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

Leigh Tesfatsion

Professor of Economics and Mathematics, ISU

and

Deddy Koesrindartoto

Ph.D. Economics Candidate, ISU

funded in part by the

Los Alamos National Laboratory

(Work in Progress)

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 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?

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

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.

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

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

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…

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

- ## *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,…)

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

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
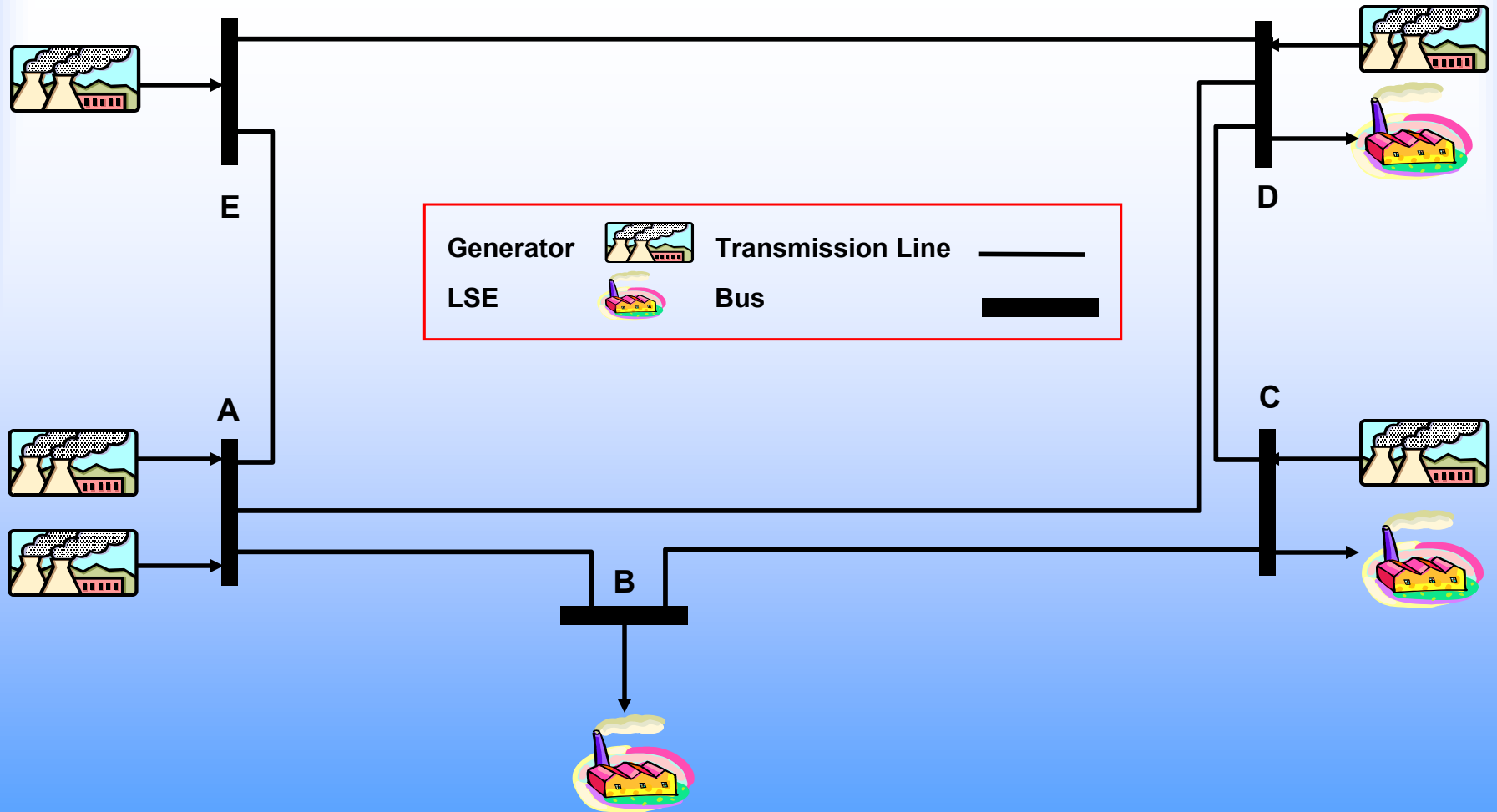 - Follow market rules
  - Learning abilities

➢ **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)

