From Theory to Smart Grid Simulator for Assessing and Demonstrating The Potentials of New Technologies

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Acknowledgements

❖ Le Xie
  ▪ Former PhD student, Assistant Professor at Texas A&M University

❖ Marija Prica
  ▪ PhD student, EESG, ECE CMU

❖ Niklas Rotering
  ▪ Former visiting Master’s student, PhD student at RWTH Aachen, Germany
DYMONDS — Future electric energy system
Dynamic Monitoring and Decision-making System (DYMONDS) [1]

- **Dynamic Monitoring Decision-making System (DYMONDS)**
  - Distributed decision making system
  - Computationally feasible
  - Individual decisions submitted to ISO (as supply/demand bids)
    - Individual inter-temporal constraints *internalized*

- **The pieces we’ve got**
  - System operator
  - Wind generation, price-responsive demand, PHEVs, planning and PMU(phasor measurement unit)s, and more
Concepts of DYMONDS Simulator
IEEE 24-bus Reliability Test System (RTS) in GIPSYS [2]

- 11 generator buses (including a slack bus)
  - Nuclear, coal, oil, natural gas
- Inelastic demand
Current electric power systems

Static Dispatch with 0% Wind

![Graph showing net load and power outputs over time steps](image)

- **Net Load**
- Theoretically optimal coal output
- Physically implementable optimal coal output
- Theoretically optimal natural gas output
- Physically implementable natural gas output
DYMONDS Simulator

Scenario 1: + Wind generation [3,4]

- 20% / 50% penetration to the system
DYMONDS Simulator
Scenario 1: + Wind generation
DYMONDS Simulator

Scenario 2: + Price-responsive demand [3-5]

- Elastic demand that responds to time-varying prices
DYMONDS Simulator

Scenario 2: + Price-responsive demand
DYMONDS Simulator

- Interchange supply / demand mode by time-varying prices

Niklas Rotering
DYMONDS Simulator

DYMONDS Simulator

Scenario 4: + long-run decision making [4]

- Long-run planning of new generation capacity installation
  - Long-run marginal bids
  - For the next 10 years

Marija Prica
DYMONDS Simulator

Scenario 4: + long-run decision making

- Long-term load forecast
- Coal power plant
DYMONDS Simulator

Scenario 4: + long-run decision making

- Natural gas power plant
- Long-run bidding functions

![Graphs showing power dispatched over years for different scenarios]

- Long-run marginal supply function
- Long-run marginal utility function

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DYMONDS Simulator

Scenario 5: + PMU-Based Robust Control [7]

Automated Voltage Control (AVC) and Automated Flow Control (AFC)

- Design Best Locations of PMUs
- Design Feedback Control Gains
PMU-based Automatic Voltage and Flow Regulation

*System Demand Curve [8]*

Every 10 min Real Time Load of NYISO in Jan 23, 2010
PMU-based Automatic Voltage and Flow Regulation

- Robust AVC Illustration in NPCC System [7, 9]
- Limited System Observability
- Pilot Point: Bus 76663

Automatic Voltage Control for ONE Pilot Point Control Case

<table>
<thead>
<tr>
<th>No Control</th>
<th>One Pilot Point Control</th>
<th>5% Reliability Criteria</th>
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<tbody>
<tr>
<td>System Worst Voltage Deviation (p.u.)</td>
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0 0.05 0.1 0.15 0.2 0.25

Time (sec) 0 20 40 60 80 100
PMU-based Automatic Voltage and Flow Regulation

- Robust AVC Illustration in NPCC System
- Full System Observability

Automatic Voltage Control for Unlimited Information Control Case

- No Control
- Full Information Control
- 5% Reliability Criteria

System Worst Voltage Deviation (p.u.)

Time (sec)
PMU-based Automatic Voltage and Flow Regulation

- Robust AFC Illustration in NPCC System [7, 9]
- Limited System Observability
- Pilot Point: Bus 75403

Automatic Flow Control for ONE Pilot Point Control Case
PMU-based Automatic Voltage and Flow Regulation

- Robust AFC Illustration in NPCC System
- Full System Observability

Automatic Flow Control for Unlimited Information Control Case

No Control
Full Information Control
5% Reliability Criteria

System Worst Flow Deviation (p.u.)

Time (sec)
Concluding remarks

- **Current power systems simulator**
  - Centralized optimization
  - Information and decision-making concentrated on ISO

- **Future energy systems simulator (DYMONDS)**
  - Distributed optimization
    → **modularized** components and decision-makings
  - Appropriate **information exchange** between the components
  - Balance of the system by ISO
References


7. Zhijian Liu and Marija Ilić, Toward PMU-Based Robust Automatic Voltage Control (AVC) and Automatic Flow Control (AFC), 2010 IEEE PES General Meeting, July 2010, accepted in Feb 2010 and to be presented
