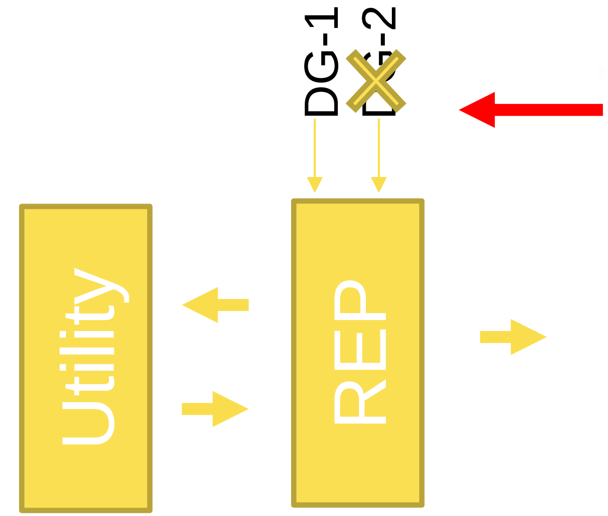




$\hat{\rho}_{RS}$ \$17.40

$\hat{\rho}_{DH}$ \$9.31





$\hat{\rho}_{RS}, \hat{\rho}_{RD}$

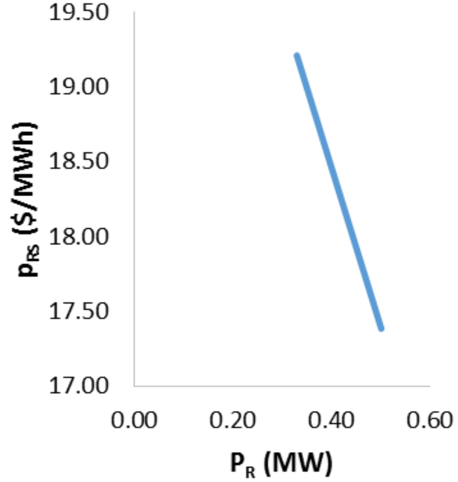
DG-1

DG-2

Utility

REP

