Carnegie Mellon

Electric Energy EESG Systems Group

Dynamic Monitoring and Decision Systems (DYMONDS) for Smart Grids: The Missing Link

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http://www.ieeeboston.org/edu/2009fall/2009_fall_courses/smarter_elec_grid.html

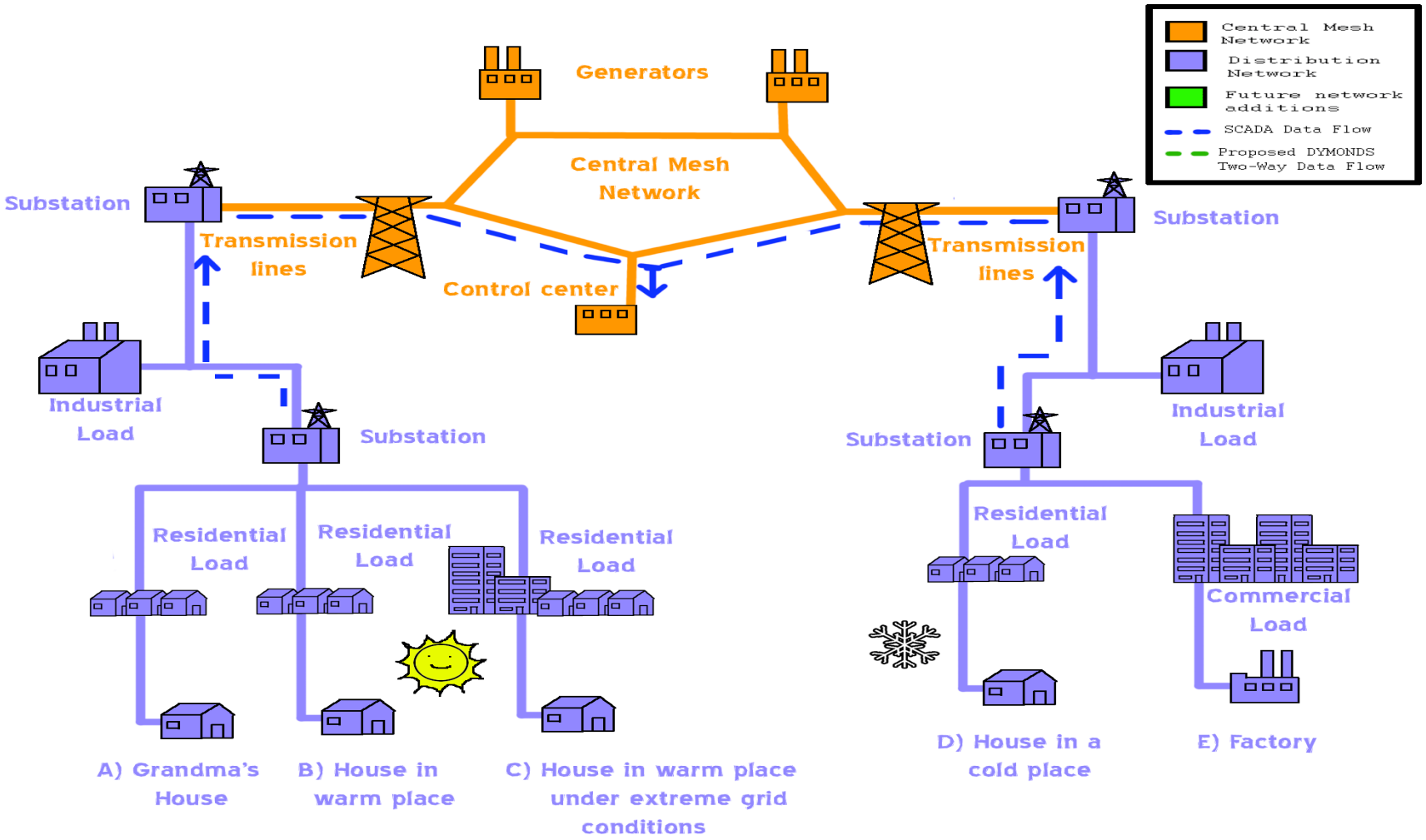
TU Delft Delft University of Technology

PSERC

Outline

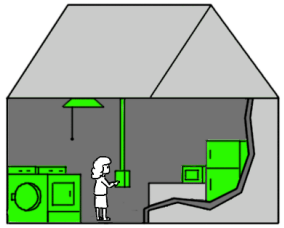
- Quick summary of today's operating and planning practices (stress on SCADA)
- Smart Grids: A means of enabling customer choice in coordination with societal objectives; enabling innovation.
- The key question: What information to exchange, why and how?
- DYMONDS-enabled monitoring and decision making (transformed SCADA)
- IT-enabled Rules, Rights and Responsibilities (3Rs) –Smart Regulation

Today's power grid

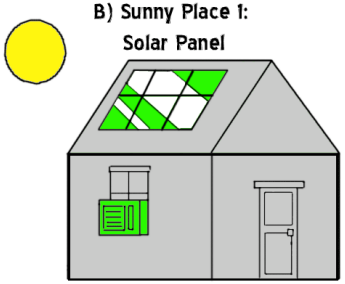


Diverse users

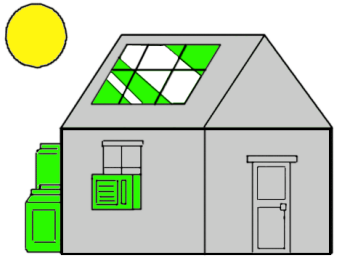
A) Grandma's House:
Smart Metering, Automation for Appliances



B) Sunny Place 1:
Solar Panel

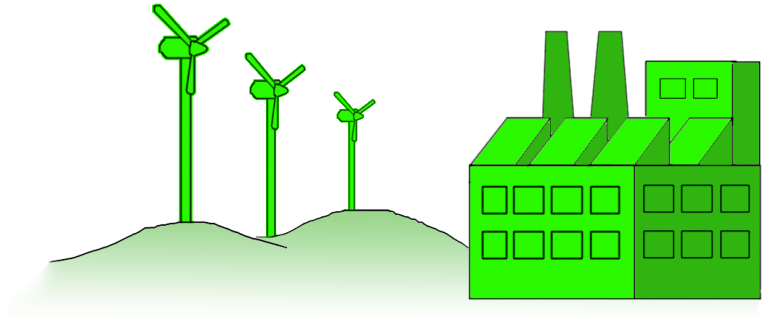


C) Sunny Place 2:
Solar Panel, Backup Power, Storage



D) Cold Place:
Backup Power, Micro CHP

E) Green Factory: Automation, Proximity to Wind Farm



What is Changing?

