

## Appendix F.2- ABB Market Simulator

### Purpose and Scope

RMATS has used ABB Market Simulator to simulate the West's system operations to determine production costs. Production costs include fuel and small amounts of other variable O&M costs. ABB<sup>1</sup> developed the Market Simulator model to forecast the economic and physical performance of large power networks on an hourly basis. The application is designed to produce:

- Transmission congestion estimates— demonstrates where transmission bottlenecks may occur
- Market clearing prices – estimates forward price curves that vary by location (bus or node), including spot energy and shadow transmission price curves.
- Generating resource dispatch – estimates the lowest cost dispatch for the Western Interconnection.
- Transmission expansion – shows system-wide effects of proposed transmission development
- Various sensitivities – allows the user to examine events/scenarios that would introduce volatility in bulk power prices.

The model accomplishes this through an algorithm that dispatches generating resources to minimize total west-wide production costs. This dispatch algorithm matches hourly generation to hourly loads and losses while taking into account:

- Transmission constraints
- Hydro and wind inputs
- Thermal plant characteristics and maintenance schedules

To minimize system production costs, the model factors in variable fuel costs, thermal plant heat rates, and variable O&M costs. Production costs and nodal prices are catalogued for each hour of the study year.

The model yields an optimal dispatch of generation, corresponding power flows, and resulting nodal price information. Specifically:

- Hourly dispatch for each generating unit;
- Hourly production costs;
- Hourly line and interface flows and flow duration curves;
- Net import, load and generation for each area;
- Congested paths/lines;
- Transmission shadow prices (opportunity costs); and
- Locational marginal prices for loads and generators.

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<sup>1</sup> ABB: serves electric, gas and water utilities as well as industrial and commercial customers, with a broad range of products, systems and services for power transmission, distribution and automation.

## Modeling Limitations and Implications

Large amounts of load, resource, and transmission data are required to model west-wide system operations on an hourly basis at the nodal level. To keep the modeling efficient and flexible, certain simplifying assumptions were made to the model's dispatch engine and to the data. The model is a useful tool for screening potential economic transmission additions, but it is not the "real world".

There are limitations inherent in all models. For example, the model assumes a single, seamless west-wide market, with none of the inefficiencies of multiple control areas or rate and loss charge pancaking that exists today. It assumes an optimal one-world dispatch of generating resources using perfect information. Hydroelectric and wind resources are dispatched outside the model, and then entered as fixed, shaped inputs around which thermal resources are dispatched. "Must run" generation and unit commitments are not modeled, and strategic bidding behavior by market participants is not considered.

These simplifying assumptions have implications. The modeling tends to make a fuller, more optimal use of the transmission system than today's control area, contracts and tariffs actually allow. The modeling assumes the efficiencies of a centralized, seamless, and somewhat idealized RTO world. This contrasts with today's practice of multiple control areas, rate pancaking, transmission loss charge pancaking, contractual terms and conditions, and other practices that can impede a fuller, more economic use of existing assets. If these institutional impediments were included, congestion and congestion costs would tend to be higher than modeled, as would system-wide production costs.

Second, the limitations on simulating resource dispatch, for example, the absence of unit commitment logic and the fixed treatment of hydro and wind dispatch, also affect production costs. Wind resources appear to be more economic because the model's assumption of fewer constraints leads to greater dispatch than would occur in practice.

Figure F.2.1: ABB Market Simulator algorithm process sequence includes a step by step depiction of the algorithm process.

## Hydro and Wind Modeling

The ABB Market Simulator logic shown in Figure F.2.1 does not include a step to model hydro and wind generating units. To model these resources, dispatch is treated as a fixed input to the model. Hydro fixed inputs are created by a combination of "run of river" and "load peak shaving" algorithms calculated outside ABB Market Simulator. These algorithms create an hourly generation shape for each unit/plant. The shaped dispatch associated with these units/plants is entered into the model and set as a fixed dispatch. Thermal plants then meet the remaining load requirement with the model's optimization algorithms. For additional detail on hydro methodologies, please read the 2003 SSG-WI Report at <http://www.ssgwi.com>.

