Electrical & Computer ENGINEERING

System requirements in support of renewable resource integration

Marija Ilic, EPP and ECE
milic@ece.cmu.edu

ARPA-E Workshop, December 13, 2010

Carnegie Mellon

Single optimization subject to constraints (old) vs. Reconciling multi-dimensional tradeoffs (new)

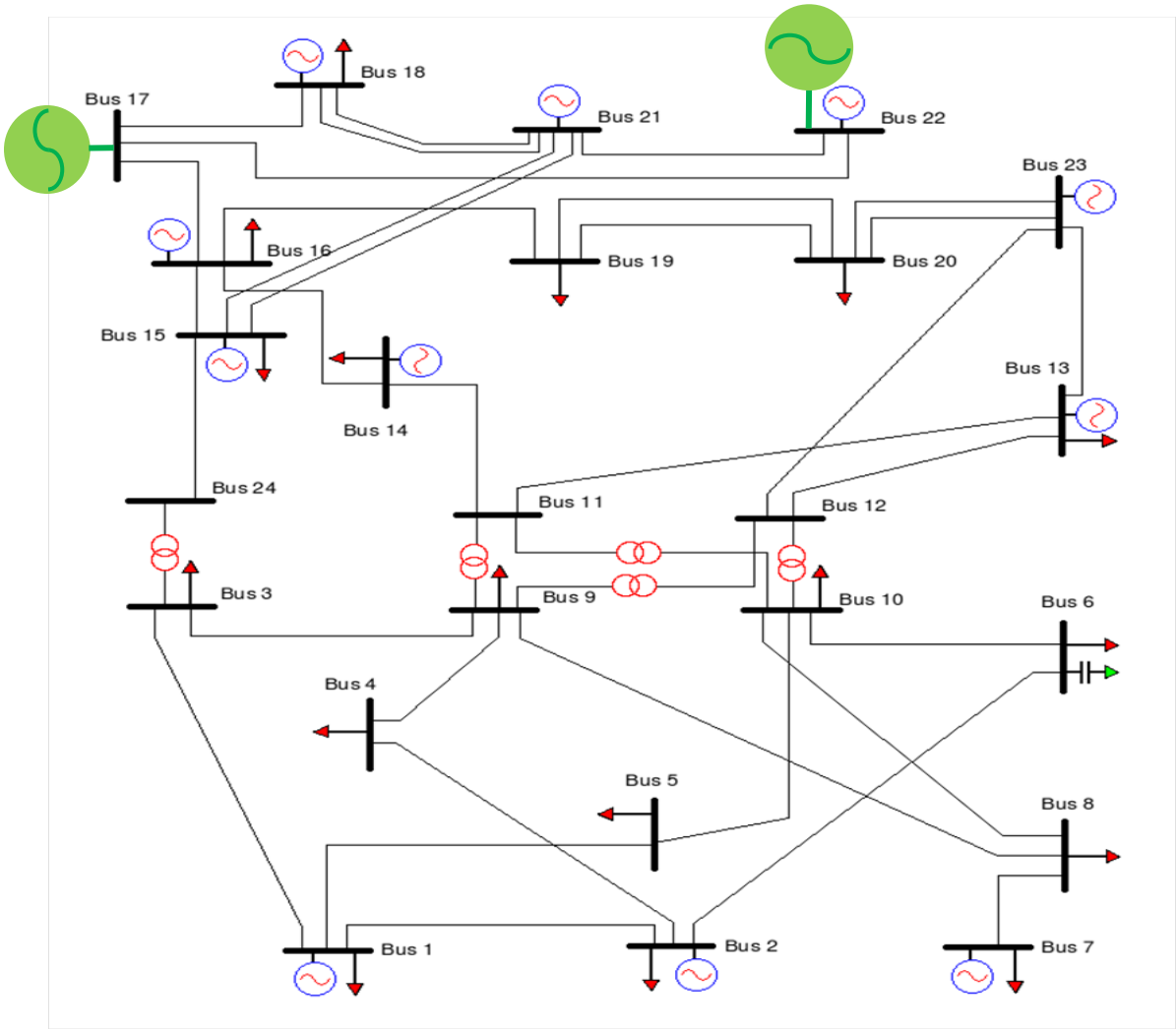
Single optimization subject to constraints	Reconciling tradeoffs
Schedule supply to meet given demand	Schedule supply to meet demand (both supply and demand have costs assigned)
Provide electricity at a predefined tariff	Provide electricity at QoS determined by the customers willingness to pay
Produce energy subject to a predefined CO_2 constraint	Produce amount of energy determined by the willingness to pay for CO_2 effects
Schedule supply and demand subject to transmission congestion	Schedule supply, demand and transmission capacity (supply, demand and transmission costs assigned)
Build storage to balance supply and demand	Build storage according to customers willingness to pay for being connected to a stable grid
Build specific type of primary energy source to meet long-term customer needs	Build specific type of energy source for well-defined long-term customer needs, including their willingness to pay for long-term service, and its attributes
Build new transmission lines for forecast demand	Build new transmission lines to serve customers according to their ex ante (longer-term) contracts for service

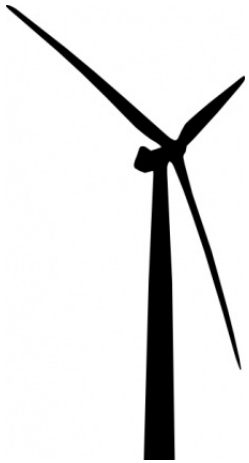
Examples of Enhanced Asset Utilization with Better Dispatch

- ***Conventional system operation***
  - *Centralized decision making*
    - *ISO knows and decides all*
  - *Not proper for future electric energy systems*
    - *Too many heterogeneous decision making components : DGs, DRs, electric vehicles, LSEs, etc.*

- ***Dynamic Monitoring Decision-making System (DYMONDS)***
  - *Distributed decision making system*
    - *Distributed optimization of multiple components → computationally feasible*
  - *Individual decisions submitted to ISO (as supply/demand bids)*
    - *Individual inter-temporal constraints* ***internalized***
    - *Market clearance and overall system balanced by ISO*

DYMONDS Simulator
IEEE RTS with Wind Power [3,4]



