

## Electricity Market Complex Adaptive System (EMCAS) Software

### INTRODUCTION

Argonne National Laboratory developed the Electricity Market Complex Adaptive System (EMCAS) software to meet the growing need for advanced modeling approaches that simulate how electricity markets may evolve over time and how participants in these markets may react to the changing physical, economic, financial, and regulatory environments in which they operate.

### DISTINGUISHING FEATURES

EMCAS is a revolutionary technology for electricity market analysis with the following distinguishing features:

- Agent-based modeling approach represents power markets with multiple and diverse participants (Figure 1), each with its own unique set of business and bidding strategies, risk preferences, objectives, and decision processes;
- Capability to simulate markets using either a uniform or discriminatory auction format, including a simplified representation of ancillary services markets;
- Detailed representation of the transmission system, using a Direct Current Optimal Power Flow (DC OPF) algorithm to compute locational marginal prices (LMP) and identify transmission congestion and price impacts of congestion;
- Chronological simulation of hourly market prices over short or long time periods;
- Hourly bid-based market clearing, scheduling and dispatch in day-ahead and real-time markets;
- Representation of different bidding strategies, from production cost bidding to various forms of price probing strategies (i.e., company bids are a result of EMCAS, rather than an exogenous input);

- Complex adaptive systems approach empowers market agents to learn from past experience and adapt their behavior when future opportunities arise;
- Simulation of decentralized and market-based generation capacity expansion for investment planning;
- Ability to change prevailing market rules provides the opportunity to test the robustness and vulnerability to gaming of different market designs; and
- Calculation of cost, revenues, and profits for all relevant agents in the system.

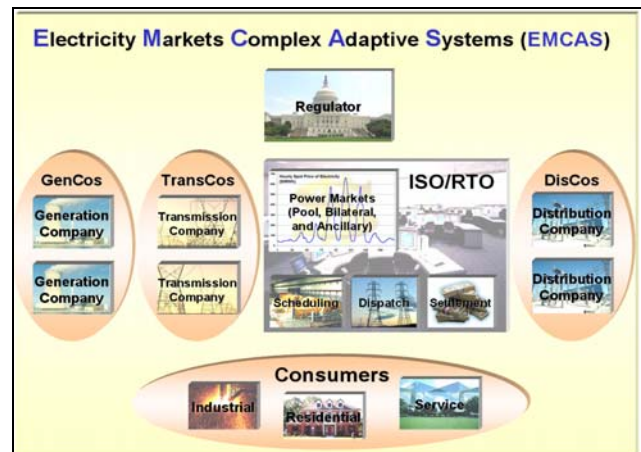


Figure 1: Market Participants modeled in EMCAS

### STRATEGIC ANALYSIS CAPABILITIES

With EMCAS being grounded in both established *engineering modeling* techniques and advanced quantitative *economic market principles*, the software redefines what is best-of-class technology for analyzing electricity market issues, such as:

## 1. MARKET DESIGN AND DEVELOPMENT

EMCAS provides unique and valuable insights for the development of effective electricity markets. Regulatory agencies and system operators can utilize EMCAS to test the impact that different regulatory structures and market rules (e.g., price setting mechanisms, tariff rules, settlement options) would have on the various market participants and the market as a whole.

Market rules can be tested for vulnerabilities to system shocks and price spikes caused by systemic problems (lack of capacity or inadequate transmission grid), random events (low hydrology, component outages, load variations), or market gaming by participants who are in a position to exploit a set of market rules to their advantage. This type of analysis is particularly useful in the early stages of developing a new market design or when there is a need to explore alternative structures for an already existing market.

## 2. MARKET MONITORING AND MARKET POWER

As today's power markets tend to be highly dynamic with rapid and far-reaching changes such as transfers of ownership of existing generating assets and new market entrants quickly altering the playing field, regulators and system operators need to be in a position to monitor these ongoing changes and understand the near- and long-term implications for market performance and system reliability. Part of this oversight is an ongoing assessment of the potential for market power exercised by the different generation owners. EMCAS is specifically designed to assist in these market monitoring functions.

