

Testing the reliability of FERC's Wholesale Power Market Platform: An Agent-Based Computational Economics Approach

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Outline of Talk

- What is Agent-Based Computational Economics (ACE)?
- ACE and Electricity Market Design
- An ACE Framework for Testing the Economic Reliability of FERC's Wholesale Power Market Platform

What is Agent-Based Computational Economics (ACE)?

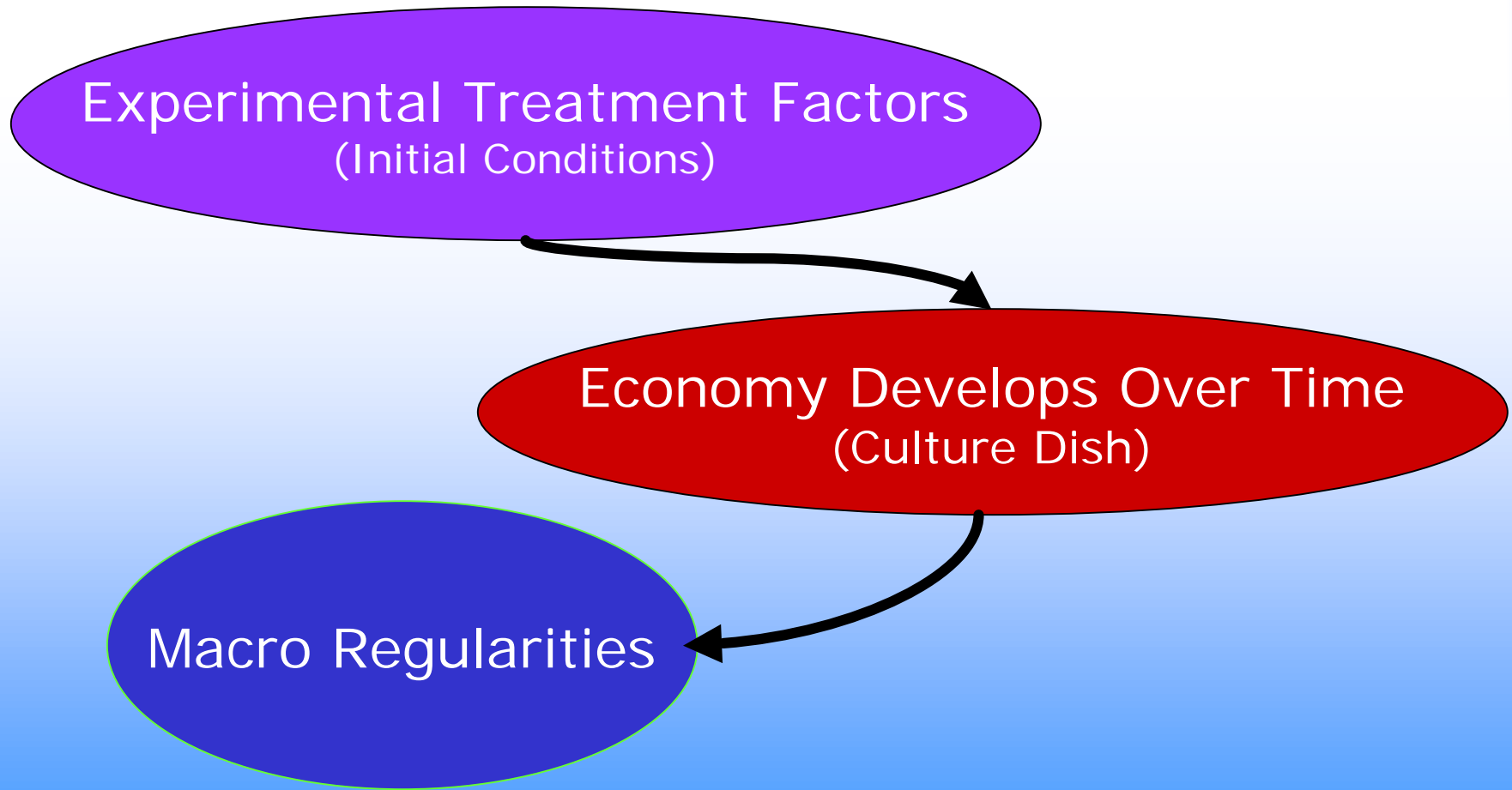
<http://www.econ.iastate.edu/tesfatsi/ace.htm>