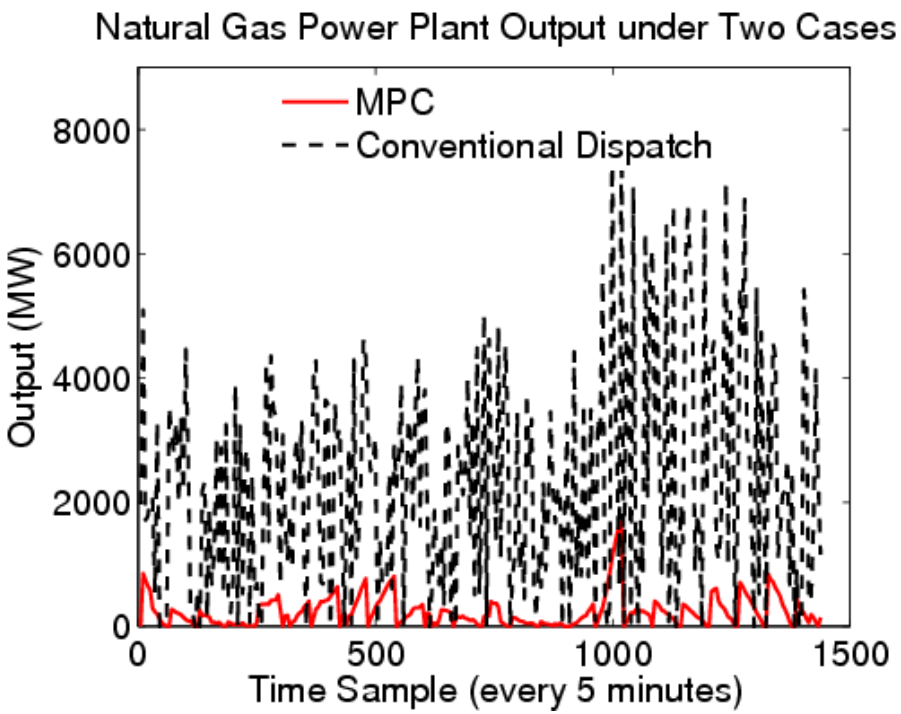


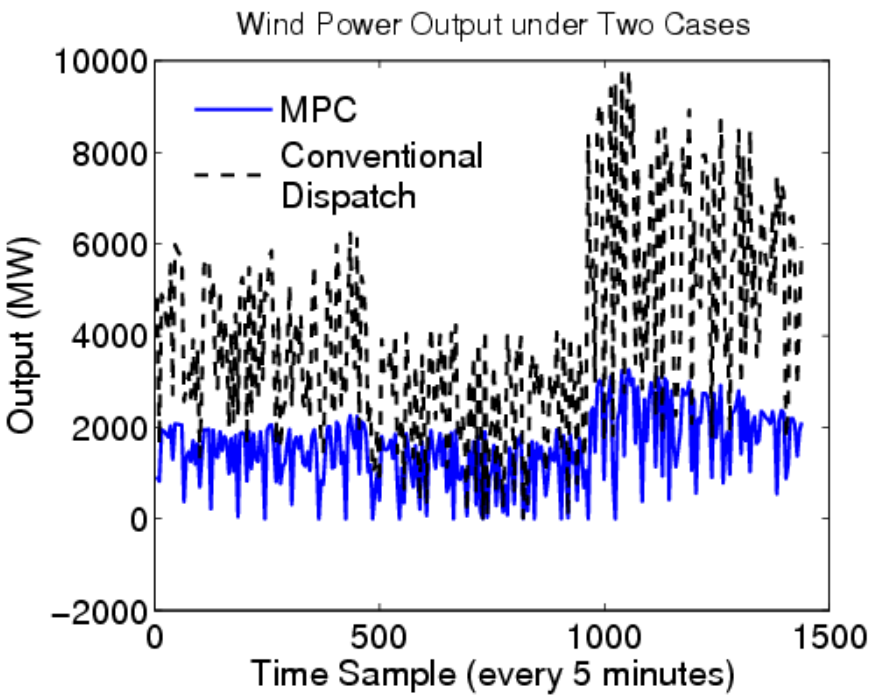
Le Xie

- ***20% / 50% penetration to the system***

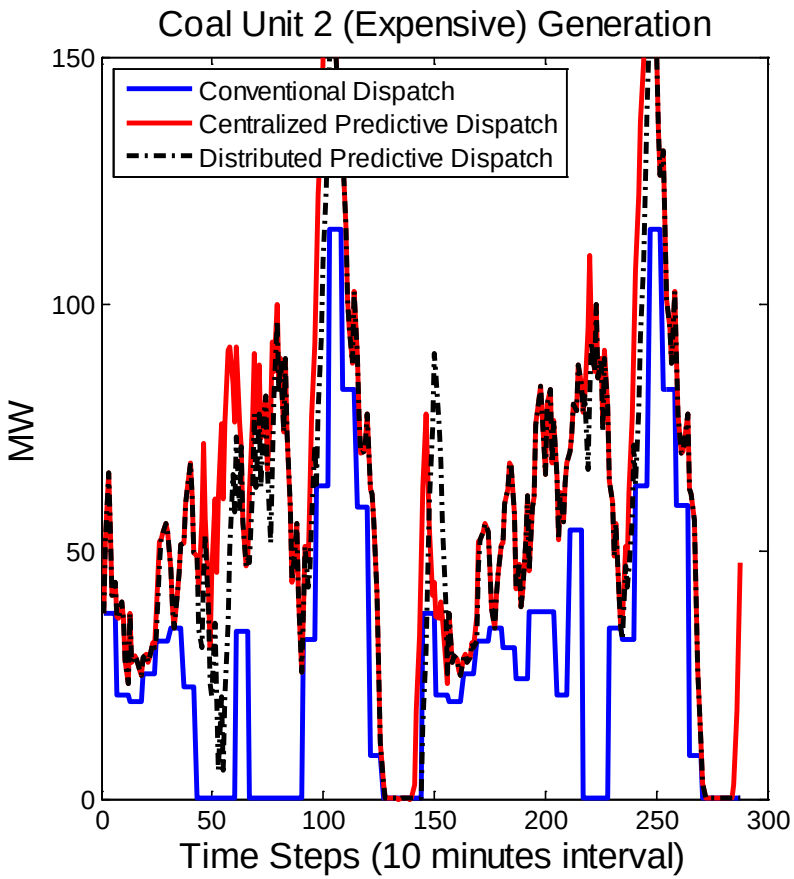
Electrical & Computer ENGINEERING

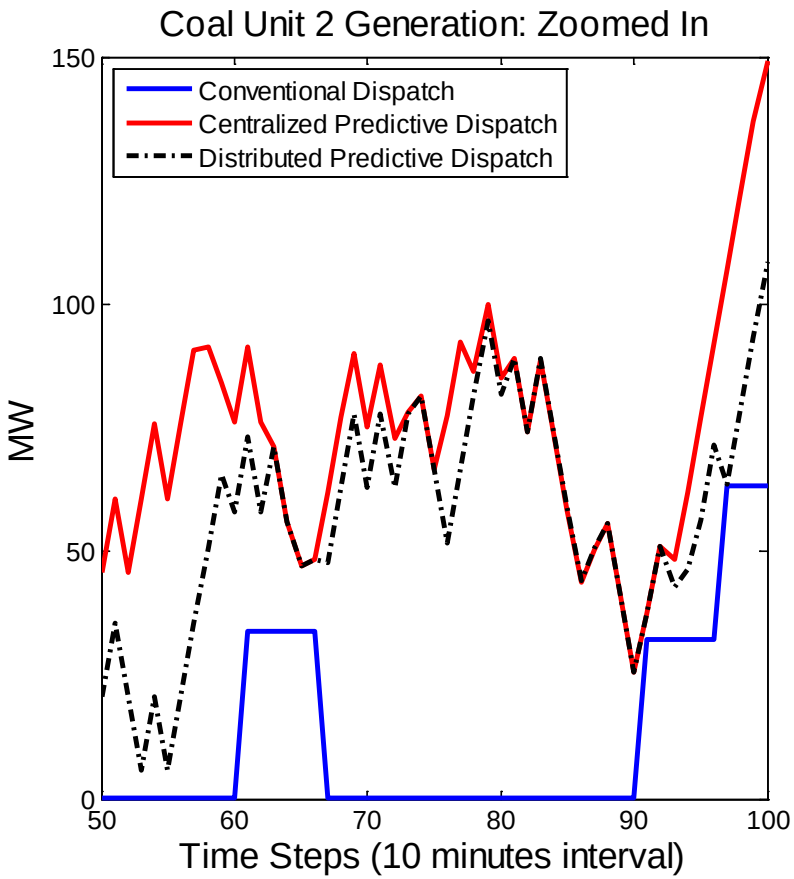
Conventional cost over 1 year *	Proposed cost over the year	Difference	Relative Saving
$ 129.74 Million	$ 119.62 Million	$ 10.12 Million	7.8%





*: load data from New York Independent System Operator, available online at http://www.nyiso.com/public/market_data/load_data.jsp