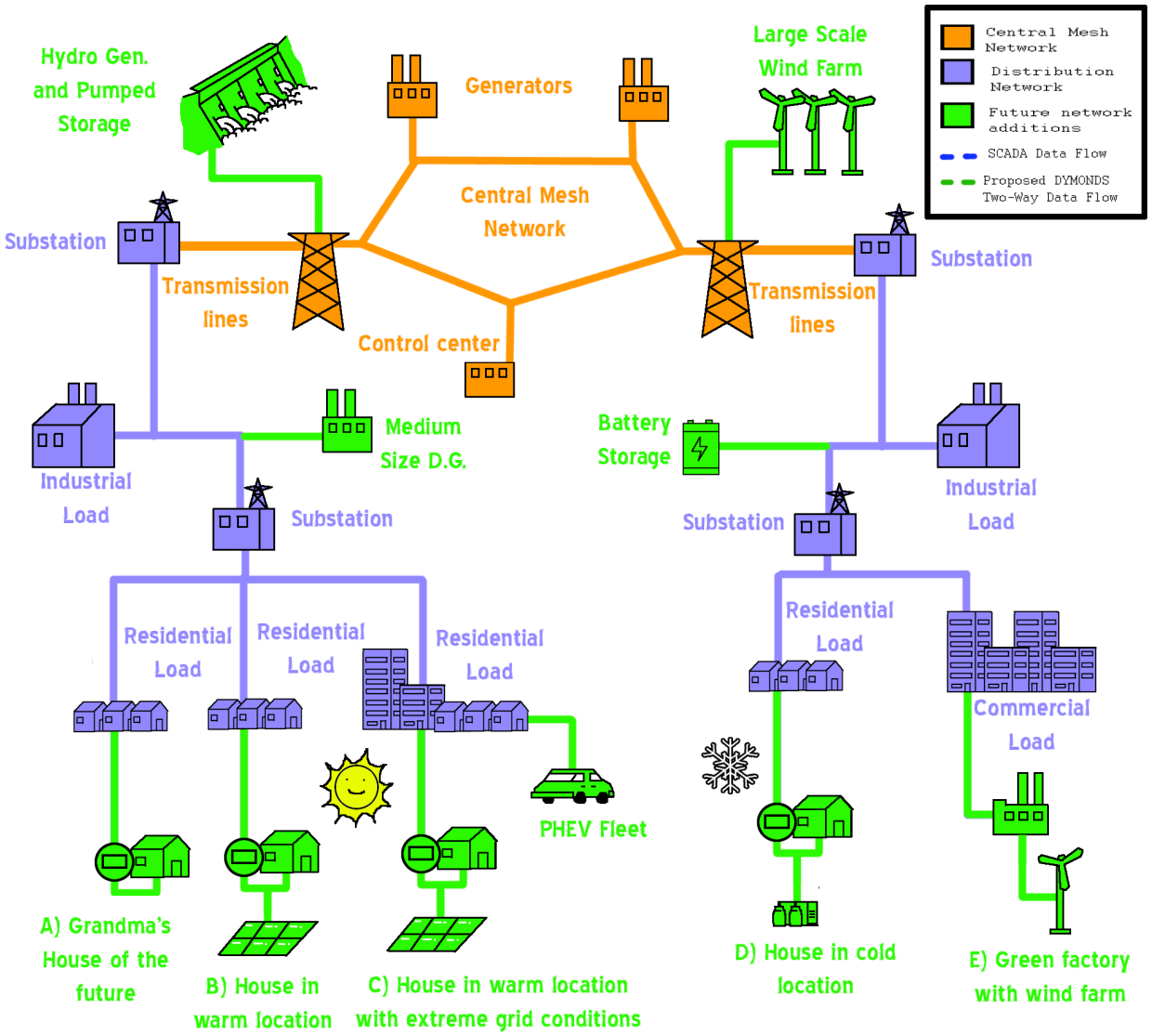
- Much more action at the D level due to:

  (1) responsive demand; (2) variable distributed resources (DRs); (3) new security and environmental constraints.

- Much harder to predict supply-demand (SD) imbalance accurately by the control centers without self-commitment by the DRs and LSEs (both short-term and long-term).

- Correlating diverse loads and DRs much harder than in the past (T level cannot assume D-loads known.)

Future Smart Grid (Physical system)

