ENERGY PORTFOLIO MANAGEMENT

GridView
Simulate security-constrained unit commitment and economic dispatch in large-scale transmission networks
The electrical industry is changing rapidly.

The ongoing restructuring of the electrical industry around the world has brought fundamental changes to the way the industry conducts its business and to the way the physical transmission systems are utilized. The increasing volumes of energy transactions over longer distances are stressing the transmission systems in ways not anticipated by system planners.

The winners in the new markets will be those who can efficiently manage risks such as generator-forced outages, transmission line outages, congestions, fuel prices and load forecasts. Power marketers also play in the long-term, day-ahead and real-time markets, and need to predict what the price will be under likely scenarios. With billions of dollars at stake, they need to assess the exposed risks that can change with every fluctuation in generation dispatch, transmission outage or load change.

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**GridView**

is a powerful and user-friendly software tool for integrated engineering and economic analysis of the electric power grid.

GridView mimics the market operation of an electric power system under constrained transmission. GridView can be used to study the operational and planning issues facing regulated utilities, as well as competitive electric markets. Typical applications of GridView include:

- Determining the utilization of generators and transmission lines in a regulated or deregulated environment
- Calculating the production cost of generation in a deregulated environment
- Calculating the location marginal price (LMP) in a deregulated environment
- Identifying transmission bottlenecks and congestion in the system
- Assessing the impacts of uncertainties, such as forced outages of transmission line/generation, fuel price forecasts, load forecasts, wind/solar forecasts, etc.
- Evaluating the operational and economic impacts of renewable energy resources, such as wind and solar systems
- Allocating/purchasing congestion revenue rights (CRR)/financial transmission rights (FTRs) to hedge congestion costs
- Calculating the resource adequacy indices, loss of load expectation (LOLE) and expected energy not served (EENS)
- Evaluating the impacts of emission policy compliance
- Co-optimizing the energy market with ancillary service markets
- Coordinating hydro schedules with thermal and renewables to best utilize hydro energy

GridView simulates the economic operation of power systems in hourly intervals for periods ranging from one day to many years. It incorporates detailed supply models, demand models, and transmission system models for large-scale transmission grids.

By performing transmission and security-constrained optimization of the system resources against spatially-distributed loads, GridView produces a realistic forecast of the utilization levels of power system components and power flow patterns in the transmission grid.

Locational marginal pricing (LMP) provides investment signals to the energy provider as to the locations of high profit potential, and can be used as a basis for analyzing the projected revenue stream for independent power producers (IPP). The congestion and the shadow prices for constraints provide valuable insight to system planners as to the stressed pathways in the system and the potential economic benefits if expansion options are used to alleviate the congestion.

In GridView, information on LMP and transmission system utilization can be contoured and displayed in a geographic information system (GIS). Transmission line loading conditions such as average loading factor, number of congested hours and shadow prices can be displayed on a map using numerical values as well as thematic coloring, making it easy to view transmission loading conditions in large systems and quickly screen out the bottlenecks.

GridView is a powerful and user-friendly software tool for integrated engineering and economic analysis of the electric power grid. Its many advantages include comprehensive modeling of the physical and financial aspects of the energy market; an intuitive, Windows®-based graphical user interface; and state-of-the-art programming for faster simulation speed.
Effective market simulation

GridView offers key features to carry out market simulations:
• Detailed representation of the large-scale transmission network
• Standard output reports in Excel® and graphs
• Database management tool with tracking changes and scenario management
• Marginal loss model with distributed reference buses
• HVDC model and phase angle regulator model
• Monte Carlo simulation for modeling forced outages of generators and transmission lines, load and fuel price forecasts, wind/solar forecasts, etc.
• Creation of one-hour load flow snapshots, post-contingency analysis in AC or DC load flow solution
• Hydro-thermal coordination for long-term and short-term based on dynamic programming

The typical output includes:
• Transmission line utilization levels – maximum loading, loading factors
• Generator utilization – dispatch, production cost, revenues, hours on marginal
• Location market clearing prices for energy and ancillary services
• Transmission bottlenecks – hours of congestion, economic value of expansion
• Reliability measures for the systems such as LOLE and EENS