➢ **ISO roles**
  - Reliability assessment
  - Security-constrained dispatch
  - Settlement procedures
  - Market power oversight

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

5-Bus Transmission Grid (Demo Model)

Generator   **Transmission Line** _____

LSE   **Bus** ▬▬

E

A

B

C

D

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

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)

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

GenBot: A Virtual Seller

Public Access:

// **Internalized Market Protocols**
Protocols for communication with ISO
Protocols governing submission of supply offers
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
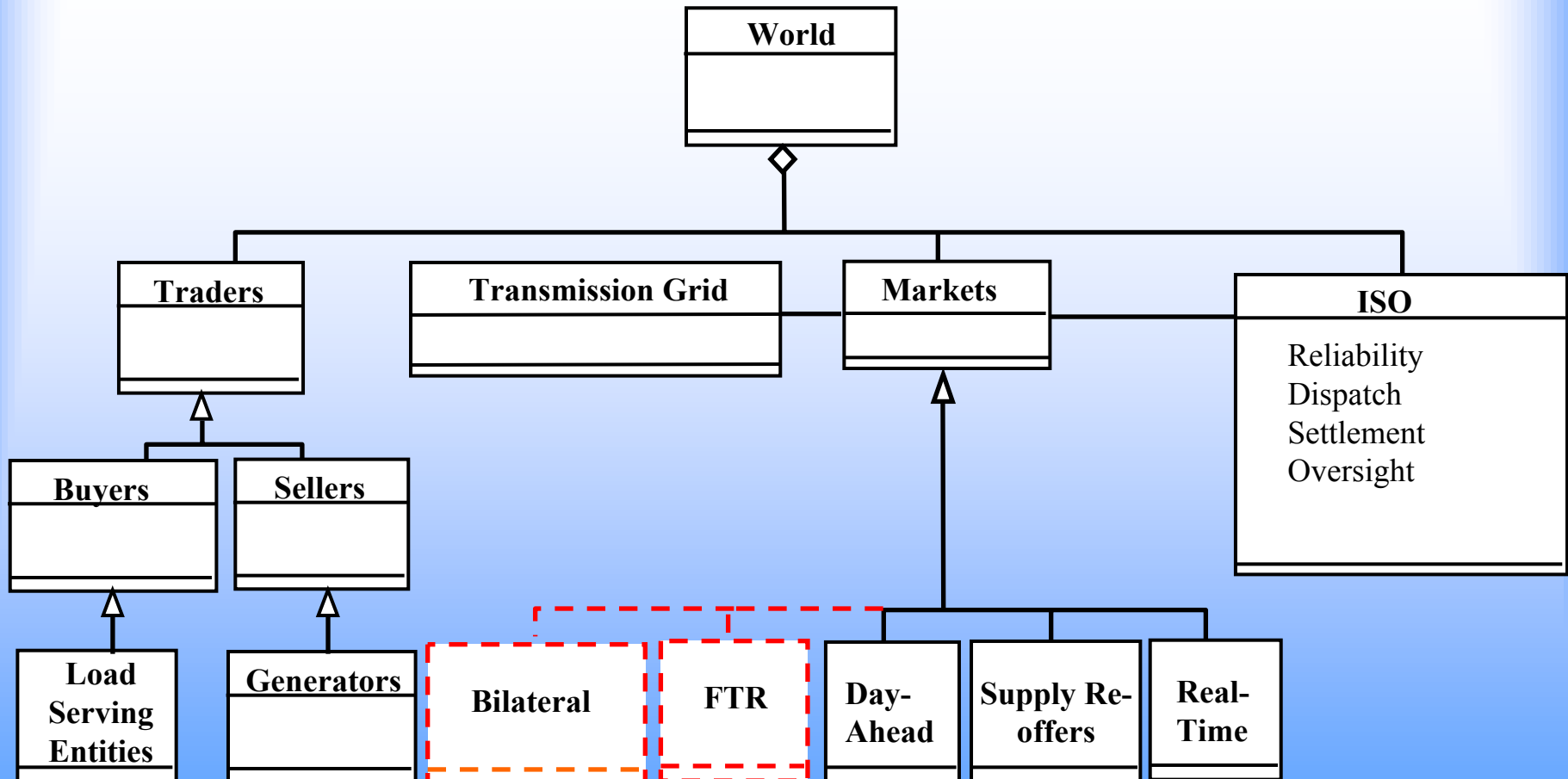My supply offer updating method (my learning mode)