$\Delta DGRD_{\widehat{DG}_k,\widehat{\Delta U}_H}$

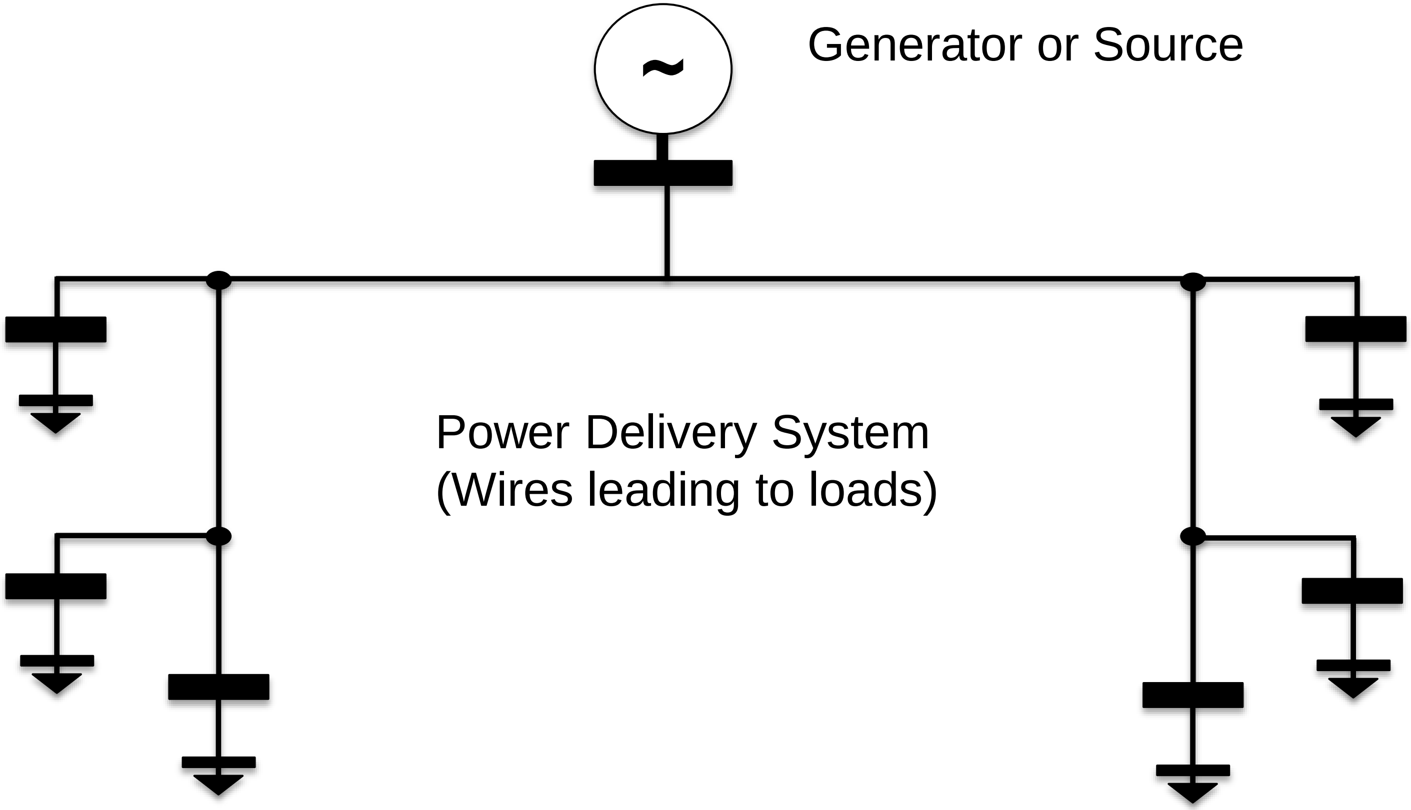


NIST Project: Ensuring Feasible Power Delivery Using Distributed Smart Wires

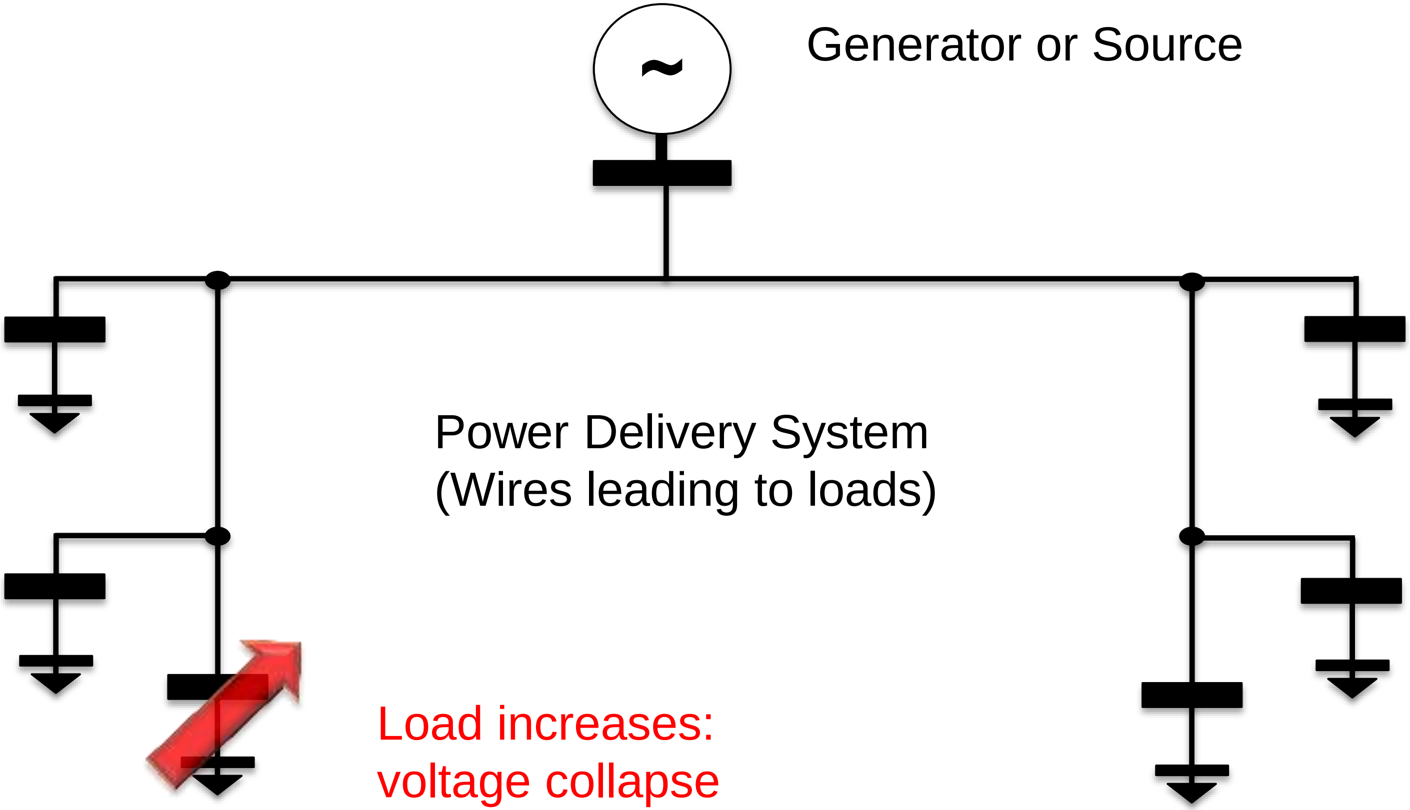