At the SCUC stage, GridView determines the startup, shutdown schedules, and dispatch generators to minimize the total system cost to serve load and ancillary services while satisfying the various generation and transmission constraints. The unit commitment is performed using the following information:
• Day-ahead (or week-ahead) load forecast
• Maintenance scheduling
• Production cost curves
• Generation operation constraints
• Start-up cost
• Load and distribution
• Ancillary services (regulation reserve, etc.)
• Transmission constraints and contingencies
• Wind / solar generation forecasts

Figure 1 summarizes a production or market simulation process. At the center is the simulation engine, which primarily includes transmission security-constrained, multi-area unit commitment and economic dispatch. The simulation program requires data from the following broad categories:
• Supply model: generating capacity location, heat rates, fuel cost, operation constraints and bidding information
• Demand model: spatial load distribution over time
• Transmission system model: transmission line impedance, normal and contingency limits
• Market scenarios: characterized by different fuel prices, generating capacity additions and/or retirements, different generator bidding strategies, etc.
The electric power transmission system is the physical medium that supports the electricity market. The electricity market cannot operate outside the transmission system constraints, no matter whether they are thermal constraints, stability constraints or contingency constraints. Due to the immutable law of physics, the power flows on transmission lines cannot be arbitrarily and independently directed.

Modeling a power market without proper modeling of the physical transmission system will produce analysis results that no physical system can support.

Figure 2 illustrates several levels of transmission system modeling. The supply curve model completely ignores system constraints and is used only under very limited cases, due to its lack of credibility. The bubble model attempts to use a transportation model to simplify transmission systems. The third model, which GridView adopts, uses a complete, detailed transmission system model as the physical structure of the power market model. This detailed transmission system model produces the most realistic simulation and most reliable analysis.

 GridView features related to its transmission modeling include:

- Chronological unit commitment and economic dispatch that takes the normal as well as contingency limits of lines, interfaces and nomograms into account.
- Seamless data exchange with PSS/E and PSLF loadflow program.
- Capability to perform DC contingency analysis – GridView can read the familiar PSS/E’s *.CON and *.MON contingency files through Python® API. Once the contingency files are read into GridView, a DC contingency analysis can be performed to identify additional contingencies that need to be monitored in the security-constrained unit commitment and economic dispatch process.
- Marginal loss model that takes the effect of transmission losses into unit commitment and economic dispatch.
- Users can define the distributed reference buses for loss model and remove estimated losses from load forecasts for all areas.
- Phase angle regulators (PARs) and high voltage DC lines (HVDC) can be modeled and PAR angle and HVDC flow can be exported hourly. The HVDC model with marginal losses enables users to accurately capture HVDC operation.
- Modeling of scheduled transmission maintenance/outages.
- The generation shift factors need to be re-computed whenever the topology of the system changes due to line outages.
- Modeling of operational nomograms such as reliability must runs (RMRs) and remedial action scheme operating procedures.
- Debugging tool enable users to export generator shift factors (GSF), congestion analysis (decomposition of congestion component of LMP by binding constraints) and flow analysis (decomposition of flow to all generation, load, PAR and HVDC) for any given hour.
Large system modeling capability

GridView is designed to analyze real and large-scale power transmission network and energy markets under either centrally-coordinated competitive or bundled multiple coordination operating conditions. GridView has been tested on both synthetic systems designed for the testing of specific simulation features as well as large systems based on the transmission systems in the United States.

Seven separate systems, generally following the regional transmission organization (RTO) footprint and collectively covering the continental United States, have been simulated successfully with GridView. These systems range from a few thousand buses to around 80,000 buses. The location and geographic scope of these systems are shown in Figure 3. The system magnitudes in terms of number of buses, loads, generators, branches, transformers and other controllable components are identified in Figure 4.