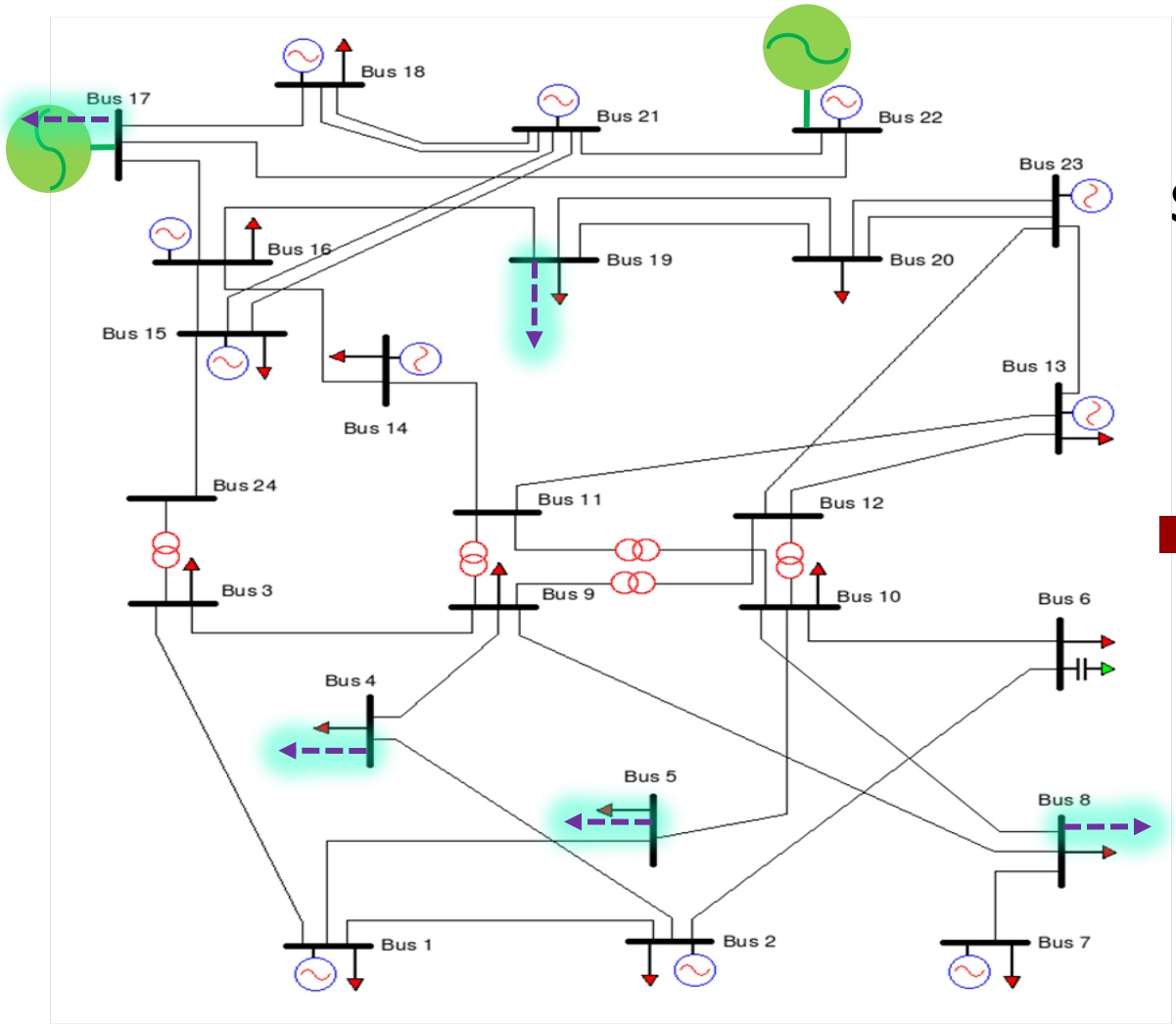


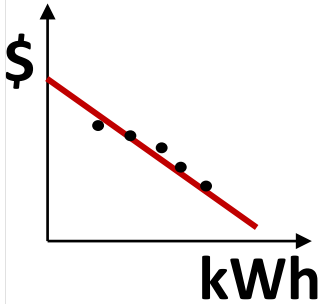


BOTH EFFICIENCY AND RELIABILITY MET

Electrical & Computer ENGINEERING

DYMONDS Simulator
Impact of price-responsive demand

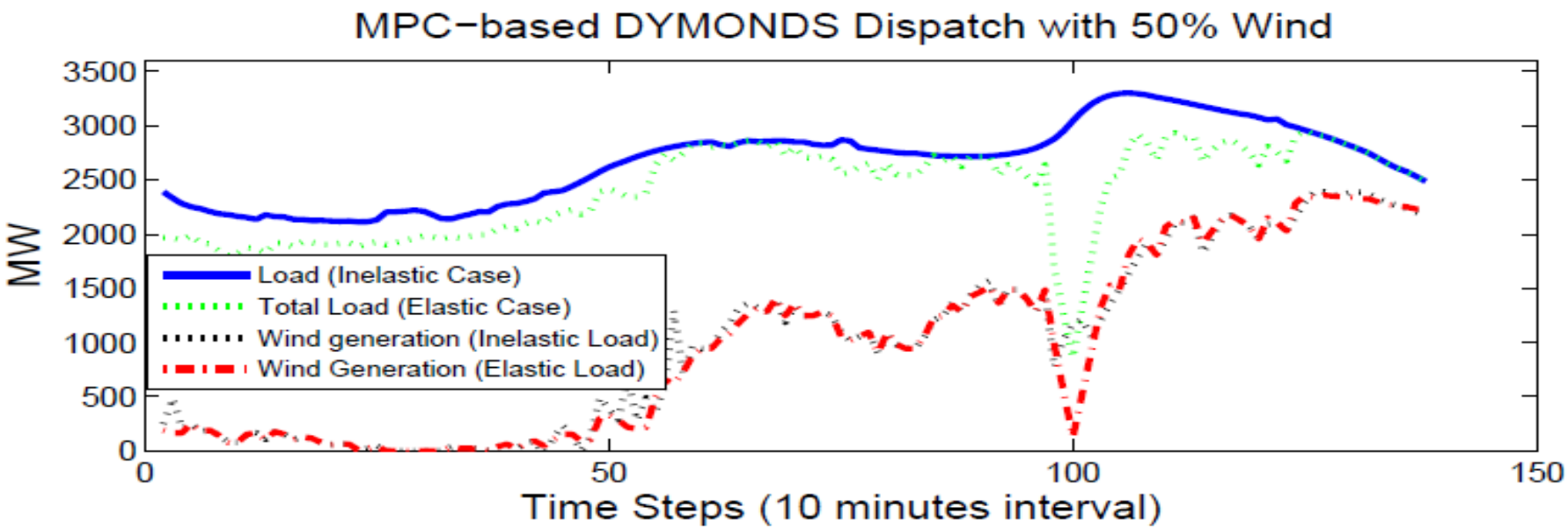


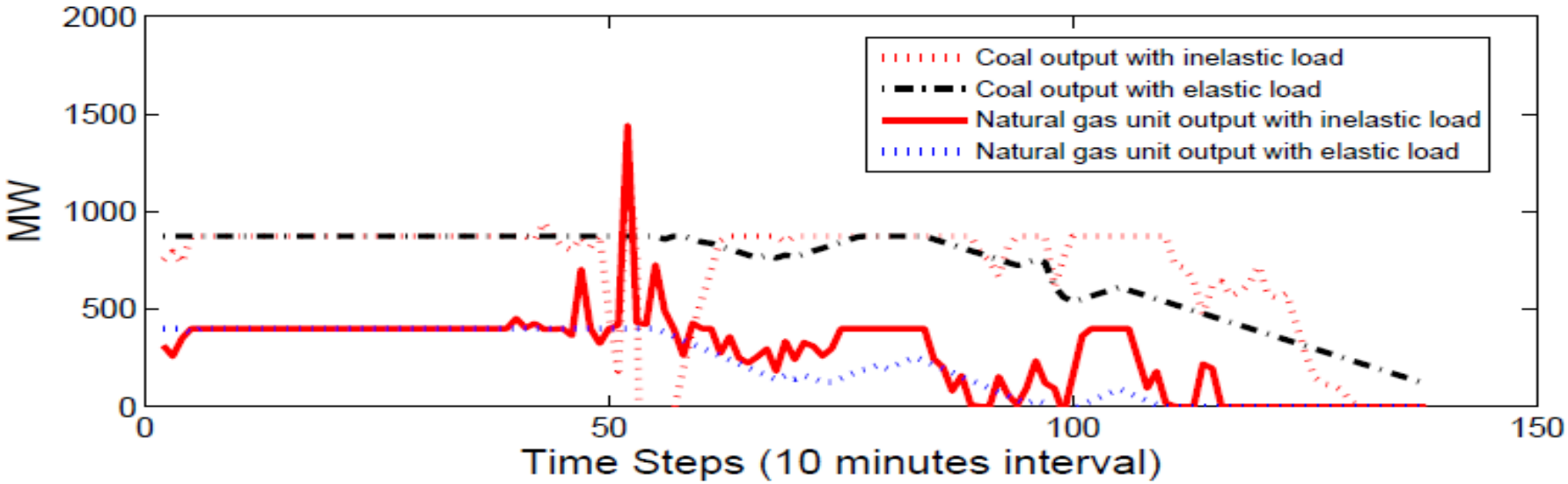


J.Y. Joo

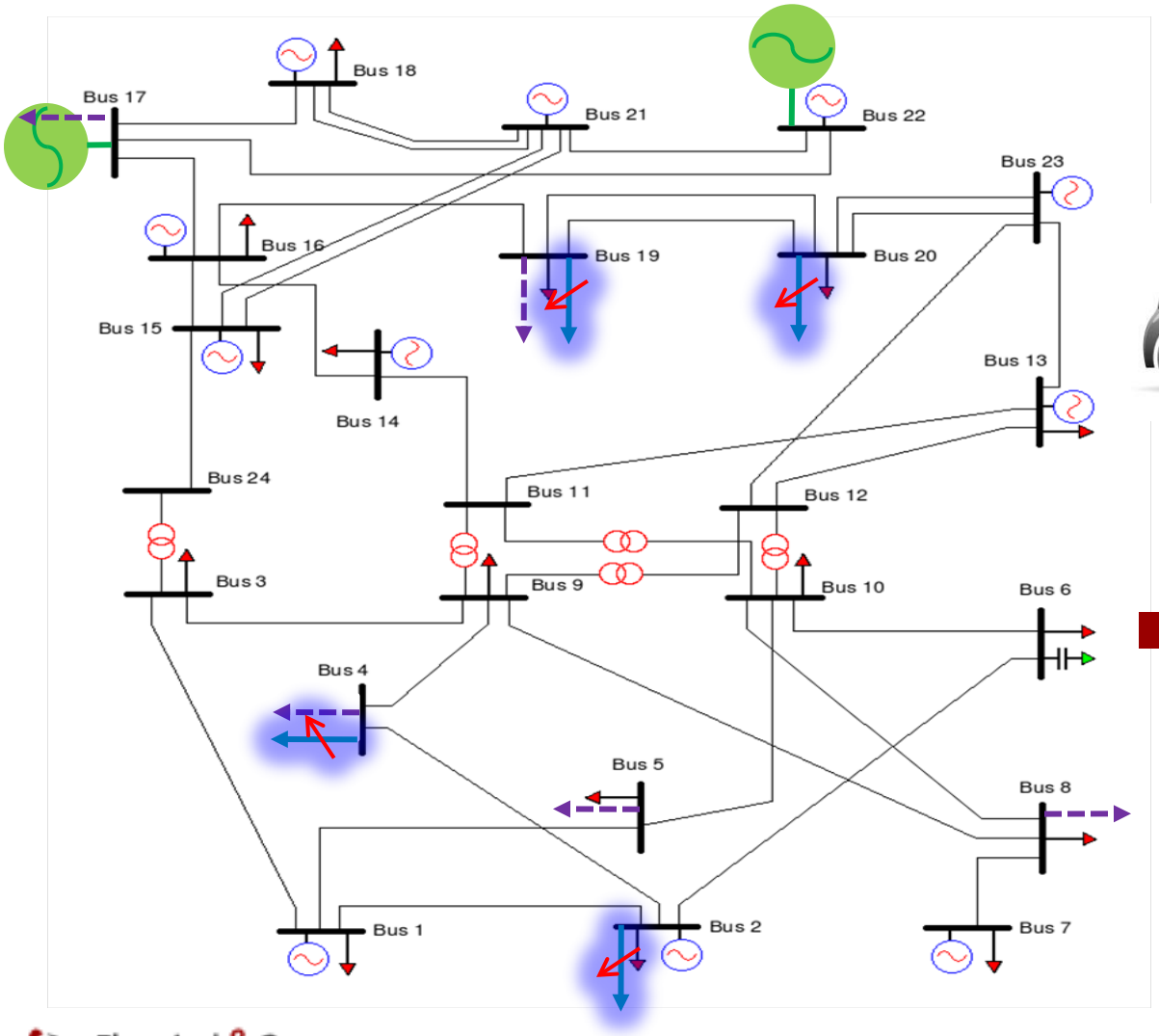
- ***Elastic demand that responds to time-varying prices***

Electrical & Computer ENGINEERING


MPC−based DYMONDS Dispatch with 50% Wind
MW
3500
3000
2500
2000
1500
1000
500
0
0
50
100
150
Time Steps (10 minutes interval)
Load (Inelastic Case)
Total Load (Elastic Case)
Wind generation (Inelastic Load)
Wind Generation (Elastic Load)


MW
2000
1500
1000
500
0
0
50
100
150
Time Steps (10 minutes interval)
Coal output with inelastic load
Coal output with elastic load
Natural gas unit output with inelastic load
Natural gas unit output with elastic load