Andrew Hsu

ECE PhD Fall 2015

Ensuring Feasible Power Delivery



Ensuring Feasible Power Delivery

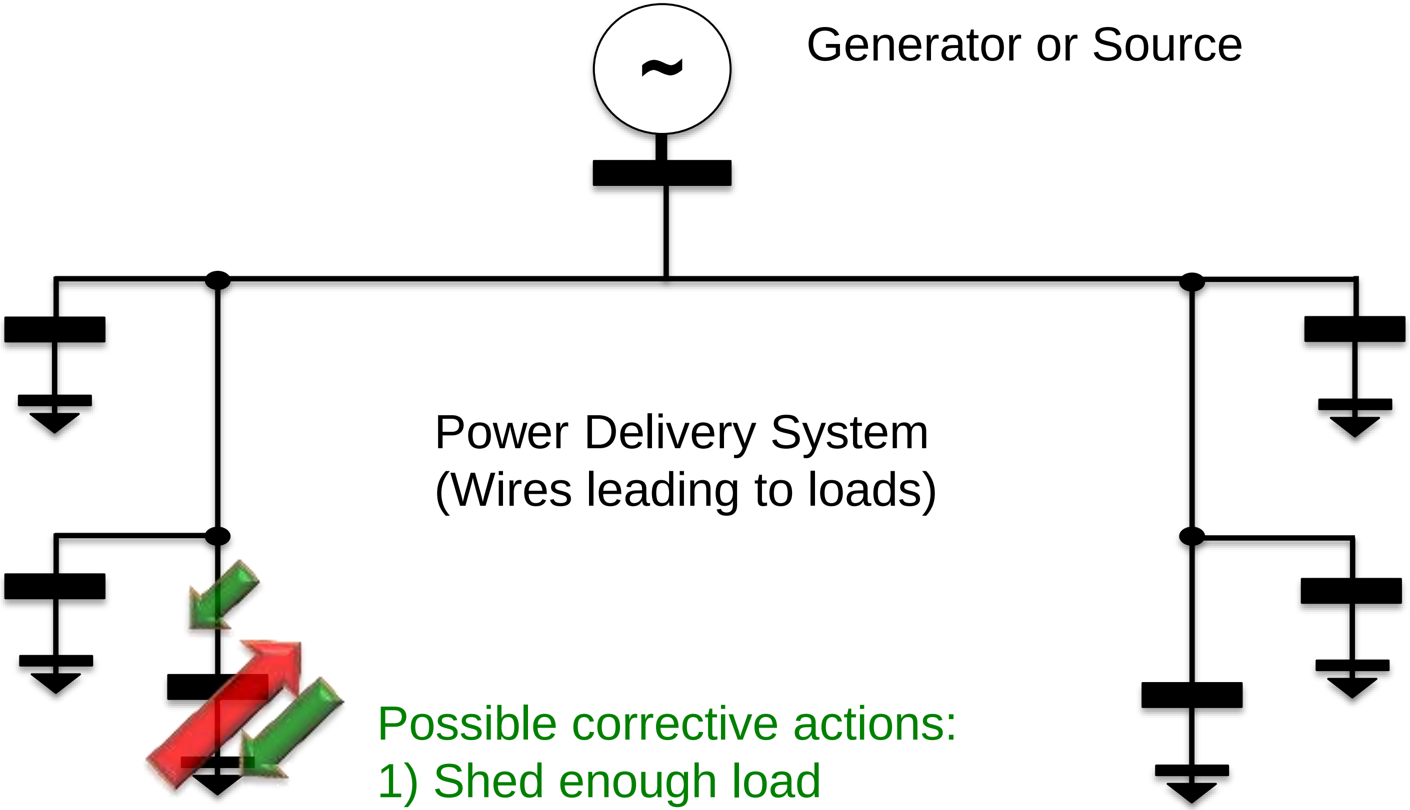


Generator or Source

Power Delivery System
(Wires leading to loads)

