GridView

Mimicking electricity markets to optimize asset utilization

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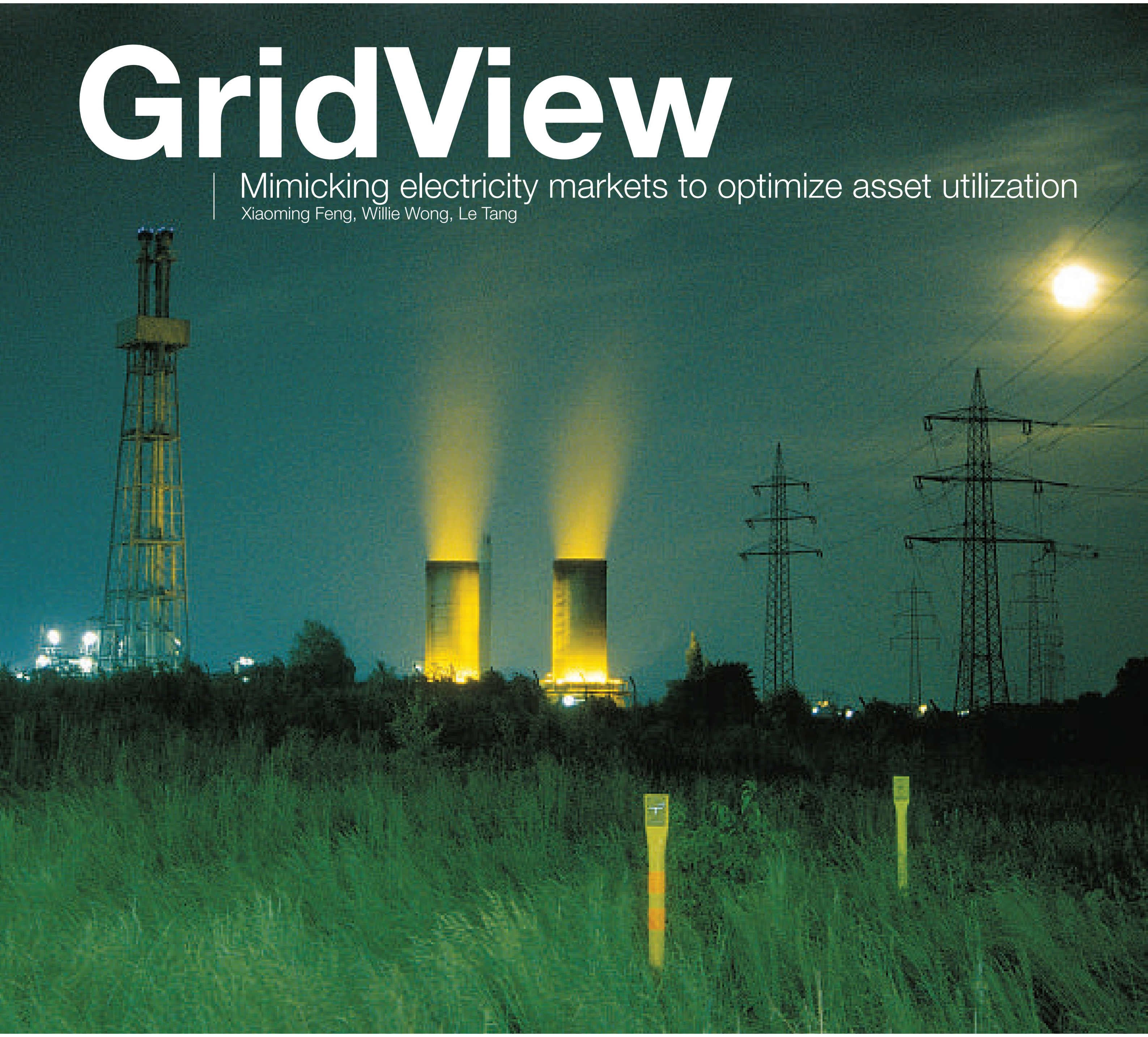


Most power transmission grids are not only highly intermeshed but also subject to complex engineering constraints. Operating one efficiently in a deregulated market, with assets utilized cost-effectively, calls for a simulation tool that takes these constraints into account while running different 'what-if' scenarios. GridView is such a tool. The critical decision support it provides has benefits for all market participants and lets them identify transmission bottlenecks just as easily as opportunities for system expansion.

The ongoing restructuring of the electrical energy industry is having a fundamental effect on the way utilities do business and on how they utilize assets such as generating units and power lines. Ultimately, the success of the restructuring has to be measured by the competition mechanisms it introduces to the production, transportation and distribution of electrical energy, and by the ability of these mechanisms to reduce and contain the cost of electricity to consumers.