DYMONDS Simulator
Impact of Electric vehicles

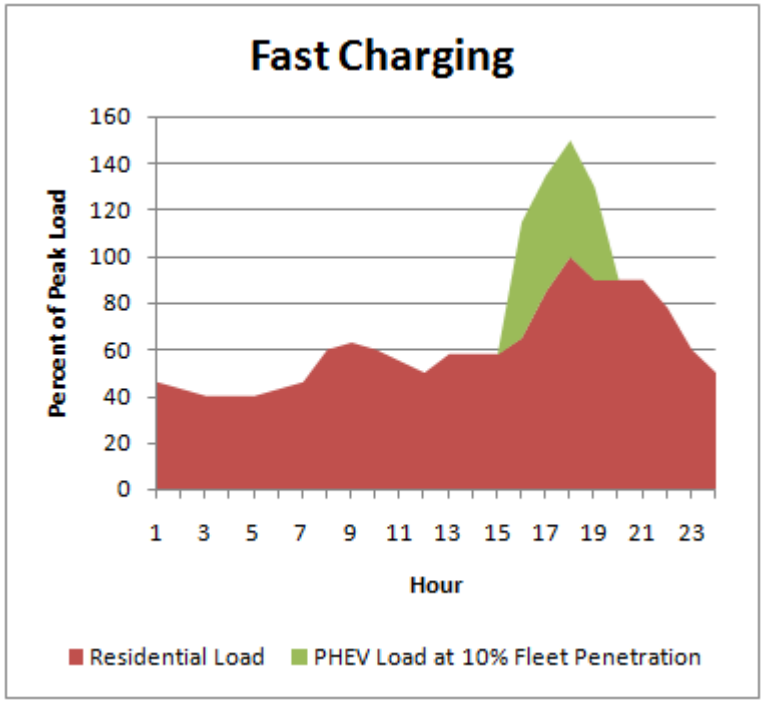


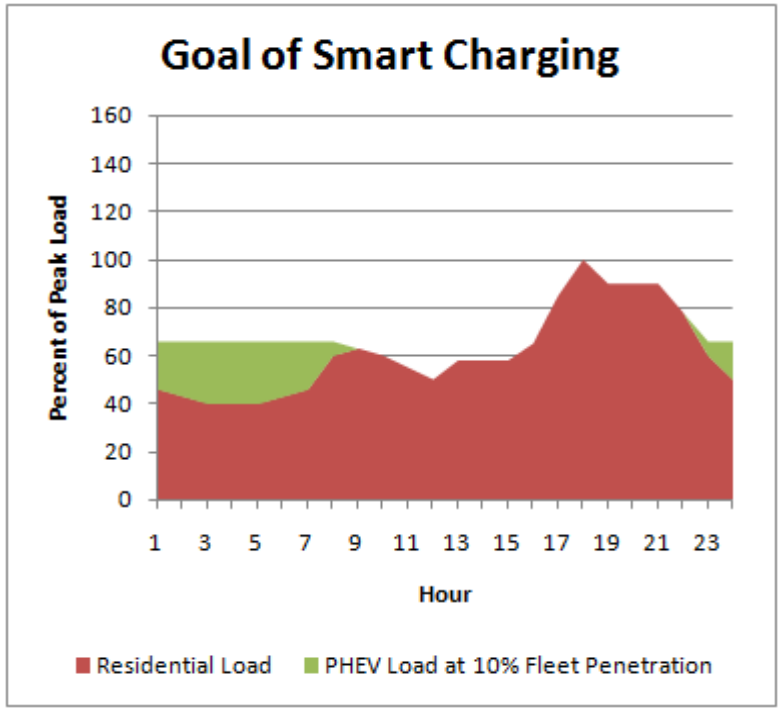
NiklasRotering

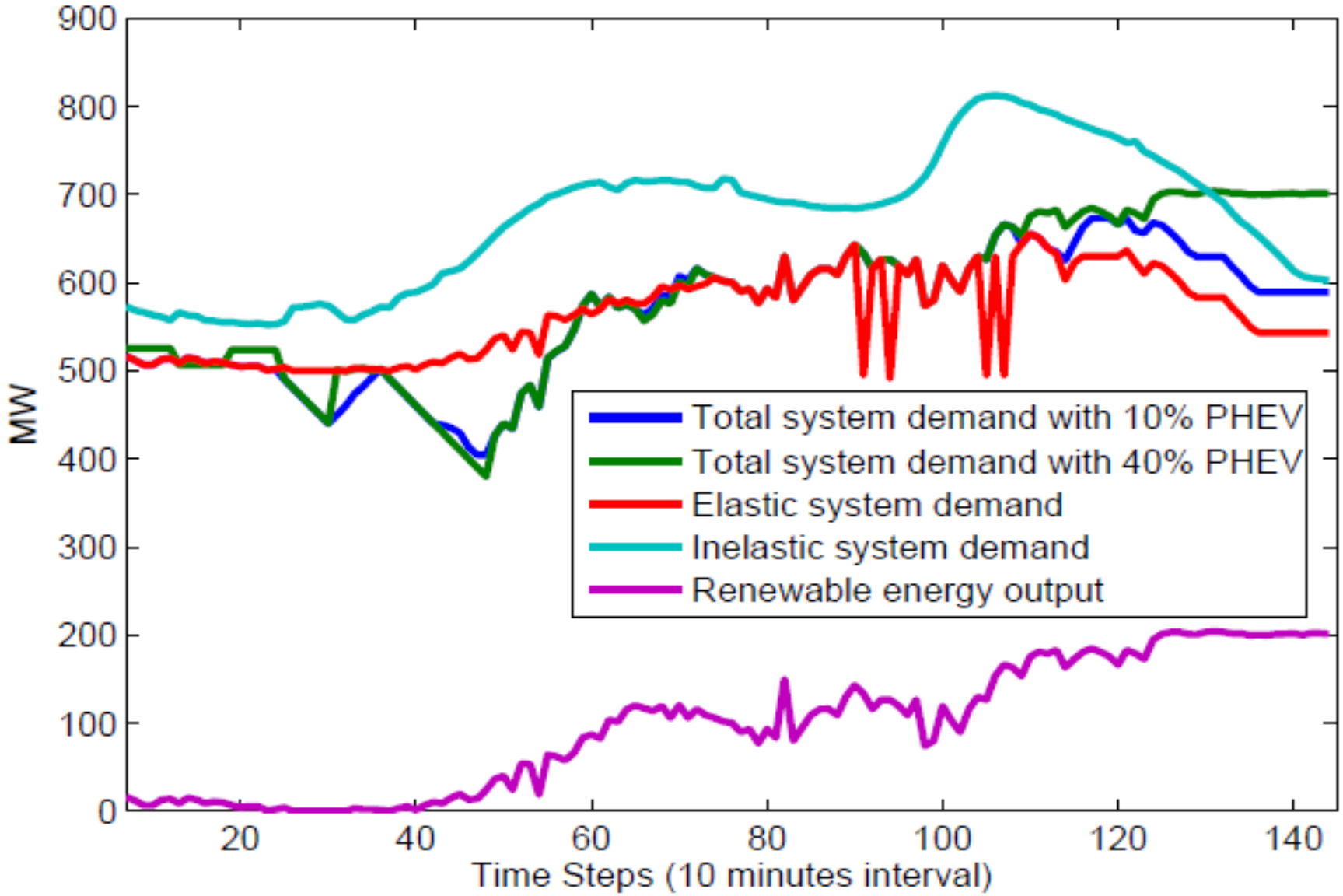
- ***Interchange supply / demand mode by time-varying prices***