Load increases:
voltage collapse

Ensuring Feasible Power Delivery

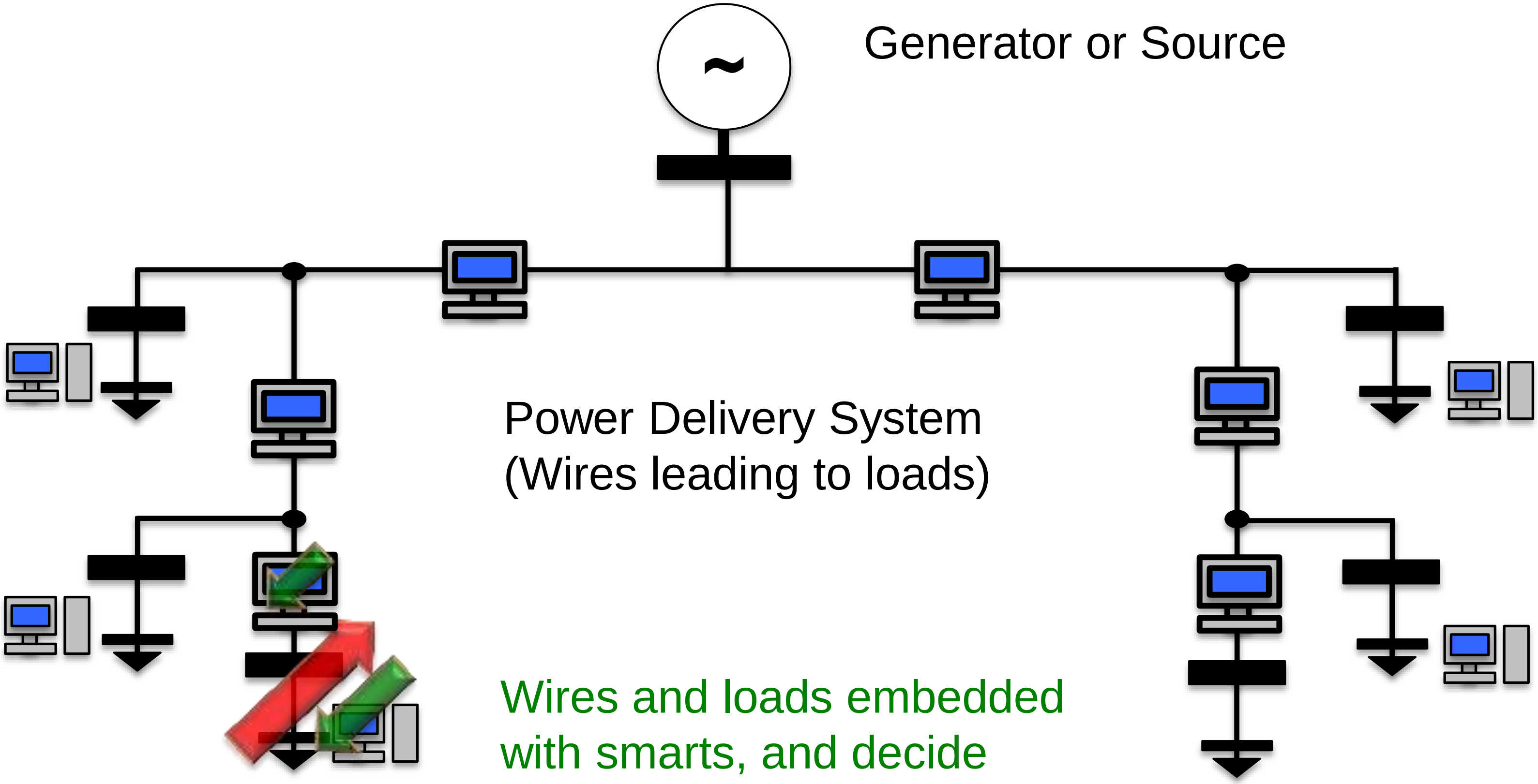


Generator or Source

Power Delivery System
(Wires leading to loads)

Possible corrective actions:
1) Shed enough load
2) Adjust reactance of wire
delivering power