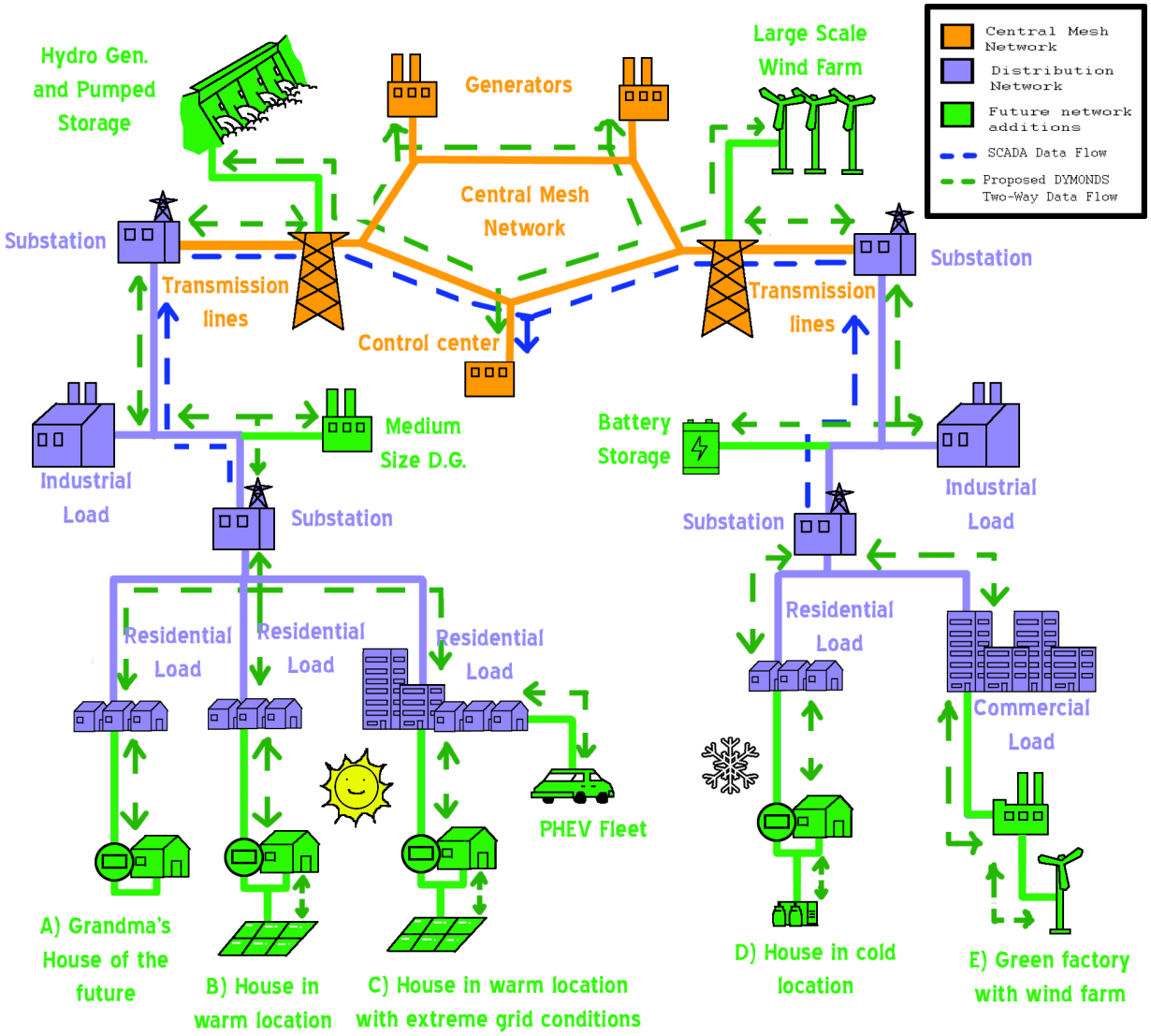


Critical: Transform SCADA

- From single top-down coordinating management to the multi-directional multi-layered interactive IT exchange.

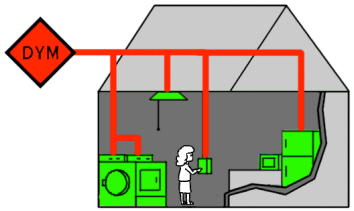
- At CMU we call such transformed SCADA Dynamic Monitoring and Decision Systems (DYMONDS) and have formed a Center to work with industry and government on: (1) new models to define what is the type and rate of key IT exchange; (2) new decision tools for self-commitment and clearing such commitments. \http:www.eesg.ece.cmu.edu.

New SCADA


Hydro Gen. and Pumped Storage
Generators
Large Scale Wind Farm
Central Mesh Network
Distribution Network
Future network additions
SCADA Data Flow
Proposed DYMONDS Two-Way Data Flow
Substation
Transmission lines
Central Mesh Network
Control center
Substation
Transmission lines
Substation
Industrial Load
Medium Size D.G.
Battery Storage
Industrial Load
Substation
Substation
Residential Load
Residential Load
Residential Load
Residential Load
Commercial Load
PHEV Fleet
A) Grandma's House of the future
B) House in warm location
C) House in warm location with extreme grid conditions
D) House in cold location
E) Green factory with wind farm

Smart users

A) Grandma's House:
Smart Metering, Automation for Appliances



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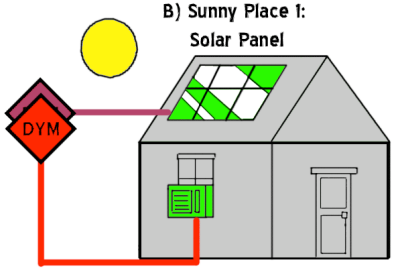

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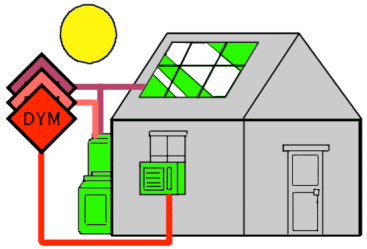

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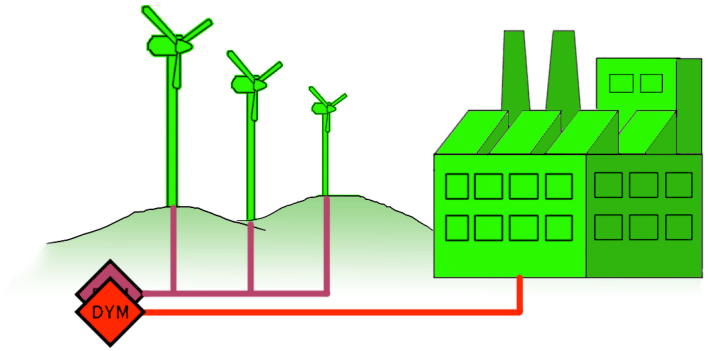
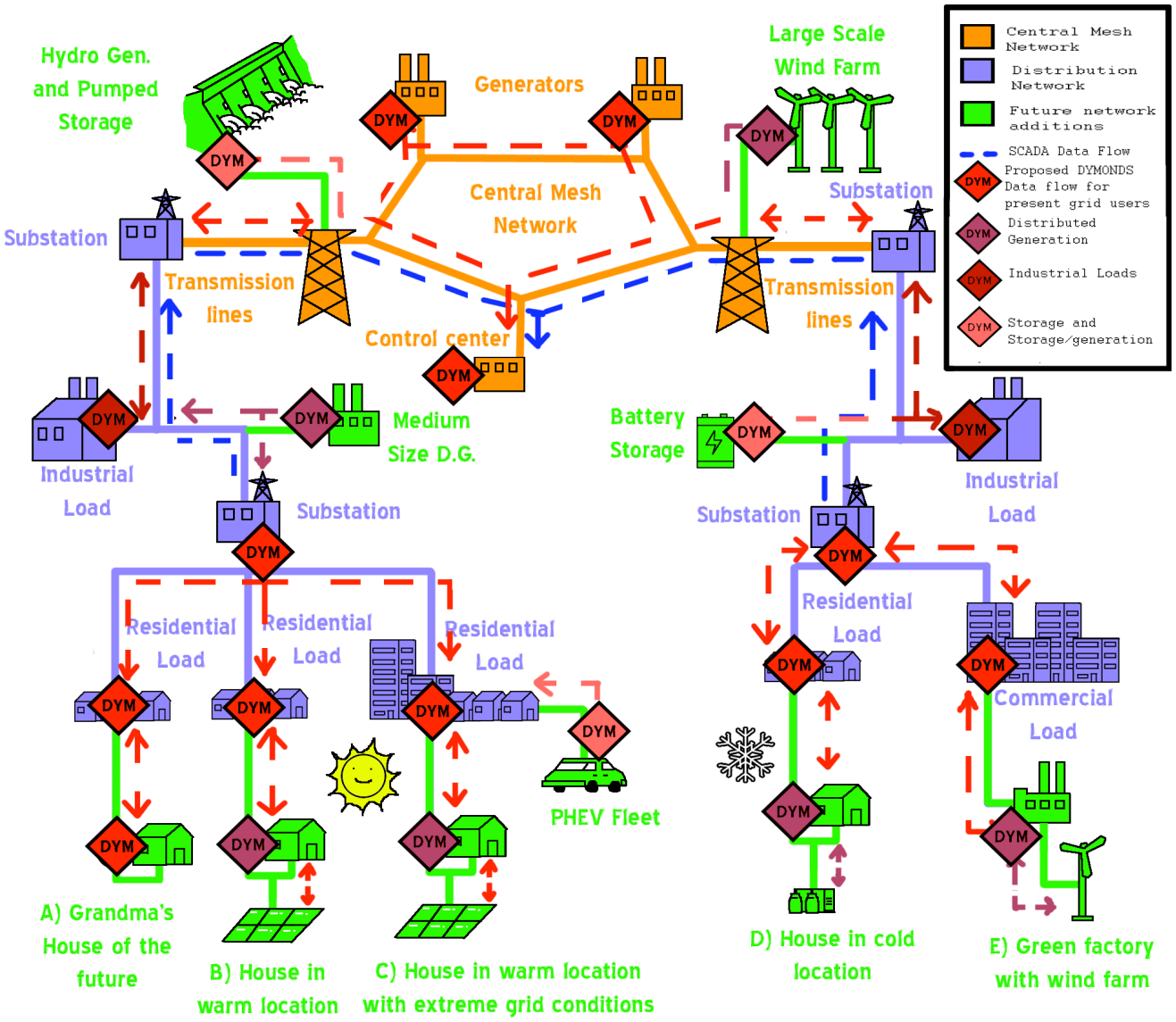


