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

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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?
• DYMOMDS-enabled monitoring and decision making (transformed SCADA)
• IT-enabled Rules, Rights and Responsibilities (3Rs) – *Smart Regulation*
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.)
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.
Smart 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
DYMONDS-enabled Physical Grid [1]

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
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—ongoing 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)

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

Table 1: Generator parameters of the 12-bus system

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

Compare the outcome of ED from both the centralized and distributed MPC approaches.
Coal Unit 2 (Expensive) Generation

Conventional Dispatch
Centralized Predictive Dispatch
Distributed Predictive Dispatch

BOTH EFFICIENCY AND RELIABILITY MET
Adaptive Load Management (Joo, 2009)

Tertiary level

Secondary level

Primary level

End-user

Load aggregator I

Load aggregator II

Load aggregator III

Bid function $y(\lambda)$

Market price $\lambda$

Demand function $x(\lambda^I)$

End-user rate $\lambda^I$
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]

MPC-based DYMOMDS Dispatch with 50% Wind

![Graph showing MPC-based DYMOMDS Dispatch with 50% Wind.](image-url)
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

• [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.