Increased competition and open access to high-voltage transmission grids has already drastically changed the utilization pattern of system resources. High-cost producers are losing business to newer and cheaper merchant power plants operated by IPPs, while power marketers are successfully offering transactions over ever-greater distances to take advantage of market price differences. Against such a background, it can come as no surprise that grid power flow patterns have changed and power lines are being stressed in ways none of us could have imagined just a short time ago.

Huge financial stakes

While a competitive market creates many new opportunities and attracts new investment – merchant power plant and transmission projects are just two examples – it also brings with it some risk and uncertainty. Market participants – ranging from government policymakers and power producers, through power marketers and transmission asset owners, to the consumers – are being forced to come up with answers to a whole host of difficult questions. Among the issues are market structure, stranded cost, investment opportunities, market risks and benefit analysis, and the potential need for more transmission capacity.

The financial stakes are huge – from several hundred million dollars for a merchant power project to many billions of dollars in the case of market structure. Among the key questions that have to be addressed are:

- Is a power plant competitive at a given location in the market? How much of the time will it run? How much revenue will come from the spot energy market?
- Should a producer enter into a long-term energy sale contract, or risk spot market prices, with the chance of greater rewards?
- Where should a new merchant power plant be sited for maximum profit? How volatile are the market energy prices?
- Where are the bottlenecks in the transmission grids? How often are the systems congested?
- Given that system expansion options to mitigate congestion exist, how effective would they be?
- How can the economic value of these options be measured? How do they affect the market participants financially?
- Is there any concentration of market power?
- Does the system have enough transfer capability to deliver power to the desired market? Should a power marketer purchase firm transmission rights as a hedge against possible transmission congestion?

To be able to address these questions intelligently and objectively, decision-makers need a credible model of the electricity market for simulating different scenarios beyond the decision evaluation horizon and for evaluating the business consequences. And to accurately reproduce realistic market conditions, this model has to be able to integrate supply and demand economics with the engineering model of the transmission grid.

Realistic modeling with GridView

GridView is such a software tool. Developed by ABB, it simulates the operation of competitive electricity markets while enforcing complex engineering constraints imposed, for example, by thermal and security restrictions or interface and simultaneous transfer limits. Specifically, GridView simulates the day-ahead energy market in an hour-by-hour chronological sequence, for time spans ranging from one day to several years. It allows users to run various 'what-if' analyses by playing out different scenarios and examining the consequences.

GridView provides critical decision support capability for the deregulated electrical energy industry. A robust algorithm design, an easy-to-use graphical user interface, a high simulation speed, data visualization, and, most importantly, reliable and realistic simulation results, set GridView apart from its less sophisticated competitors.

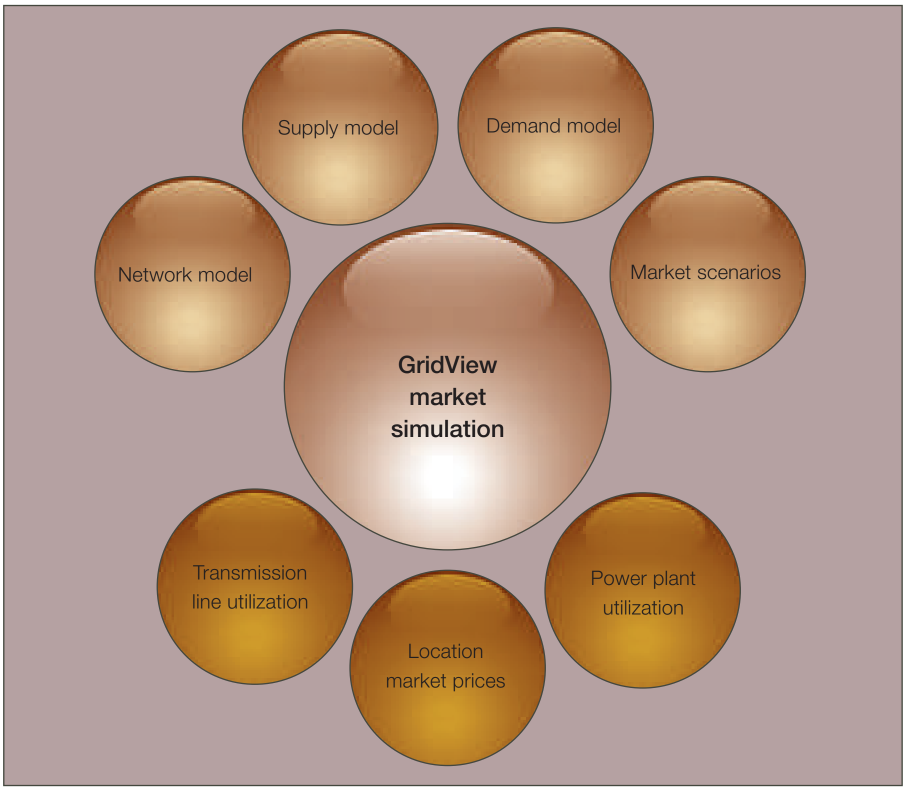
> GridView simulates the day-ahead energy market hour-by-hour, for time spans ranging from one day to several years.

