Argonne NATIONAL LABORATORY

Energy, Environmental, and Economic Systems Analysis

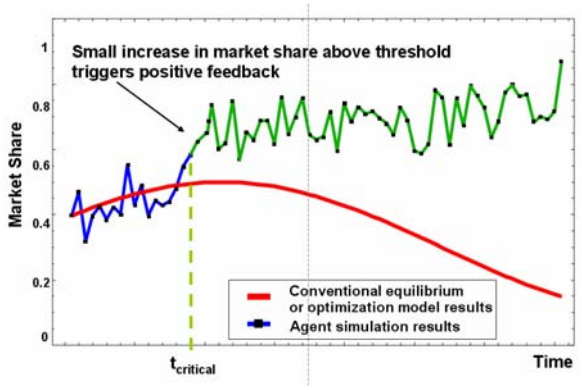
Electricity Market Complex Adaptive System (EMCAS): A New Long-term Power Market Simulation Tool

Opportunity

Energy systems are being privatized and deregulated, shifting control from a single decision maker (i.e., a single, government-owned electric utility) to an open market with many participants. In this new configuration, many decision makers, each with a different set of objectives, are basing their decisions on a number of methods.

Conventional optimization techniques used for energy systems analysis are based on a single decision maker who wants to maximize (or minimize) a particular objective. Conventional equilibrium simulation techniques assume that systems gravitate to an equilibrium point where all participants reach a common ground.

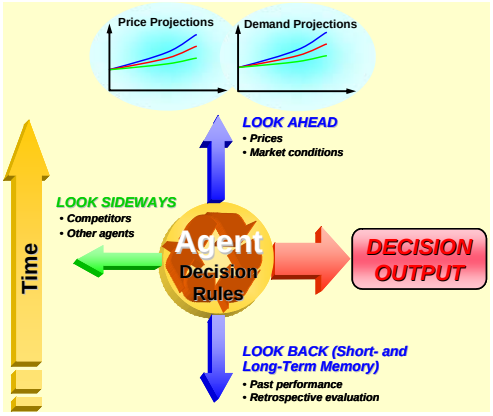
Neither of these techniques, however, can capture transitory fluctuations driven by system evolution nor identify inflection points, phase transitions, or critical conditions under which systems diverge from the past in totally new and unanticipated ways. California's recent struggle with electricity deregulation is a practical example of the kind of shocking instability that cannot be adequately simulated by using current analysis techniques.



Approach

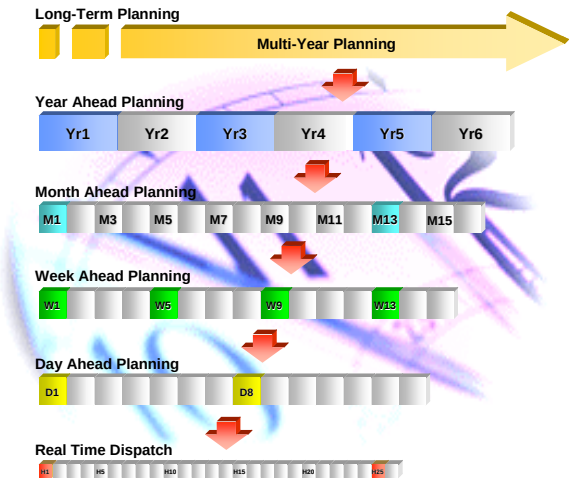
Argonne's Center for Energy, Environmental, & Economic Systems Analysis (CEEESA) has been developing EMCAS, the Electricity Market Complex Adaptive System model, in which the diverse participants in the electricity market are represented as "agents." All agents can have their own set of objectives, decision-making rules, and behavioral patterns. Further, agents can draw on an array of historical information (e.g., past power prices) and projected data to support their unique decision process.

Unlike conventional electric system models, the EMCAS agent-based modeling (ABM) techniques do not postulate a single decision maker with a single objective for the entire system. Rather, agents follow their own objectives and apply their own decision rules. The complex adaptive systems (CAS) approach empowers many agents to learn from their previous experiences and change their behavior when future opportunities arise. That is, as the simulation progresses, agents can adapt their strategies, based on the success or failure of previous efforts.

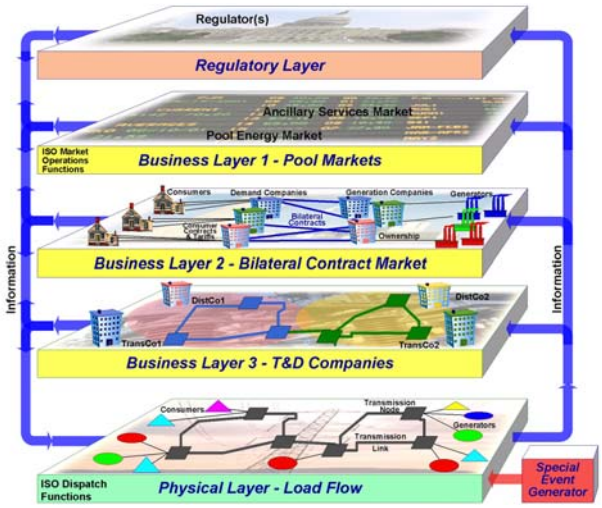


EMCAS Design

An EMCAS simulation runs over six decision levels, ranging from hourly dispatching to long-term planning (see figure below). At each decision level, agents must make a set of decisions, including determining electricity consumption (customer agents), unit commitment (generation companies), bilateral contracting (generation and demand companies), and unit dispatch (ISO/RTO agent). Agents then apply their own decision rules and evaluate how well these rules meet their objectives. Agents learn from past efforts and try to improve their respective positions. This approach allows for exploration of a wide range of behaviors that cannot be captured by conventional optimization or equilibrium methodologies.



EMCAS has several interaction layers that provide the environment for the agents to operate in. This environment is typically multi-dimensional, that is, agents operate within a number of interconnected layers, including a physical layer, several business layers, and a regulatory layer. EMCAS can simulate various market operating rules established by a regulator agent. The rules can range from a conventional vertically integrated utility operating under rules established by a local public utility commission to a fully deregulated market operating under forward bidding procedures, such as some that are already in place. A market information system provides data used by all participants. A random event generator allows for simulation of unexpected incidents, such as generator or transmission line outages.



EMCAS Applications

EMCAS is increasingly used to study restructuring issues in the United States, Europe, and Asia. Clients include regulatory institutions interested in market design and consumer impact issues, transmission companies and market operators studying system and market performance, and generation companies analyzing strategic company issues. In its first application, CEEESA staff members used the software to simulate the Illinois and Midwest power markets. This work was performed for the Illinois Commerce Commission, which needed advice on whether the existing transmission system could support a competitive market. Other model implementations are being conducted for clients in Europe and Asia.

Learn more about the Center for Energy, Environmental & Economic Systems Analysis at:
http://www.dis.anl.gov/ceeesa

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