// **My attributes (data)**
My capacity, bus location, cost fct., current wealth…
Data recorded about external world (dispatch schedule…)
Addresses for ISO, other traders (permits communication)

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

ACE WPM Model: Class Hierarchy

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

Testing the reliability of FERC's Wholesale Power Market Platform:
An Agent-Based Computational Economics Approach
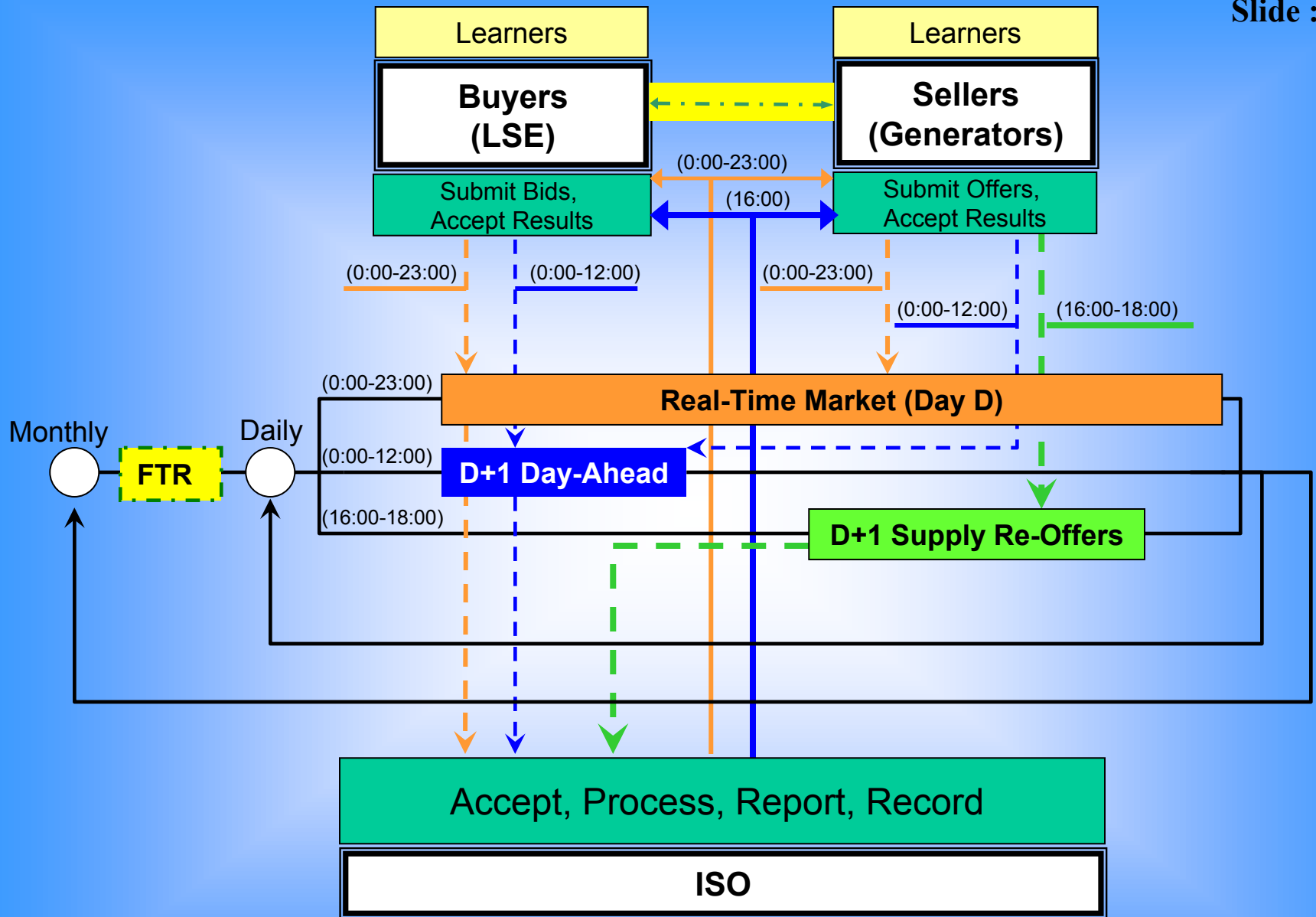
Experimental Design: Treatment Factor Ranges

- **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.