Electrical & Computer ENGINEERING

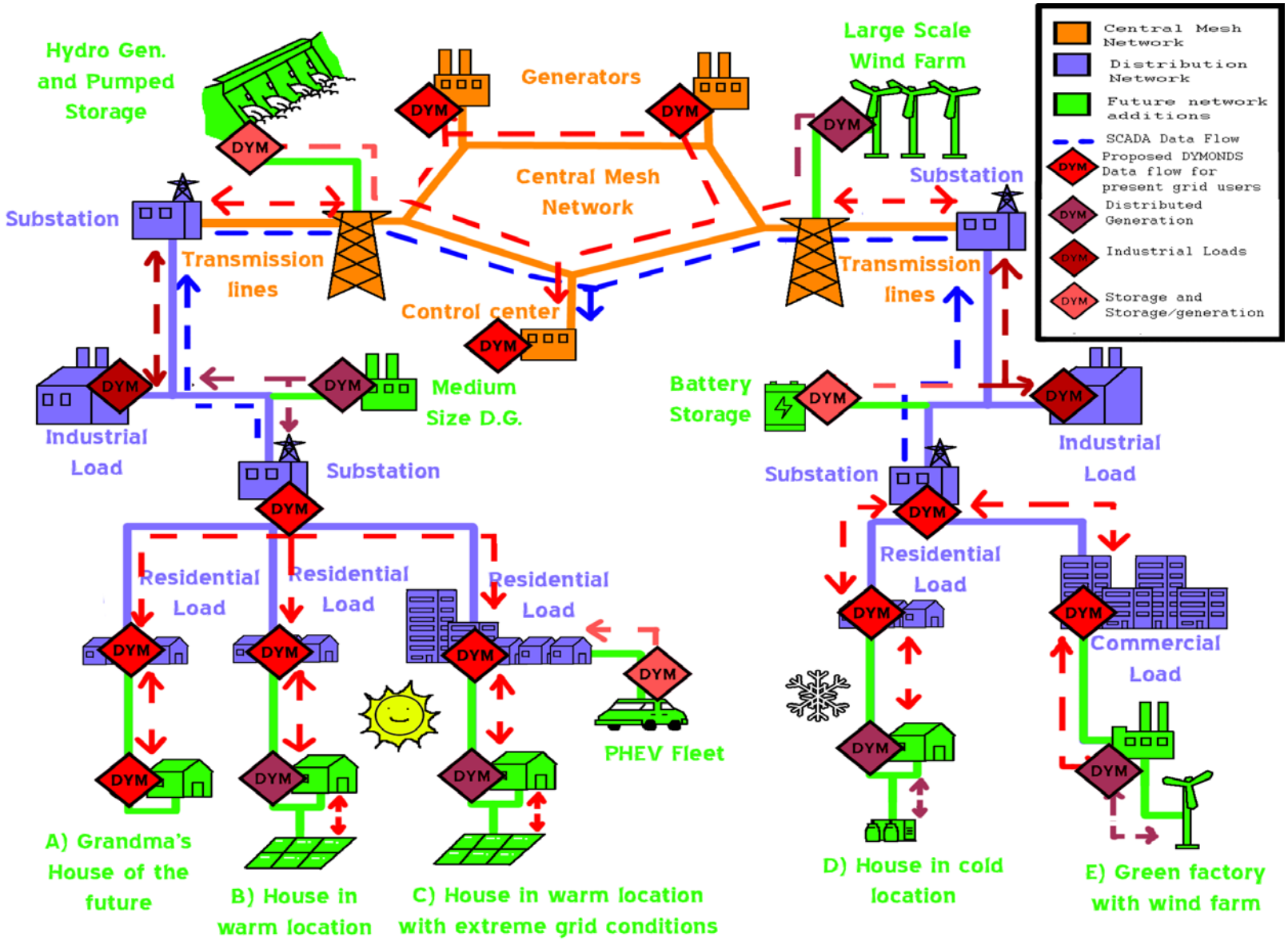
Optimal Control of Plug-in-Electric Vehicles: Fast vs. Smart






900
800
700
600
500
400
300
200
100
0
MW
20
40
60
80
100
120
140
Time Steps (10 minutes interval)
Total system demand with 10% PHEV
Total system demand with 40% PHEV
Elastic system demand
Inelastic system demand
Renewable energy output

Smart Grid –DYMONDS-Enabled Electric Energy System



How Much is VAR Support at a PV Inverter Worth?

- *It depends on many factors [Elizondo, 2006]*
- *Measures require complex dynamic performance metrics (DPM) of reliability enhancements*
- *Economic metrics for measuring cost different from generation-based control (mainly capital cost, no O&M cost)*