DYMONDS-enabled Physical Grid [1]



T&D as an Enabler

- New dispatch of self-committing resources will make it possible to fit different pieces of the puzzle together.
- Much more reliance on distributed sensing, actuation and coordinated management of these resources. Real time awareness of D flows.
- No models, no simulations, no decision tools. Without these, it will be much more costly to proceed. R&D ahead of us.

New DYMONDS Functionalities

- Just-in-Time (JIT) --predictions; dynamic look-ahead decision making
- Just-in-Place (JIP) --distributed, interactive, multi-layered
- Just-in-Context (JIC) ---- performance objectives function of organizational rules, rights, and responsibilities (3Rs) and system conditions.
- Sample examples of improved performance—on-going work in EESG http://www.eesg.ece.cmu.edu

Just-in-Context (JIC) –Need for Smart Regulation [2]

- Need to revisit the performance metrics in the changing industry (cost vs. benefits; cost allocation vs. value-based services)
- The cost of managing uncertainties –very different depending on the context
- The value of high technologies (DYMONDS) –very different depending on the context
- Heterogeneous performance metrics (reliability, short term-, long term-efficiency; environmental impacts; cyber security)
- Who takes the risks for what and at which price?

Wind prediction, look-ahead management using storage (Xie,2009)

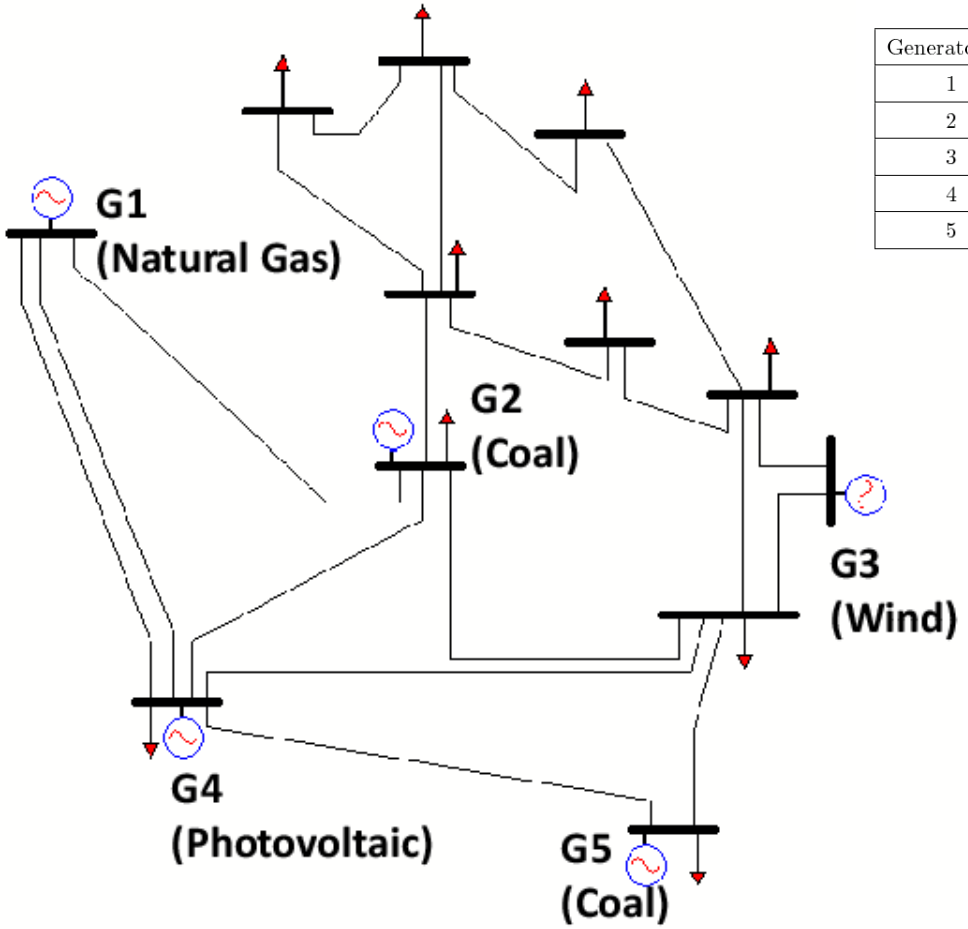
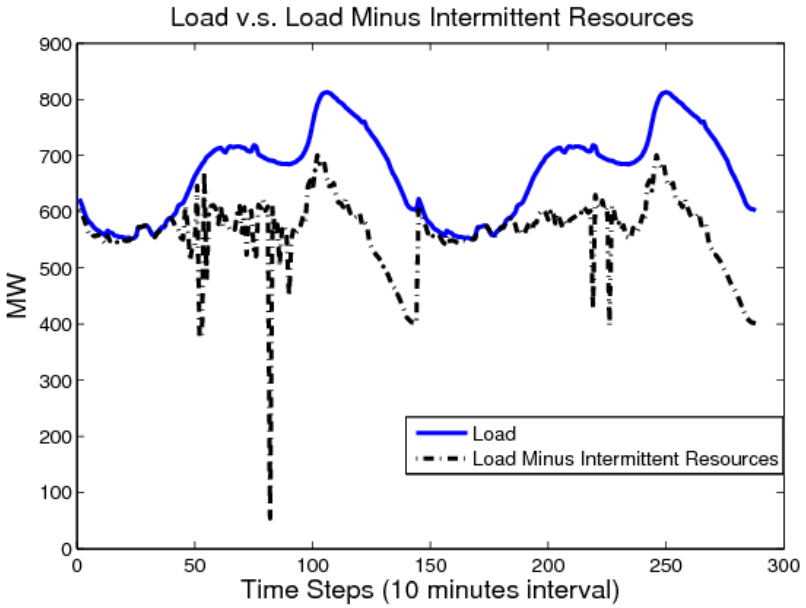
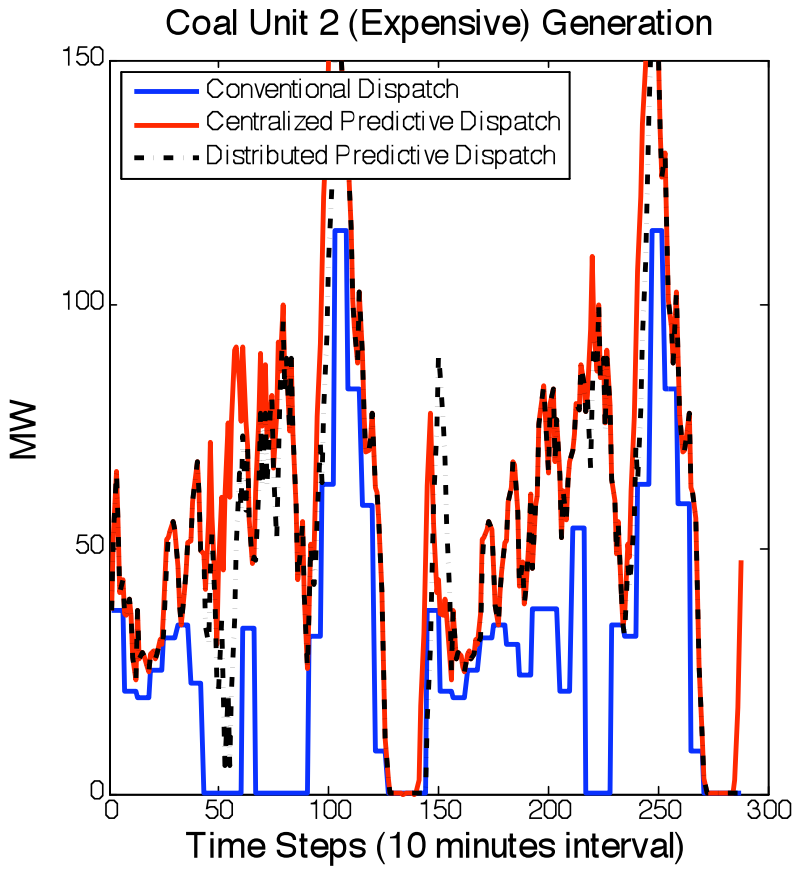