- **Culture-dish approach** to the study of decentralized market processes
- **Computational study** of economies modelled as dynamic systems of autonomous interacting agents with learning capabilities

ACE Modelling: Culture Dish Analogy

- Modeller constructs a **virtual economic world** populated by various agent types (economic, social, biological, physical)
- Modeller sets **initial world conditions**
- The world then **develops over time** without further outside intervention
- World driven solely by **agent interactions**

ACE Modelling: Culture Dish Analogy



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ACE and Market Design

- Construct an **ACE world** capturing salient aspects of a proposed or actual market design.
- Introduce strategic profit-seeking traders with learning capabilities, and permit the ACE world to **develop over time** with no further intervention.
- **Key Issue:** Does the market design ensure **efficient, fair, and orderly market outcomes over time** despite repeated attempts by traders to game the design for their own personal advantage?

Key Issues for the Design of Wholesale Power Markets

- **Short-Run:** Efficient reliable production of electricity from **existing** generation capacity
- **Short-Run:** Efficient reliable transmission of electricity to **existing** load
- **Longer-Run:** Efficient planning and investment for **new** generation and **new** transmission capacity

Wholesale Power Market Platform -- WPMP (FERC, White Paper, April 2003)

WPMP Basic Objectives

- Customer-based competitive wholesale power markets providing reliable service;
- Fair and open access to the transmission grid at reasonable prices;
- Good price signals to encourage appropriate investment in new generation and new transmission;
- Market power oversight and mitigation.

WPMP Key Features

- Independently operated transmission grid (Independent System Operator ISO, or RTO);
- Day-ahead electricity market (financial contracts);
- Real-time electricity market to supplement longer-term contracts (multi-settlement process);
- Ancillary services (e.g., reserves adequacy,...);
- Congestion management, preferably through Locational Marginal Pricing (LMP) and Financial Transmission Rights (FTRs);
- ISO/RTO market power monitoring/mitigation.

FERC's Basic WPMP Proposal Adopted?

- **Mid-Atlantic (PJM)** implements similar plan (1998)
- **New York (NYISO)** implements similar plan (1999)
- **New England (ISO-NE)** implements similar plan (2003)
- **California (CAISO)** files to adopt similar plan (2003)
- **Midwest (MISO)** **files to adopt** similar plan (7/2003), **withdraws** filing (10/2003), then **refiles** (3/2004)
- **Opposition** from states in Northwest and Southeast

Why Resistance to FERC's WPMP?

- **Midwest (MISO)** files/withdraws/refiles
Key cited problem:
Lack of sufficient reliability testing
- **Opposition** from Northwest and Southeast
Key cited problems:
Lack of sufficient reliability testing;
Questions about suitability given special local conditions (hydroelectric power, TVA...).

Economic Electricity Research (www.econ.iastate.edu/tesfatsi/epres.htm)

- ***Analytical/Empirical:***

- Berkeley (Borenstein, Bushnell, Oren,...); Cambridge (Green, Newbery,...); DOE (POEM/MAPS model,...); EPRI (Chao, Peck,...); Harvard (Hogan,...); MIT (Joskow,...); U of Oslo (Halseth, von der Fehr,...); Stanford (Wilson, Wolak,...); many others ...

- ***Human-Subject Experiments:***

- Cornell (Mount,...); George Mason U (Rassenti, Smith, Wilson,...); others ...

- ***Dynamic Simulation:***

- EPRI/DOD (CIN/SI,...); Sandia (Baker, other USEGM researchers,...); Simon Fraser Univ. (Jaccard, Nyboer, Rivers,...); many others...

- ***Agent-Based Electricity Research***
(www.econ.iastate.edu/tesfatsi/aelect.htm)

- Argonne National Lab (Boyd, Cirillo, Conzelmann, Koritarov, Macal, North, Thimmapuram, Veselka,...)
- Carnegie Mellon University (Hines, Illic, Talukdar,...)
- CSIRO-Australia (Batten,...)
- Helsinki University (Hamalainen,...)
- Iowa State University (Koesrindartoto, Sheble, Tesfatsion,...)
- London Business School (Bunn,...)
- Los Alamos National Lab (Barrett, Marathe,...)
- Pacific Northwest National Lab (Fathelrahman, Roop,...)
- Sandia National Lab (NISAC/N-ABLE group,...)