<table>
<thead>
<tr>
<th>REGION</th>
<th>EASTERN INTERCONNECTION</th>
<th>ERCOT</th>
<th>WECC</th>
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<tr>
<td>Case description</td>
<td>2019 series NERC/MMWG base case</td>
<td>2023 SSWG summer peak</td>
<td>2028 SP</td>
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<td>Case series</td>
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<td>2023</td>
<td>2028</td>
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<td>NPCC, MRO, SERC, FRCC, RFC, SPP</td>
<td>ERCOT</td>
<td>WECC</td>
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<tr>
<td>Buses</td>
<td>83,153</td>
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<td>Generators</td>
<td>1,1525</td>
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<td>Pumped storage</td>
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<td>Hourly resource</td>
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<td>Loads</td>
<td>38,514</td>
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<td>Branches</td>
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<td>Phase shifter</td>
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<td>DC lines</td>
<td>37</td>
<td>5</td>
<td>7</td>
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<tr>
<td>Peak load (MW)</td>
<td>625,498</td>
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<td>Generation max dispatched (MW)</td>
<td>642,089</td>
<td>80,513</td>
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<td>Generation Pmax (MW)</td>
<td>869,671</td>
<td>105,657</td>
<td>255,664</td>
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</table>
Multiple simulation results presentations

Transmission-constrained market simulation produces volumes of output data. For every hour in the simulation period, the marginal clearing price is recorded for every bus, pricing zone, generator, and load. The various ancillary service prices are reported. The capacity, generation, outage status, commitment status, fuel cost, variable cost, etc., can be recorded for every generator. The power flow, congestion cost, and shadow price are also recorded for every monitored transmission line.

The output can be viewed in graphical format or exported to CSV files to be viewed by Excel®. A contour map, shown in Figure 7, shows transmission congestion causing high LMP in the New York City and Long Island areas.

GridView also provides Python API to generate comprehensive reports or plots as in Figure 5, a summary report for a one-year simulation. Python code can also automate the iterative process to update input data, run simulation, and calculate results until the result meet the requirements.
Monte Carlo simulation results presentations

Monte Carlo simulation allows detailed modeling of pre-contingency conditions and the outages of generation and/or transmission equipment and/or changes of load demands and fuel prices and/or wind generation. The program can also model the correlation between area load demands and fuel prices.

GridView uses probability distributions for equipment outages during a sequential mode of hour-by-hour simulations, and typically for a year. The selection of testing conditions is emulated through a random sampling. In order to obtain accurate risk indices, many simulations will have to be performed. In general, the simulations provide outputs on production cost, LMPs, level of transmission congestion, loss of load reliability indices, and other production quantities. The output can be viewed in a convergence plot (Figure 8).

For reliability assessment, a linear programming model is applied to the generation dispatch calculation for every hour in each trial in order to compute the amount of load that has to be shed in order to honor transmission constraints and operational nomogram. Annual reliability indices, such as energy not served, LOLE, etc., are computed within a predefined standard error.
Sub-hourly simulation

As the renewable penetration increased, it is required to assess the uncertainties from wind and solar generation and consequently ramping challenges to dispatchable resources not only in hourly simulation but also in sub-hourly simulation. The ramping in 5 minutes could be much more challenging than that in one hour, even though 5-minute ramping is normally much smaller than one-hour ramping. This is because all dispatchable units have limited ramping rate to response to wind and solar generation changes. See Figure 9 for a solar generation 5-minute profile in one day.

GridView can run sequential simulations for the day-ahead market and the real-time market as actual market settlements (Figure 10). The user can choose sub-hourly intervals such as 2 minutes, 5 minutes, 10 minutes, or 15 minutes. The unit commitment in the day-ahead market simulation will be passed on to the real-time market simulation.

Markets may require a 15-minute simulation to calculate the optional interchanges for NERC Control Performance Standard 2 (AKA, L10 limits). The interchanges may be maintained within L10 limits in real-time market simulation.

Ancillary services will be co-optimized with the energy market in the sub-hourly simulation. It can be used to evaluate benefits of energy storage and energy imbalance market.