Multi-Agent Systems and Electricity Markets: State-of-the-Art and the Future

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***Abstract* — This is a summary of the presentation in the panel session, "Agent-Based Test Beds for Restructured Electricity Markets" for the 2008 IEEE PES General Meeting. The multi-agent system concepts have been applied to power engineering in the areas of protection, defense system, diagnosis, control, distribution, etc. For electricity markets, multi-agent models have been used for analysis of gaming, learning, and decision support. In this presentation, the panelist will provide a review of the state of the art. For the future, it is believed that a platform for the evaluation of multi-agent systems is critically needed in order to gain further insights into the performance of suppliers, load serving entities, market operators and market rules. Simulation examples of the agent learning behavior using the Java Agent DEvelopment Framework (JADE) platform will be provided.**

***Index Terms* — Multi-agent systems, electricity market, java agent development framework.**

I. Introduction

Countries around the world continue to restructure their electricity markets in different ways. The wholesale level has experienced dramatic changes, whereas the retail level restructuring is moving slowly. Costly and valuable lessons have been learned from the California energy crisis in summer 2000 and from the problems identified in the England and Wales wholesale electricity market in the 90s. Although our experience is growing, there is very little knowledge of how to properly design a retail electricity market, how to effectively incorporate ancillary services, etc. To address these issues, a flexible simulation platform is critically needed to investigate the interaction among structural conditions, market designs, and adaptive behaviors of market participants and their impact on short-term and long-term market performance. This simulation platform will not only help us evaluate existing market rules, but also explore and test new market designs before their implementation.

This research is sponsored by the Power Systems Engineering Research Center (PSERC) through a collaborative project involving Iowa State University, Washington State University and Smith College/Cornell University. The authors would like to thank Professor Gerald Sheblé, Anjan Bose and Judith Cardell and Mr. Jim Price, California ISO, for their contributions.

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II. Multi-agent systems in electrcity markets

The agent-based computational method is well suited for the study of the behaviors of an electricity market, which is modeled as a complex adaptive system. With embedded learning capabilities, agents that are autonomous, proactive, and reactive can properly emulate various behaviors of heterogeneous market participants.

A wide variety of software toolkits and services have been used to develop different kinds of test beds for electricity markets. RepastJ, a Java toolkit designed specifically for agent-based modeling in social sciences, was used to develop the wholesale electricity market framework in [1] – referred to as AMES (Agent-based Modeling of Electricity Systems). Open Agent Architecture (OAA), a framework for integrating heterogeneous software agents in a distributed environment was used in [2] to develop MASCEM: a multiagent system that simulates competitive electricity markets. JADE, the most commonly-adopted agent-oriented middleware that conforms with Foundation for Intelligent Physical Agents (FIPA) was adopted in [3] to develop the wholesale electricity market that is modeled as a multi-agent system. Argonne National Laboratory has developed the Electricity Market Complex Adaptive System (EMCAS) model to test regulatory structures of electricity market before they are applied to real systems [4]. This modeling framework considers a wide range of agents, interaction layers and planning periods.

Some useful simulation results from different agent-based platforms have proven that the multi-agent system approach to modeling and simulation of the electricity market is effective. For example Generation Company (GenCo) agents using Q-Learning [5], stochastic reinforcement learning [6], and even simple fixed-increment price probing strategy [7] all learned to bid in a non-competitive manner to keep the price significantly higher than the competitive level. As shown in Fig. 1, the GenCo agents with Q-learning capabilities easily find their way to manipulate the market under the condition of a simple demand-side response model. The simulation successfully detected the lack of demand elasticity in the market.

III. Multi-agent systems standard and platform

FIPA, a formal IEEE standard for industrial and

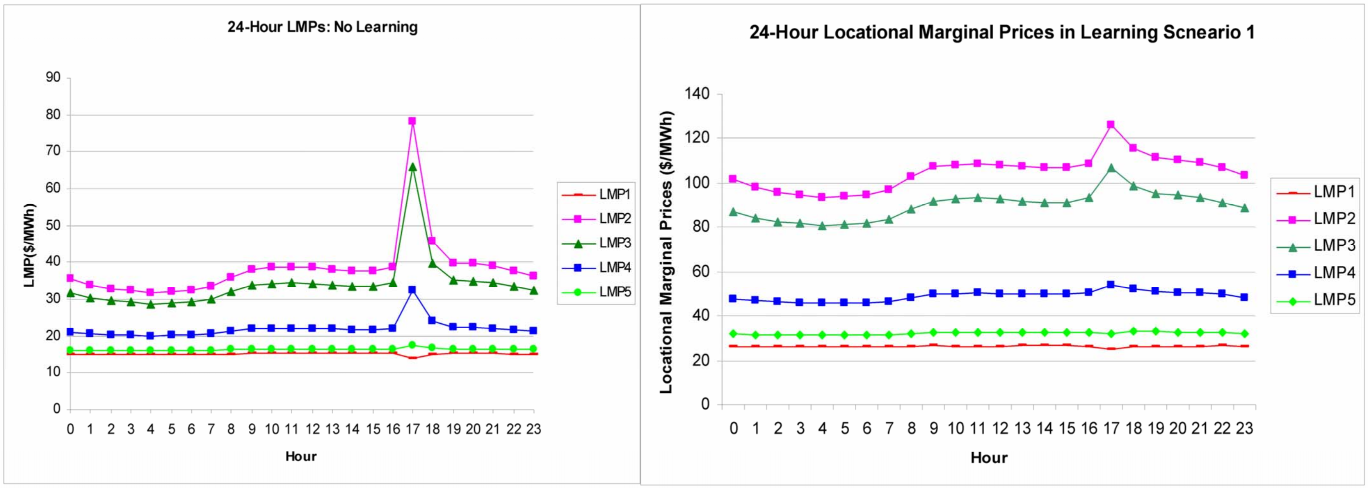

Fig. 1: 5-bus Transmission Grid Simulation Results for 24-Hour LMPs (No-Learning Compared with Learning Scenarios 1)

commercial multi-agent system applications focus on facilitating the interoperability of agents and multi-agent systems across different software platforms. Multi-agent platforms and programming languages are enabling the development of multi-agent systems in actual operations. Today, several agent-oriented languages are available to facilitate the implementation of multiagent system [8] such as FULX, JACK Agent Language, 3APL, Jason etc. Several agent platforms such as DESIRE, Jadex, TuCSoN and JADE are constructed to simplify the development of multi-agent systems. Currently, the most popular solution is to use JADE as underlying agent infrastructure combined with some other (higher-level) approach to program the agents' behavior [9].

IV. Future Applications

Multi-agent systems have a wide range of potential applications in electricity markets. The learning algorithm and tools developed in the multi-agent platform for GenCos can support critical decision-making such as capacity expansion, maintenance scheduling, electricity price forecasting, bilateral contracts negotiation, and designing bidding strategies. Software tools tested to be useful in detecting market power exercise in electricity market simulations might be used for monitoring by the Market Operator. Designs of a price-responsive retail electricity market, ancillary service market and transmission expansion planning protocol that are shown to be effective in simulation may be considered for implementation in actual markets. In simulations, potential retail market contracts that offer proper incentives to customers might be adopted as an alternative contract that might help LSE to reduce the risk of volatility in electricity prices. Automated agents that reside in price-responsive controllers might help customers decide which type of retail contracts to establish and even act on behalf of customers to adjust energy consumption according to pre-specified preferences.

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Biographies

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