DOE's Quantitative Assessment of WPMP (DOE/S-0138, 4/03)

- **GE's Multi-Area Production Simulation (MAPS) Model:** Transmission issues on a short-run regional basis
- **DOE's Policy Office Electricity Modeling System (POEMS) Model:** Mid-term and longer-run projections of usage of generation infrastructure

Key Aspects of DOE's Quantitative Assessment

- **Comparison of Non-WPMP case** (projected continuation of existing conditions) **to WPMP case** (seamless U.S. implementation assumed)
- **Many cautions about model limitations** (e.g., equilibrium assumed, no strategic bidding, demand held constant across tested cases...)
- **Estimated average long-run net consumer cost savings** (2016-2020) = \$225Million/Year (regional variability)

Potential Contributions of Agent-Based Approach for Studying FERC's WPMP

- Generators, load-serving entities, ISO,... can be modeled as **strategically interacting agents**.
- **Agent learning** can be calibrated to data.
- Agents can alter their **behaviors/interaction networks** over time in response to events.
- Relatively easy to include **actual structural features** and **actual market design protocols**.
(models should be simple but not too simple!)

Our ACE Wholesale Power Market Model

- Based on **Standard Market Design (SMD)** implemented by New England (ISO-NE) on March 1, 2003
- **SMD meets basic WPMP structural requirements:**
 - Independent System Operator (ISO)
 - Day-ahead and real-time electricity markets
 - Congestion managed via LMP
 - Financial Transmission Rights
 - Planned reserve and capacity markets as well as enhanced demand response

Our ACE Wholesale Power Market Model

➤ Traders

- Sellers and Buyers
- Follow market rules
- Learning abilities

➤ ISO roles

- Reliability assessment
- Security-constrained dispatch
- Settlement procedures
- Market power oversight