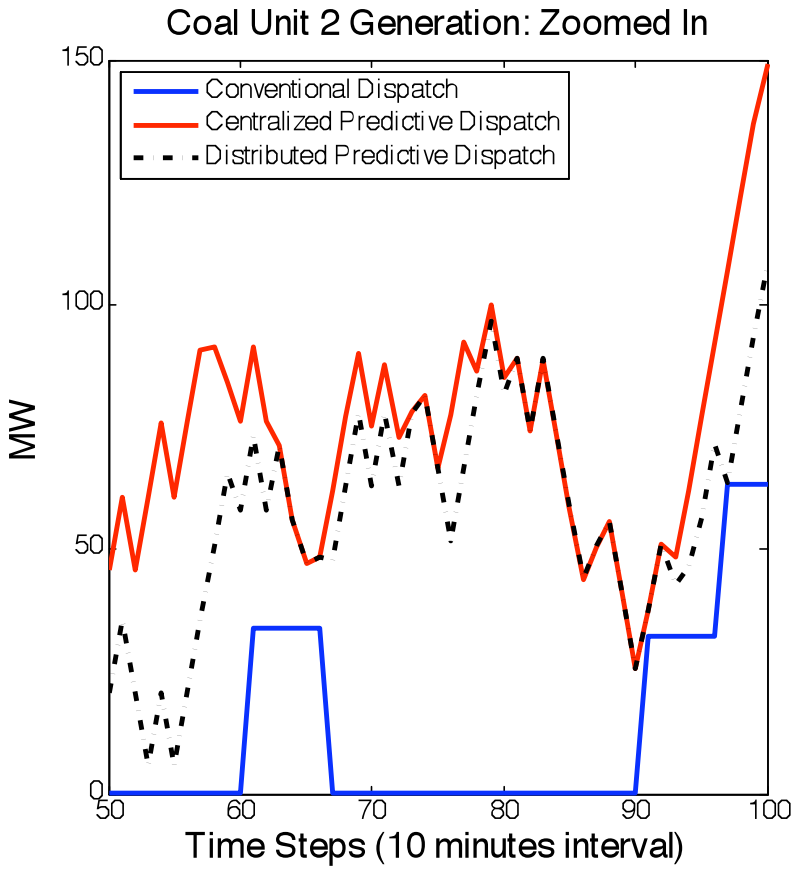
Table 1: Generator parameters of the 12-bus system

Generator ID	Type	Min Generation	Max Generation	Generation Cost	Ramp Rate
1	Gas	20	500MW	350$/MWh	150MW/5 min
2	Coal	20	500MW	150$/MWh	15MW/ 5min
3	Wind	0	250MW	0$/MWh	150MW/5 min
4	PV	0	600MW	0$/MWh	200MW/5 min
5	Coal	10	500MW	100$/MWh	10MW/5 min