Generation companies can grow quickly in their market dominance and use their position to exert price pressure and improve their financial performance. However, market power may arise in less obvious but equally consequential situations where smaller, less-dominant, generation owners happen to have a locational advantage and are able to exploit the unique characteristics and physical limitations of the transmission grid (load pocket) or weaknesses in market rules by developing bidding strategies that successfully drive up prices beyond competitive levels in that particular part of the grid. In this case, both the intensity and the frequency of the location-specific load pocket or transmission bottleneck are crucial. A large price spike may be of less concern if it occurs only during a few hours per year, whereas a moderate price spike may have much larger impacts if it can be

sustained for a sizeable number of hours per year. This type of situation can only be captured in a model such as EMCAS that reflects the transmission grid in detail, simulates the market operation chronologically on an hourly basis, and allows agents to learn from previous experiences and adapt their behavior and bidding to new situations.

## 3. TRANSMISSION CONGESTION

One key characteristic of power markets creating uncertainty and risk exposure is the possibility for transmission congestion across the grid, resulting in stranded generation assets, load pockets with the potential for market power and the ability to exert price pressure, and unserved energy. The EMCAS optimal power flow (OPF) algorithm tracks line loading and available transmission capabilities for all lines in the system and identifies transmission bottlenecks and computes ensuing congestion charges. The congestion impacts of adding new transmission lines or taking existing lines out of service can be analyzed by running various EMCAS scenarios.

## 4. PRICE VOLATILITY ANALYSIS

Given the unique characteristic of electricity, power markets are subject to levels of price volatility not typically seen in other commodity markets. EMCAS enables regulators to identify and understand the fundamental drivers of this volatility and quantify the extent of volatility in order to limit or eliminate the exposure of consumers to potentially substantial price spikes.

## 5. SHORT AND MID-TERM PRICE FORECASTING

With the increasingly uncertain business environment in deregulated electricity markets, reliable price forecasts are critical to managing market exposure and financial risks. EMCAS accounts for primary market fundamentals driving clearing prices of competitive power markets, such as load variations, available generating capacity and implied reserve margins (including planned and unplanned outages), transmission congestion, the generation cost structure, and the bidding strategies adopted by individual market players.

With its powerful analytics, EMCAS allows market participants to more accurately model today's complex electricity markets and generate forecasts of hourly

chronological electricity prices for multiple commodities (energy, capacity, and ancillary services) in a given electricity market over one or many years. Prices are computed by bus and reported to user-specification (by bus, by zone, by market hub, hourly, peak/off-peak, average daily, monthly, etc.). Forecasts can be produced for a variety of market rules, that is, bid-based, production-cost based, pay-as-bid based, price caps, etc. EMCAS users can use the forecasts to examine price volatility, analyze short and mid-term market positions, manage and hedge their risks, and take advantage of market opportunities.

## 6. RESOURCE FORECASTING AND ASSET/PORTFOLIO VALUATION

Using results from the hourly economic dispatch routine, EMCAS users can evaluate unit operations for each generator in the system, including revenues, net income, and profit over a specified period of time. In evaluating individual units, EMCAS takes into account transmission constraints to assess congestion-related risk exposure of individual generating assets (stranded assets) and to estimate impacts of locational price spikes on the profitability and economic viability of existing and proposed projects. EMCAS results can be used to calculate financial performance parameters, such as value at risk (VAR) and cash flow at risk (CFaR), and to determine spark spreads and the option values of individual assets. The model can also be used to explore various bidding strategies for a mix of units/assets and contracts and determine the strategy/strategies that best capitalize on the predicted price signals. When positioning a portfolio of assets for a company, EMCAS strives to maximize company profitability while considering a number of strategic issues, including what market(s) to bid the units or unit blocks into, and at what price to offer the blocks. Model developers at Argonne are currently implementing capabilities for long-term (multi-year) analyses in EMCAS to enable the software to be used for analyzing investment decisions.

## REAL-WORLD APPLICATIONS

With its unique combination of innovative modeling approaches, EMCAS is used to better understand and more accurately model the complex interactions between physical infrastructures (generation, transmission, and distribution) and economic behavior of market participants.

Since the initial product launch in August 2005, the EMCAS software has been licensed for use by a wide

spectrum of clients (e.g., electric utility, transmission company, regulatory agency, research center and university) in Asia, Europe and North America.