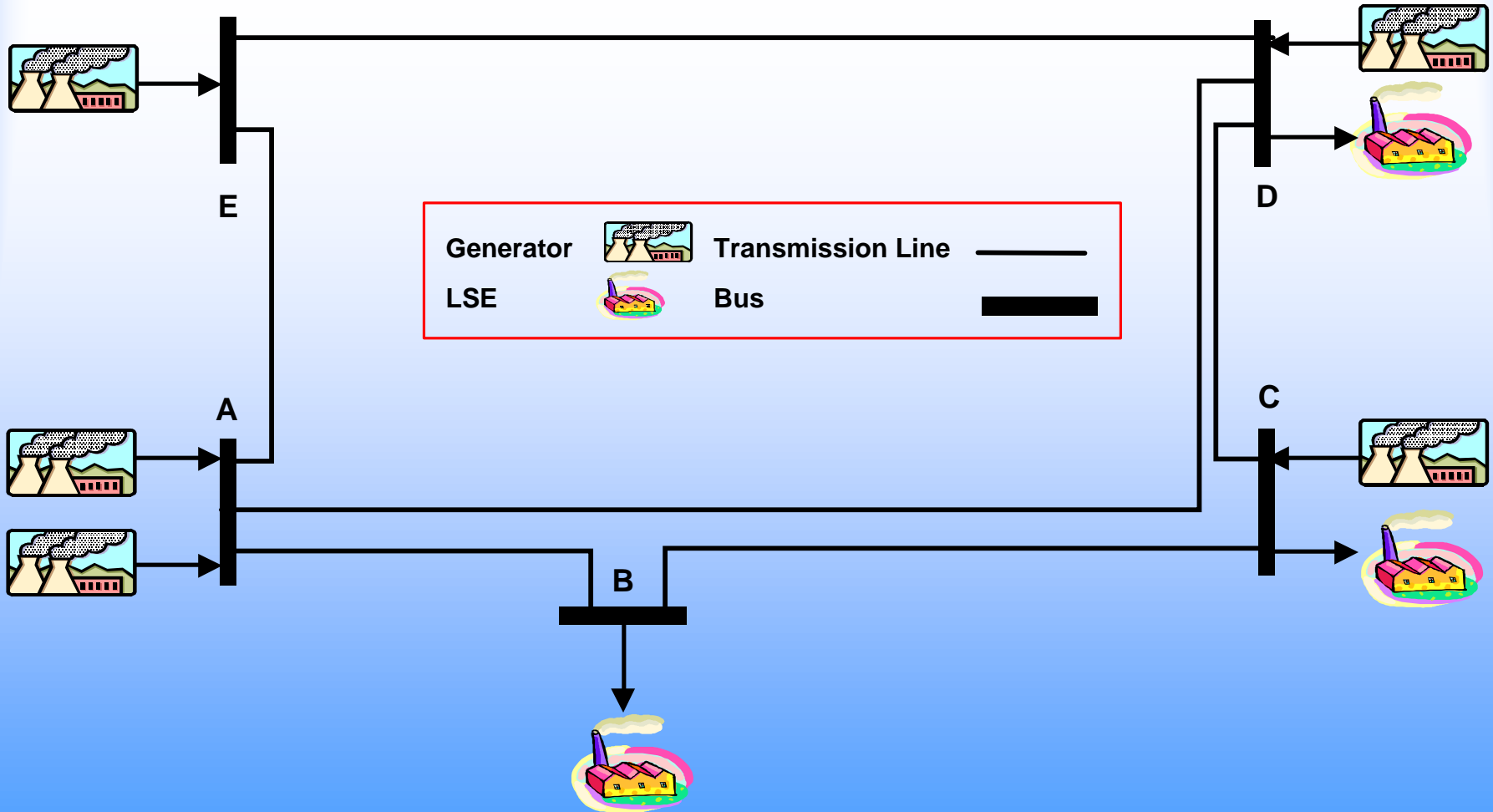
➤ Multi-settlement process

- Day-ahead electricity market
- Real-time electricity market
- Supply re-offer period

➤ AC transmission grid

- Congestion managed via LMP
- 5-bus demo model (scalable to a more complex grid)

5-Bus Transmission Grid (Demo Model)



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LSEBot: A Virtual Buyer

Public Access:

// **Internalized Market Protocols**

Protocols for communication with ISO

Protocols governing submission of demand bids

Protocols for ISO market power oversight and mitigation

Private Access Only:

// **My behavioral methods**

My method for calculating my expected profits

My method for calculating my actual profit outcomes

My demand bid updating method (my learning mode)

// **My attributes (data)**

My downstream demand, bus location, current wealth...

Data recorded about external world (dispatch schedule...)

Addresses for ISO, other traders (permits communication)

GenBot: A Virtual Seller

Public Access:

// **Internalized Market Protocols**

Protocols for communication with ISO

Protocols governing submission of supply offers

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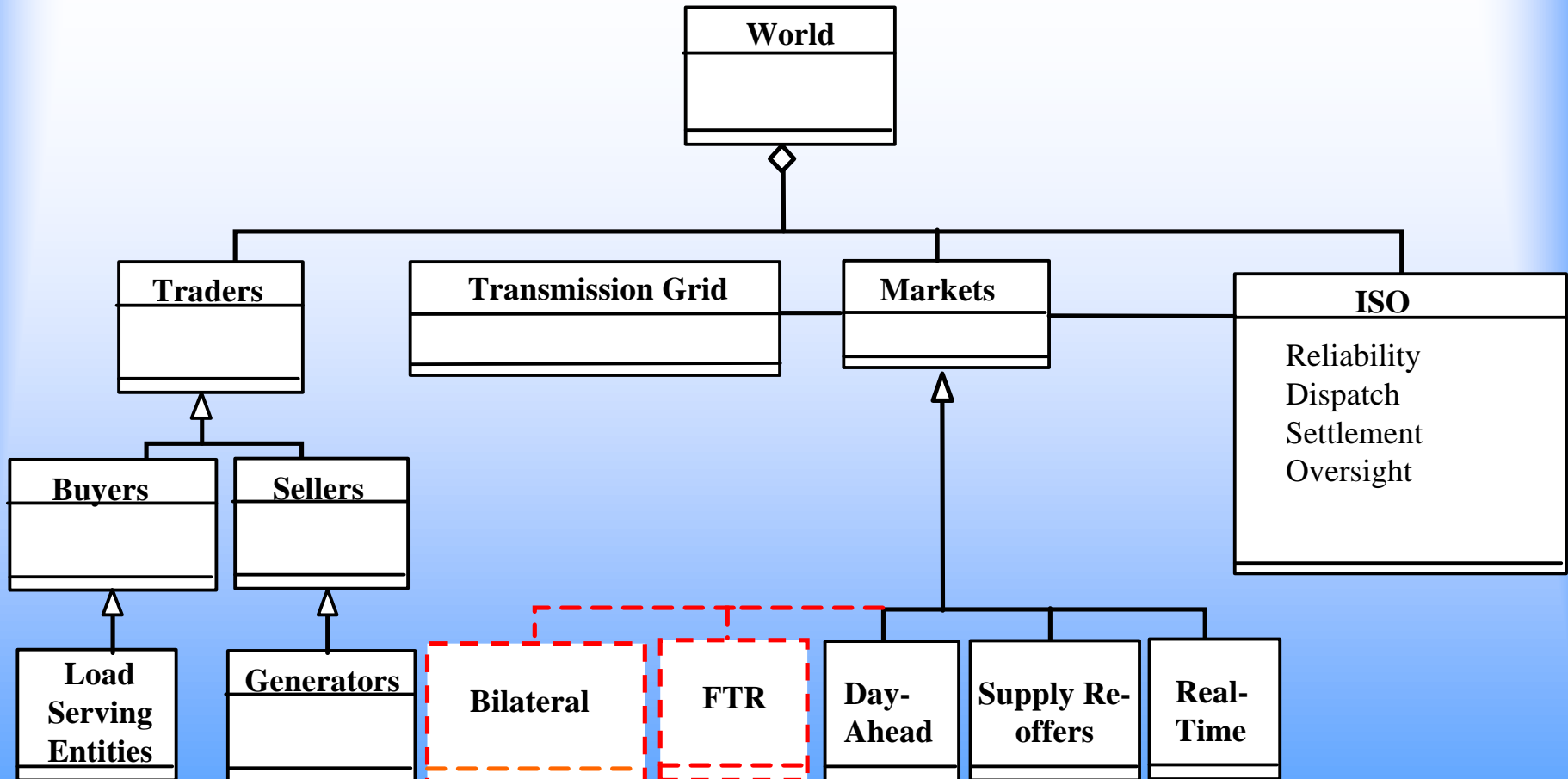
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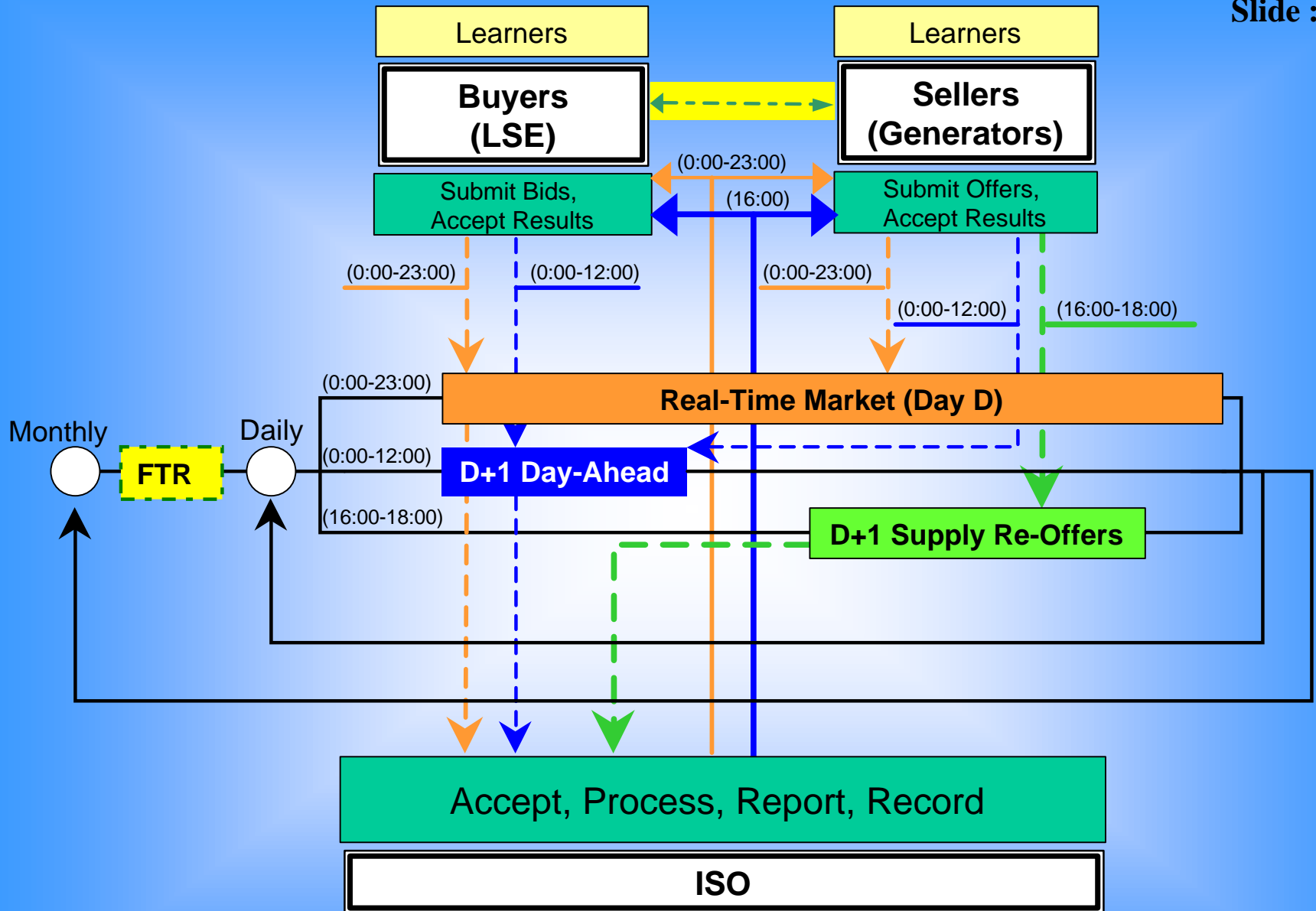
My capacity, bus location, cost fct., current wealth...