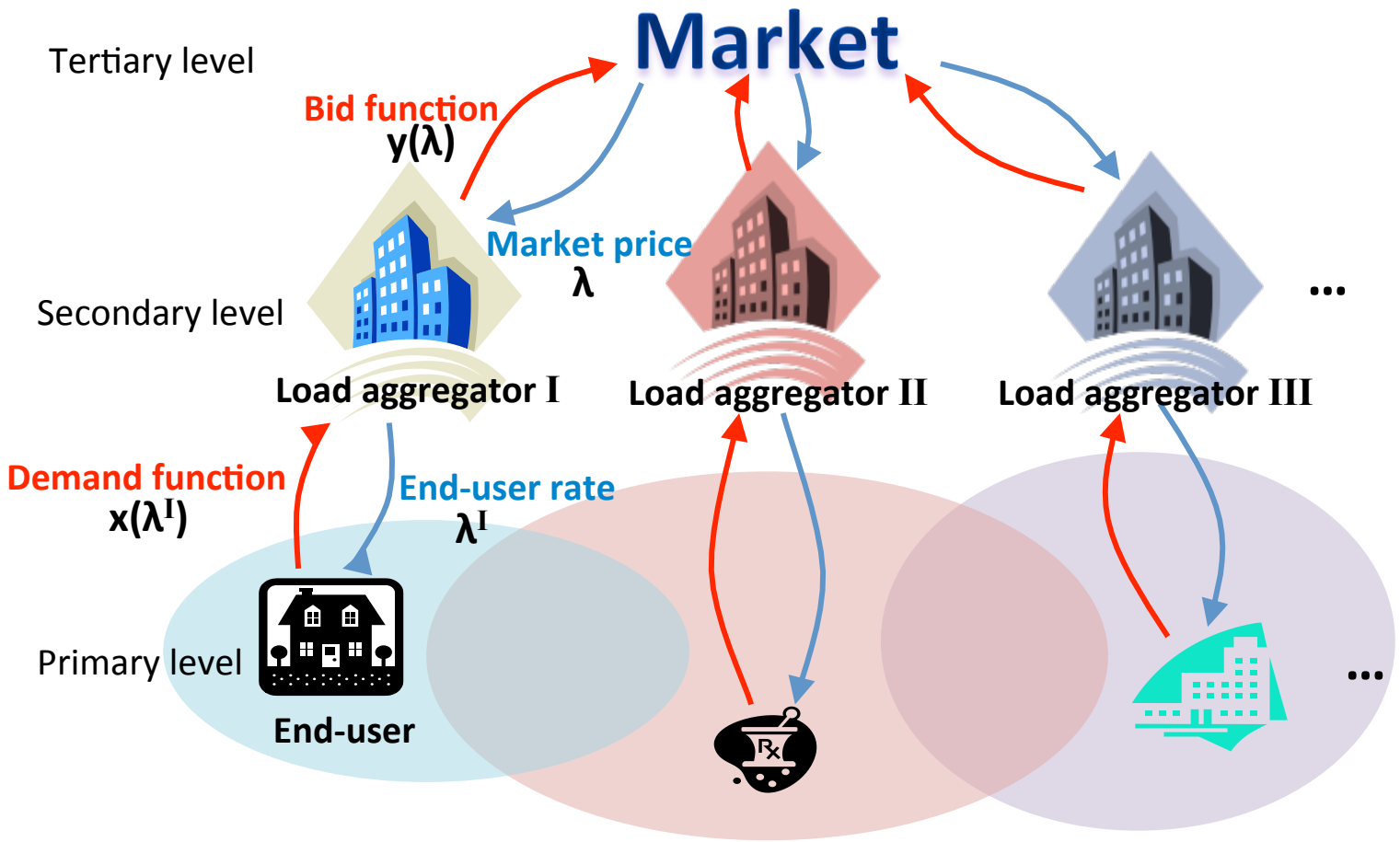
Compare the outcome of ED from both the centralized and distributed MPC approaches.



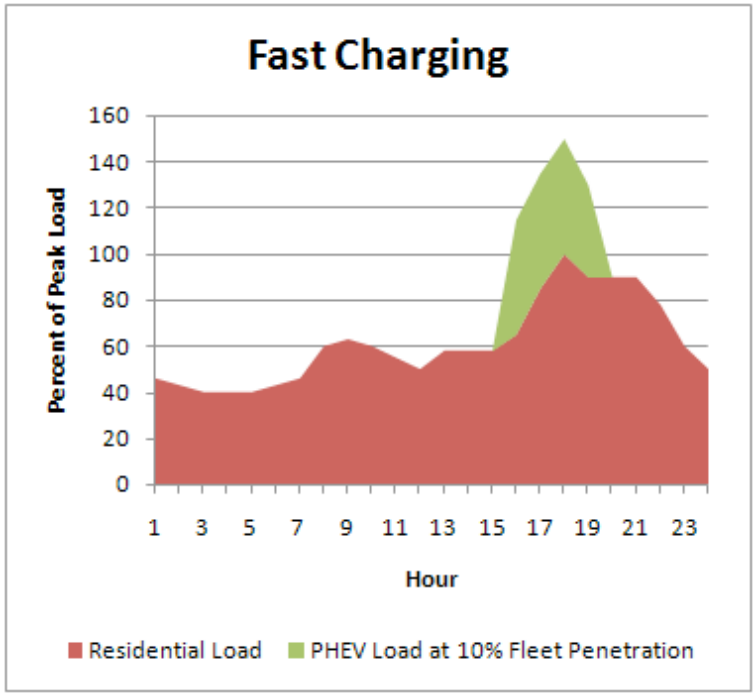


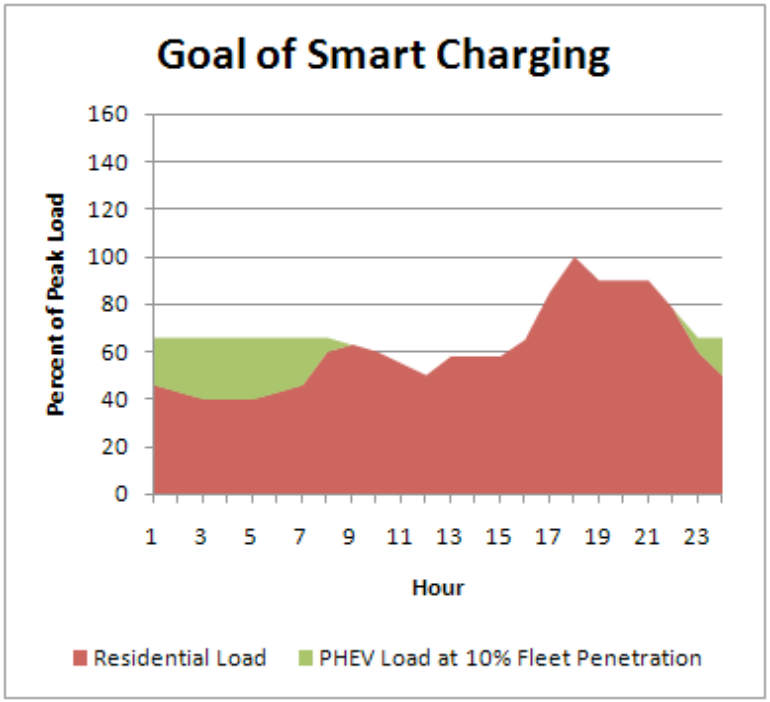
BOTH EFFICIENCY AND RELIABILITY MET

Adaptive Load Management (Joo, 2009)