Power market operation and simulation

In a competitive power market, producers submit bids to the market operator – usually a power exchange – or independent system operator, signaling to the market the megawatt (MW) capacities they are willing to provide at various price levels. The market operator, equipped with knowledge of the bids from different producers and with a system load forecast, determines the most economic utilization of the resources for the transmission grid in question. This procedure is known as 'security constrained unit commitment and economic dispatch', and is repeated every day for the day-ahead market to determine the startup/shutdown schedule and energy output for the power producers. One of its key jobs is to determine the location market price (LMP[1]) for various locations in the transmission grid. Locations

[1] **LMP** is the dollar per MWh cost of supplying the next increment of load to a specific location in the transmission grid. It is the basis for calculating how much the power producers get paid and how much customers are charged for their loads, and is a very important indicator of the market condition.

1 GridView overview

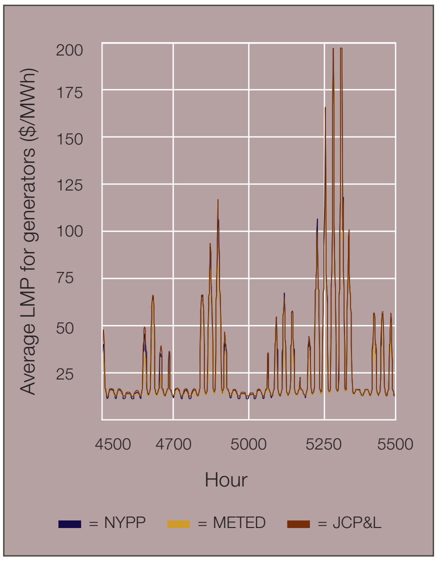


with a consistently high LMP are likely to be profitable sites for new generating plants. Differences in LMP at two locations indicate a transmission bottleneck and are a measure of the severity of the constraints. For every transmission constraint, a shadow price – an indicator of economic benefit for capacity expansion – can also be determined. This is the monetary saving to the market that could be realized by increasing the capacity limit of a transmission line.

To simulate the way the electricity market operates, GridView makes use of several different categories of information 1:

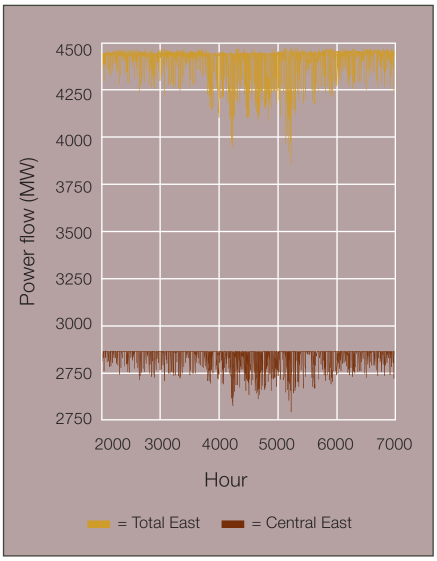
- Supply: location of generating plant, heat rate, fuel cost, operating constraints, and, optionally, bid information.
- Demand: spatial load profiles at hourly intervals.
- Transmission system: load flow model describing the topology of the grid and network parameters, DC line and phase shifter control ranges, thermal limits, security (contingency) constraints, interface limits.

2 Annual market clearing price by areas



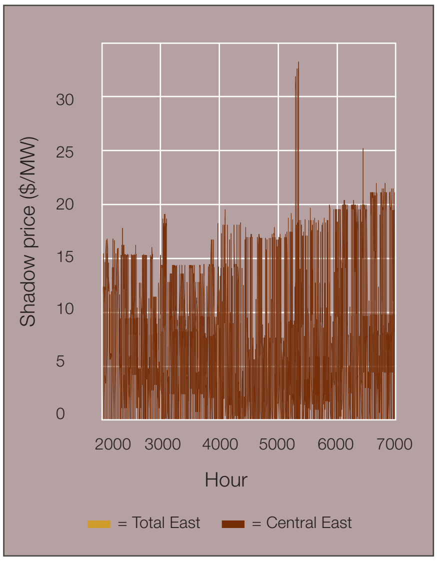
Hourly area-wise average LMP in a regional market in the USA, providing an overview of market segmentation and seasonal trend.