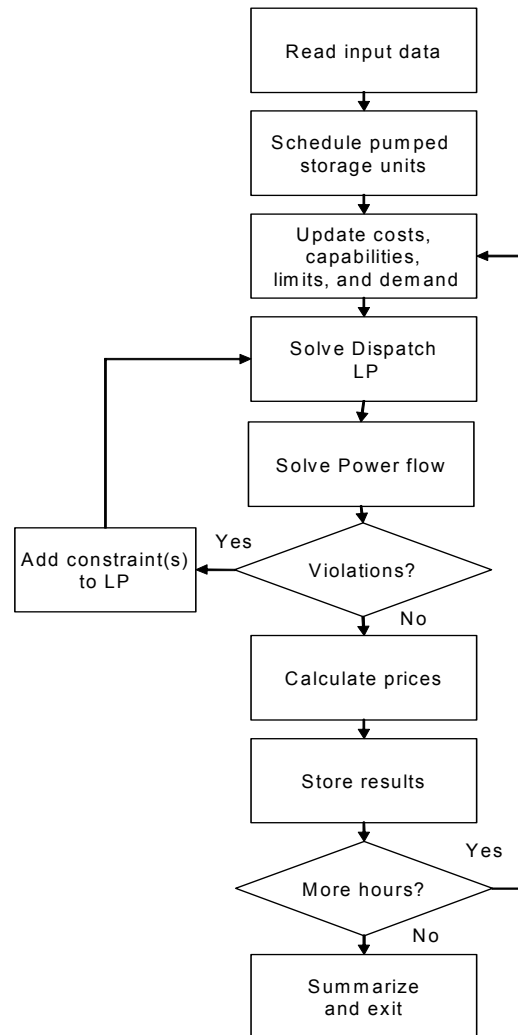
Wind modeling is similar to hydro modeling in that a fixed hourly shape is input into the model. The National Renewable Energy Lab (NREL) provided an hourly wind shape to match wind farm capacities to an hourly capacity factor<sup>2</sup>. After wind dispatch patterns are identified, they are treated as a fixed input into the model; thermal plants' dispatch would be lower, thus minimizing costs. A

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<sup>2</sup> Capacity factor is the percent of dispatch (output) versus the maximum dispatch (output) over a given duration of time.

major implication of this methodology is that if transmission capacity is unavailable near the wind farm, a plant located on the same path will cycle its dispatch as the wind levels increase or decrease.

**Figure F.2. 1: ABB Market Simulator algorithm process sequence**



### **ABB Market Simulator Strengths**

- Models a detailed version of the entire Western Interconnect on a nodal basis versus a bubble view used in most transport models
- Uses an accurate approximation of network power flows (DC Optimal Power Flow methodology, not AC)
- Solves linear program in a reasonable time
- Accurate approximation for Western Interconnect production cost and transmission utilization screening studies
- Provides transmission congestion cost estimates, market clearing prices, resource dispatch, transmission duration curves, and sensitivity analyses

### **ABB Market Simulator Weaknesses**

- Modeling assumes a single, seamless west-wide market with no rate or loss pancaking
  - No institutional, tariff, or contractual impediments to trade
  - Omits wheeling charges (Tariff \$/MWh and % loss charges)
  - Does not calculate loss
- LP optimizes dispatch on a west-wide basis ignoring inefficiencies that exist with multi-area control.
- Hydro and wind dispatch is determined outside ABB Market Simulator, and is then entered along with load as fixed, shaped inputs around which thermal resources are dispatched
- Perfect foresight on loads, transmission usage & reserve requirements
- Not modeled:
  - Must-run generation
  - Unit commitment
  - Transmission wheeling and loss charges
  - Generator forced outages
  - Contractual / tariff constraints
  - Bid behavior
  - Policy related items such as renewable portfolio standards (RPS) and carbon emission limitations
  - Sub-hourly operations
  - Actual heat rate curves- approximate only
  - Impacts of uncertainty and errors (on load estimate or generator availability)

### **Model Inputs:**

- Topology
  - Bus (node) with corresponding lines
  - Lines, with corresponding voltage & impedances (including transformers)
  - Phase shifter locations and characteristics
  - Interface/path ratings and direction (also nomograms)
  - Generator locations
  - Load locations
  
- Generating Resources
  - Hourly MW shape for each hydro plant
  - Hourly MW shape for each wind farm
  - Max MW capacity for each thermal resource
  - Average heat rate
  - Planned outage
  - Annual fuel cost per MMBtu
  - O&M per MWh
  
- Other
  - Monthly peak & energy loads for each bubble
  - Monthly load shape (historic or projected)
  - Definition of load buses and percent of the total bubble load – from powerflow
  - Area/bubble definitions

### **Model Outputs:**

- Hourly dispatch for each generating unit
- Hourly production costs for each generating unit
- Hourly line & interface flows and flow duration curves
- Net import, load and generation for each area
- Transmission shadow prices (opportunity costs)
- Locational marginal prices for loads and generators