- *Economic metrics for measuring benefits – avoiding blackouts [King, 2006]; increased voltage stability-limited transfers [Yoon, 2004]; huge cumulative reduction in O&M costs due to reduced dynamic reserves and out-of-merit-dispatch [Elizondo, 2004]; significantly lowered LMPs (due to switch from preventive to corrective operations)*

Dynamic Performance (DP) Metrics

- ***Frequency deviations;***
- ***ACE deviations (frequency and inter-area power transfer);***
- ***Voltage deviations;***
- ***Voltages at a strategic set of buses, and reactive power generated in some units;***
- ***Critical Clearing Time CCT (transient stability);***
- ***Based on energy functions;***

Benefits from controlling grid at the edge—the key role of power electronics

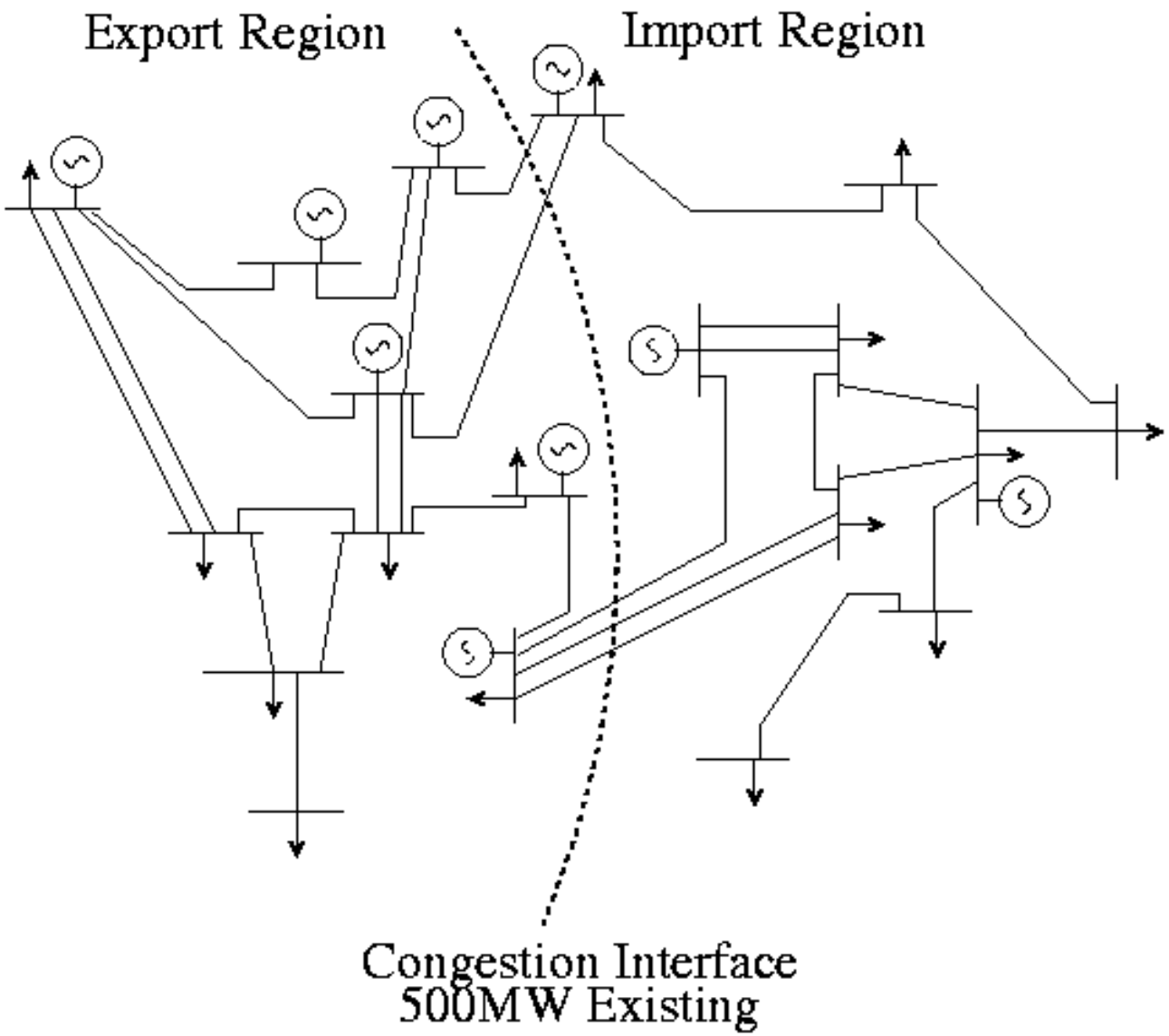
- ***Enhanced reliability—transient and small signal stabilization***
- ***Significant reduction of cumulative inefficiencies***
- ***Challenges***