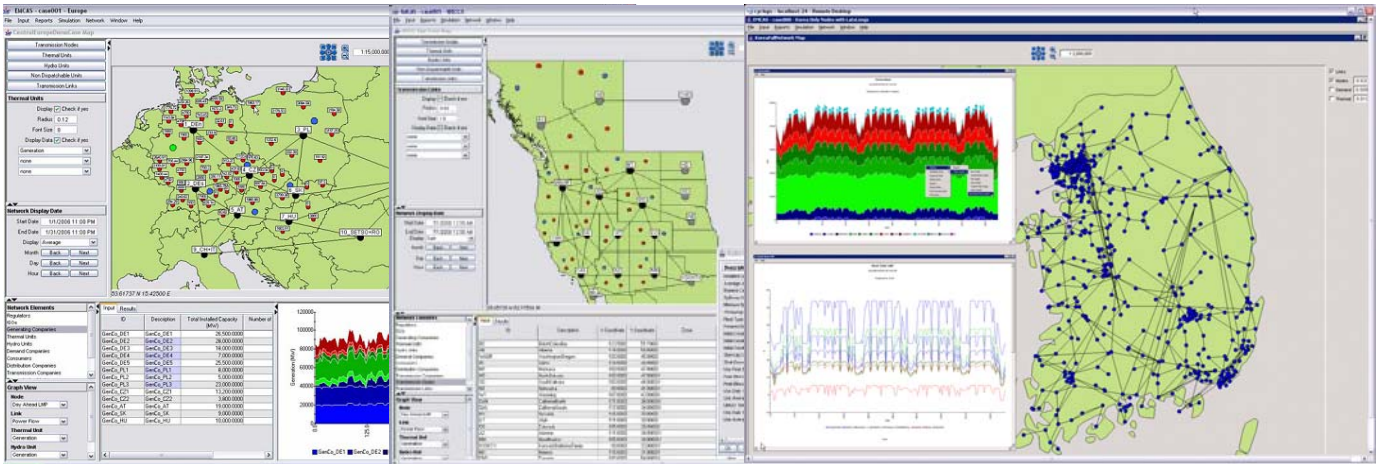
For example, with a view toward transition to a competitive electricity market, the Illinois Commerce Commission (ICC) funded a study using EMCAS to examine whether the transmission system in Illinois and the surrounding region could accommodate competition by allowing the cheapest power to be brought to where it was needed to meet loads or whether, conversely, generators would be able to exercise market power. The EMCAS study for Illinois considered a system with 32 zones, 2000 buses, and 200 units.

Key outputs produced by EMCAS are summarized in the following table:

	Detailed Output Information	Aggregated Output Information
<b>Load</b>	Hourly load at individual busses in the transmission system	Load summed by: <ul style="list-style-type: none"> <li>• Zone</li> <li>• DemCo</li> <li>• DisCo</li> <li>• Consumer type</li> </ul>
<b>Generation</b>	Hourly generation by individual units	Generation by: <ul style="list-style-type: none"> <li>• Zone</li> <li>• GenCo</li> <li>• Type of generator</li> </ul>
<b>Transmission</b>	Hourly flows on individual lines in the transmission network	Net flows: <ul style="list-style-type: none"> <li>• By TransCo</li> <li>• Into a zone</li> <li>• Line capacity loadings</li> </ul>
<b>Locational Marginal Prices (LMPs)</b>	Hourly LMPs at individual busses in the transmission system	Weighted average LMPs <ul style="list-style-type: none"> <li>• By zone</li> <li>• By time period</li> </ul>
<b>Costs, Revenues, Profits</b>	Hourly costs, revenues, and profits	Summed by: <ul style="list-style-type: none"> <li>• Generator</li> <li>• GenCo</li> <li>• DemCo</li> <li>• DisCo</li> <li>• TransCo</li> <li>• Consumer</li> </ul>

**Table 1: Key EMCAS Output Results**

Network configurations in EMCAS can be simple and aggregate consisting of a few to several dozen network nodes and links, or detailed bus-level representations with several thousand network elements. The level of detail is dependent on the particular analysis objectives and data availability. Sample electricity market representations for central Europe, western United States, and South Korea are displayed in the EMCAS screen captures shown below:



**LEARN MORE ABOUT THE EMCAS SOFTWARE AT [WWW.ADICA.COM](http://WWW.ADICA.COM)**

For additional information, contact:

Bruce Hamilton, President, ADICA, LLC, 2021 Midwest Road, Suite 200, Oak Brook, Illinois 60523 USA

Tel.: +1 (630) 705-3060, Fax.: +1 (630) 705-3061, Email: [bhamilton@adica.com](mailto:bhamilton@adica.com)