Data recorded about external world (dispatch schedule...)

Addresses for ISO, other traders (permits communication)

ACE WPM Model: Class Hierarchy





**Testing the reliability of FERC's Wholesale Power Market Platform:
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Measures of Market Performance (Economic Reliability)

- **Market Efficiency:** the ratio of *actual* profits to *maximum possible* profits for buyers and sellers
- **Market Power:** the ability to *profitably* alter prices away from competitive levels

Market Performance: Key Considerations

- **Learning Effects:** "Sellers intend to make as much money as possible and will use all available strategies to achieve this goal."
(Frank Wolak, Senate Hearing, 5/15/03)
- **Role of Demand Responsiveness:** "The symmetrical nature of the *double* auction (electricity market)...appears to prevent either buyers or sellers from successfully learning to gain market power advantages through strategic pricing."
(Nicolaisen, Petrov, Tesfatsion, *IEEE-TEC*, 2001)

Market Performance: Key Considerations ...

- **Importance of FTR Design for Long Run Management of Congestion:**

“We can make all the reliability standards in the world (but they won’t do much good) if we don’t have people willing to invest in transmission and other technologies.”

(Pat Wood III, FERC Chair, Senate Hearing, 9/10/03)

Experimental Design: Treatment Factor Ranges

- **DC Approximation for LMP** → **AC Approximation for LMP**
(Typical practice/lit. assumption) (Closer to physical situation)
- **Cournot supply behaviour** → **General strategic supply beh.**
(Typical literature assumption) (Actual ISO-NE situation)
- **Passive inelastic demand** → **Strategic LSE demand bids**
(Typical literature assumption) (Actual ISO-NE situation)
- **No transmission rights** → **Financial Transmission Rights**
(Typical literature assumption) (Actual ISO-NE situation)

Project Objectives: Summary

- FERC's Wholesale Power Market Platform (WPMP) is a **complex market design**
 - a wholesale power market with day-ahead, real-time, and ancillary markets operating over an AC transmission grid.
- An **agent-based computational laboratory** is being developed for the WPMP
 - will permit the systematic experimental exploration of WPMP design features (as implemented in ISO-NE)
- Project focus on **dynamic economic reliability**
 - the ability of the WPMP market design to ensure efficient, fair, and orderly market outcomes over time when market participants have realistic strategic capabilities.

ACE Electricity Research: On-Line Resources

- **Introduction to ACE**

ACE Website:

<http://www.econ.iastate.edu/tesfatsi/ace.htm>

ACE Self-Study eBook:

<http://www.econ.iastate.edu/tesfatsi/syl308.htm>

- **ACE Electricity Research**

<http://www.econ.iastate.edu/tesfatsi/aelect.htm>

- **Other Related ACE Research Areas**

<http://www.econ.iastate.edu/tesfatsi/aapplic.htm>

- **General Electricity Restructuring Resources**

<http://www.econ.iastate.edu/tesfatsi/epres.htm>

- **Contact Information**

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