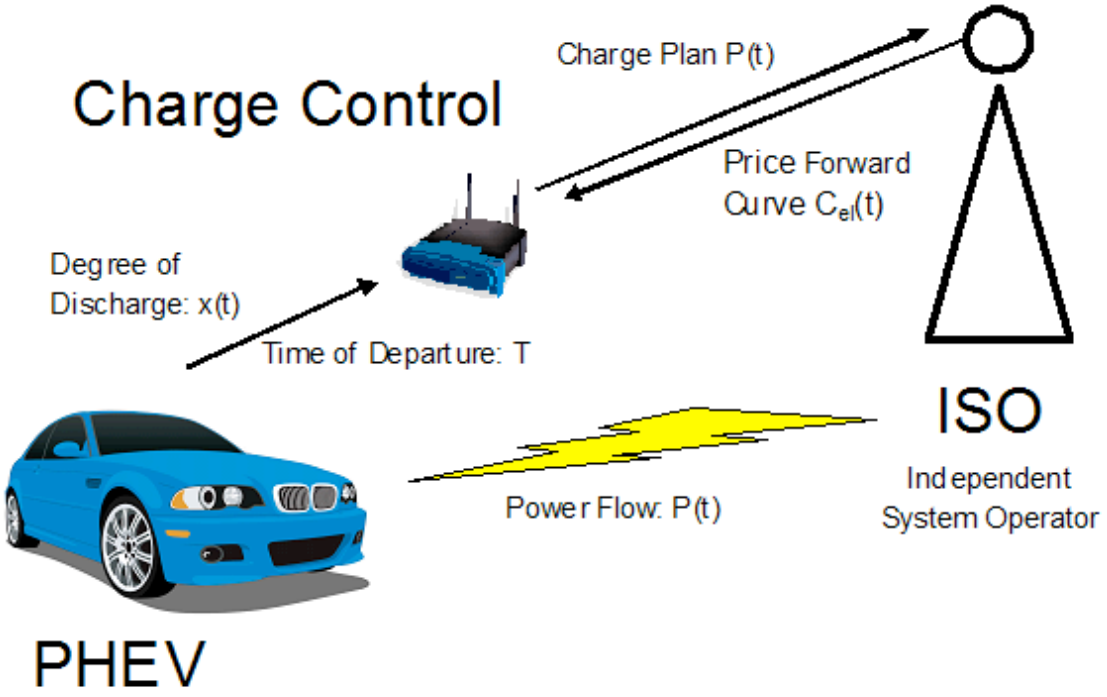


Optimal Control of Plug-in-Electric Vehicles: Fast vs. Smart (Rotering,2009)