3 Annual power flows over two selected transmission interfaces in a regional US market



The Central East interface experiences chronic congestion, ie the power flow reaches the transfer limits many hours in a year.

4 Annual shadow price of congested interfaces



The economic benefit of incrementally expanding transfer capacity is shown by the consistent non-zero shadow price.

- Market scenarios: fuel price scenarios, generating capacity additions and/or retirements, power plant maintenance, bidding strategies.

GridView uses this information to mimic the day-ahead energy market operation and determine how the given resources can be deployed most effectively. The results of the simulation include a whole range of derivative information, such as:
- Generator utilization: dispatch hours, production cost, revenues.
- Transmission line utilization: hour-by-hour load flow, maximum loading, loading factors.
- Location market prices: hour-by-hour at every location.
- Transmission bottlenecks: hours of congestion, shadow price.

Scenario simulation for decision-making

A simulation tool like GridView allows users to perform 'what-if' analyses for various scenarios and then examine the interactions and consequences of different decisions and variables before committing to costly decisions. To help users interpret the results, GridView provides the output data in a choice of formats 2 3 4.

GridView makes it easier for users to visually identify overstretched transmission resources and provides a valuable tool for analyzing system expansion opportunities. Using geographic information it can show, for example, the annual line loading in a power market 5.

With GridView, users can more easily identify overstretched transmission resources and analyze system expansion opportunities.

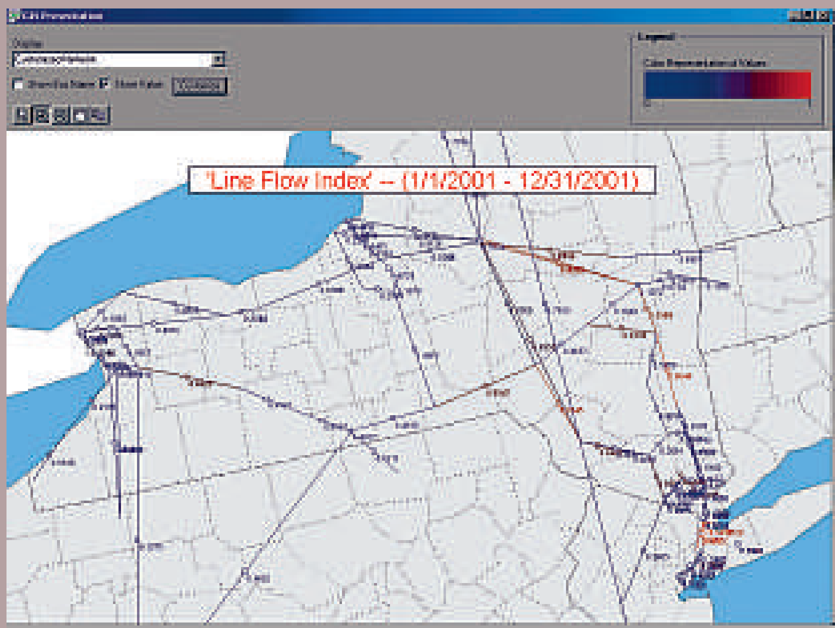
GridView cuts large grids down to size

A transmission network is fundamentally different from a transportation network like the common highway system, in that the power flows on an interconnected grid cannot be independently controlled. Simulating market operation without considering the constraints acting on the transmission system or with the electric power grid treated as a transportation network will produce results that are not feasible in a real-world system. GridView produces physically feasible market simulations by incorporating tens of thousands of grid power flow equations.

Another problem can be the size of the system. Tens of thousands of interdependent power flow equations, as well as numerous transmission costraints, such as interface, transfer and contingency condition limits, may have to be incorporated in a resource optimization procedure involving thousands, even tens of thousands of decision variables.

GridView's uniquely designed simulation procedures and algorithms resolve all of these issues. Highly detailed transmission system modeling, including the effect of every bus and line, ensures a physically realistic simulation. Thanks to specially developed algorithms, GridView can analyze large-scale power transmission networks and energy markets with ease. Just how large these can be may be gauged by the fact that GridView has already been used successfully to simulate a system covering over one-fifth of the United States, involving more than 18,000 buses.

5 Annual transmission line loading in a US power market. The line colors show the severity of the average loading of the line, blue being the lowest value and red the highest.



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