Ensuring Feasible Power Delivery



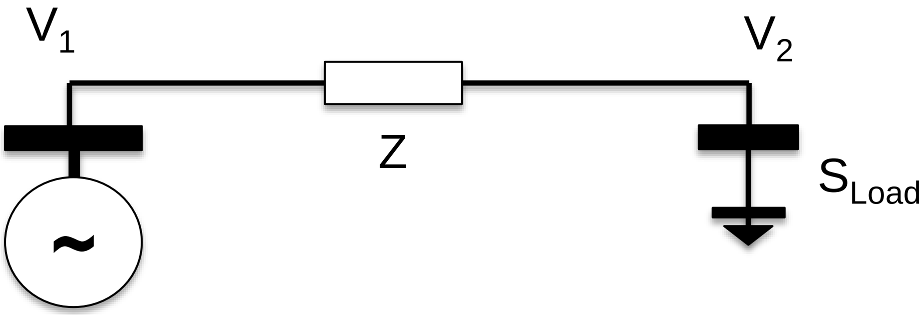
Generator or Source

Power Delivery System
(Wires leading to loads)

Wires and loads embedded
with smarts, and decide
their own adjustments

Feasible Power Delivery Across Each Wire[1]

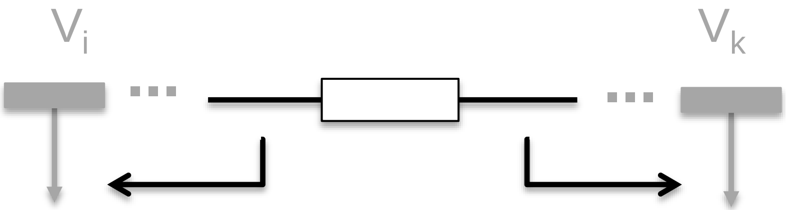
- Power delivery must satisfy mathematical conditions across any wire in network
  - A closed form solution of V_2 is found in terms of V_1, Z, S_{Load}
  - This closed form solution has non-physical answers, such as the voltage magnitude being imaginary
  - Must be satisfied by every wire of a network when calculating power flow



Wire connecting generator and load.

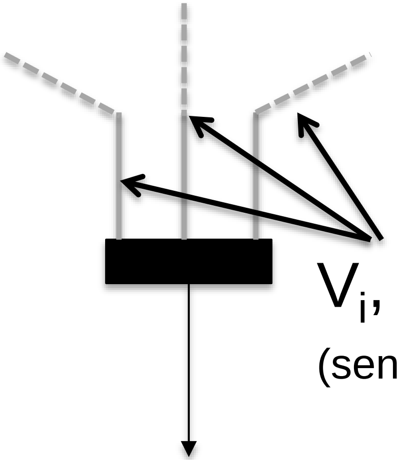
$$|V|^2 = \tfrac{1}{2} - \mathrm{re}\{Z^* S_{Load}\} \pm \ldots$$
$$\ldots \mathrm{sqrt}(\, 1 - 4(\mathrm{re}\{Z^* S_{Load}\} + \mathrm{im}\{Z^* S_{Load}\}^2)\,)$$

Distributed Algorithm To Calculate Power Flow and Needed Component-wise Adjustments[2,3,4]



$S_{f:i,k}$, $S_{L:i,k}$, V_i, V_k

(sent to both buses)



V_i, λ_i

(sent to all wires)

- Each component has internal logic and communicates variables to their neighbors iteratively
  - Wires communicate their power flow (S_f), loss (S_L), and voltages (V) at each end to their neighboring buses
  - Buses communicate their bus voltage (V), and power mismatch at the bus (λ), to all neighboring wires
  - Internal logic only operates on received neighbors' information, and on internal variables
  - S_f, S_L and Z determine reactance control
  - λ and neighboring wire flows determine load shedding

Next steps…

- Beginning to simulate a real-world sanitized micro-grid (should be able to share data)
- Webcast for industry; make it open to community
- A means of testing what is doable and what is the potential of smart grids, prior to building
- Work together toward recommending standards/protocols that could support implementable, used and useful smarts/cyber (including markets for energy, reliability and deliver)

References

[1] **Hsu, A., Ilic, M. *Ensuring Feasible Power Delivery Using An Optimization-based Power Flow Model,* Techcon 2013, Austin, Tx. Sept 2013**

[2] **Hsu, A. and Ilic, M. *Toward Distributed Contingency Screening Using Line Flow Calculators and Dynamic Line Rating Units (DLRs)* ,Hawaiian International Conference of System Sciences (HICSS). Maui, Hawaii, January 2012.**

[3] **Hsu, A. and Ilic, M. *Distributed newton method for computing real decoupled power flow in lossy electric energy networks*,North American Power Symposium (NAPS), 2012 , vol., no., pp.1-7, 9-11 Sept. 2012.**

[4] **Ilic, M. and Hsu, A. *General Method For Distributed Line Flow Computing With Local Communications In Meshed Electric Networks*, Pub. No. US 2013/0024168 A1, January 24, 2013 (status: allowed)**