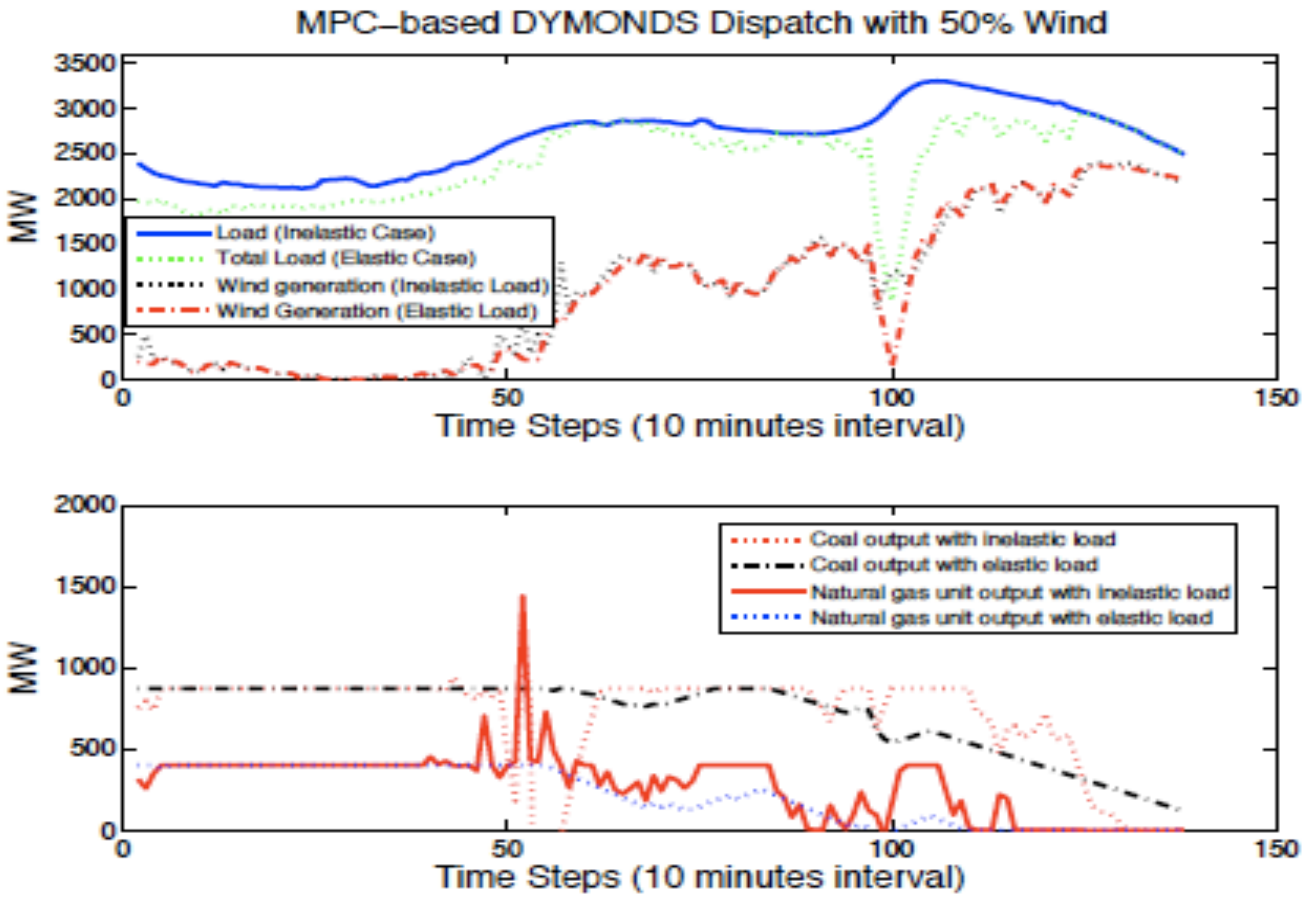




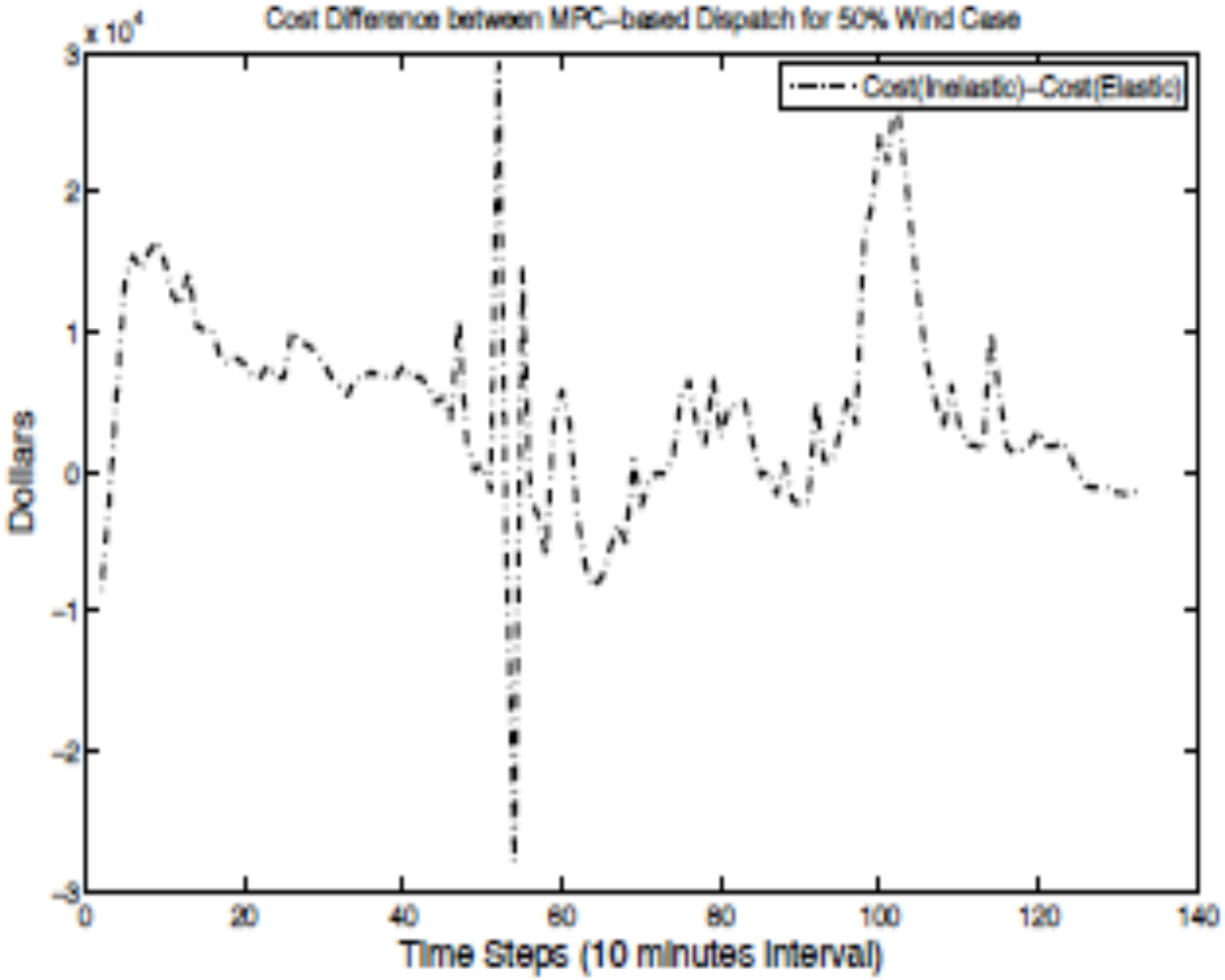
Information flow—Fantastic Use of Multi-layered Dynamic Programming



Integrating >50% Wind [2]



Potential Savings with Self - Committing Dispatch



ALM not Direct Load Control [Joo]

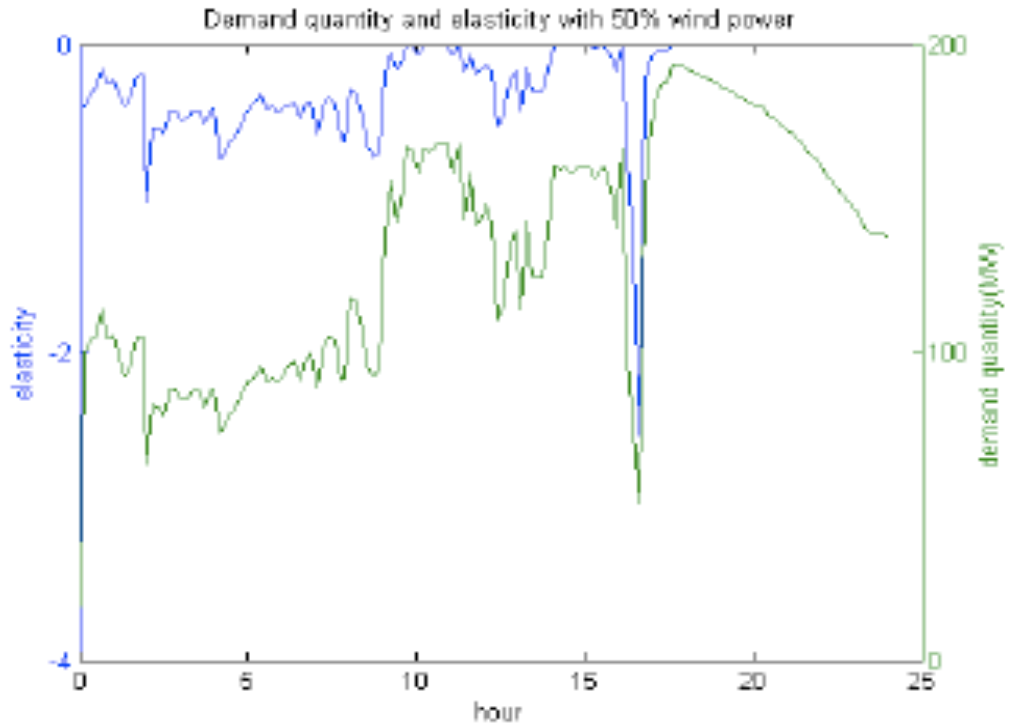


Fig. 24. Price elasticity of demand and demand quantity(MW) with 50% wind penetration

Electric Energy Systems Group (EESG)

http://www.eesg.ece.cmu.edu

- A multi-disciplinary group of researchers from across Carnegie Mellon with common interest in electric energy.
- Truly integrated education and research
- Interests range across technical, policy, sensing, communications, computing and much more; emphasis on systems aspects of the changing industry, model-based simulations and decision making/control for predictable performance.

References

- [1] Ilic, Marija "Dynamic Monitoring and Decision Systems (DYMONDS) and Smart Grids: One and the Same, CMU EESG WP 019, October 2009.
- [2] Ilic, Marija "IT-enabled Rules, Right and Responsibilities (3Rs) for Efficient Integration of Wind and Demand Side Response", Public Utility Fortnightly Magazine, Dec 2009.
- [Joo,2009] of J.Y. Joo and M, Ilić, "A Multi-Layered Adaptive Load Management (ALM) System: Information exchange between market participants for efficient and reliable energy use" Electric Energy Systems Group Working Paper R-WP17, Carnegie Mellon University, 2009.
- [Xie, 2009] Marija Ilic, Le Xie, and Jhi-Young Joo, "Dynamic Monitoring and Decision Systems (DYMONDS) for Efficient Integration Wind Power and Price-Responsive Demand: Proof of Concept on the IEEE RTS System", EESG WP 2009.
- [Rottering, 2009] Nik Rottering, CMU ECE and ETH Master thesis, 2009.