  -Technical --- critical dependence on control and communications; must ensure fail-safe mode; model verification

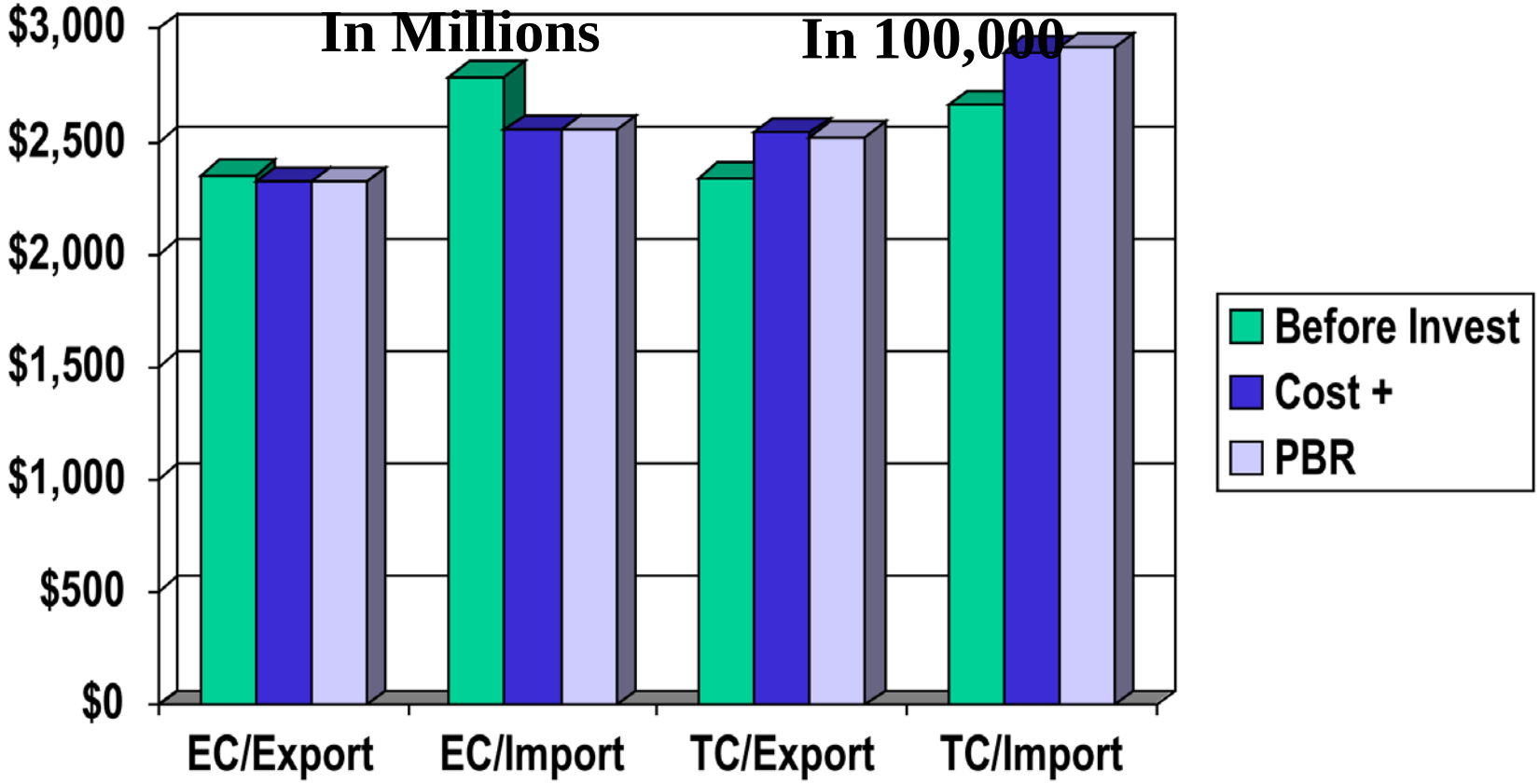
  -Regulatory/financial ---Design of insurance-like methods for recovering cost; methods for valuing technologies needed to manage uncertainties

NEED FOR SMART GRID FINANCE

NEED FOR TARGETED TECHNOLOGY TRANSFER


Export Region
Import Region
Congestion Interface
500MW Existing

Representative Charges



Conclusions

- ***Large discrepancy between the cost of transmission enhancements and the resulting value***
- ***Present planning practices generally do not assess opportunities of enhancing the grid using control technologies***
- ***Current operating practices preventive, and do not rely on just-in-time (JIT) and just-in-place (JIP) corrective actions***
- ***Importance of defining dynamic performance metrics***
- ***One could enhance grid performance significantly***
- ***Need value-based incentives for deploying the most effective transmission enhancements.***