Ascend Analytics

Better models. Better decisions.

Ascend Analytics PowerSimm Model

A description of the software platform used by NorthWestern Energy to model their portfolio in the 2019 Montana Electricity Supply Resource Procurement Plan.

Key Takeaways

- PowerSimm is a software package developed and supported by Ascend Analytics (Ascend) of Boulder, Colorado.
- PowerSimm explicitly models the impact of load variability, renewable generation, and market prices on generation dispatch and production costs.
- The analysis is performed at an hourly time-step to capture the unique operating characteristics of renewable resources and flexible resources able to respond rapidly to changing market prices.
- PowerSimm's stochastic simulation engine models both financial and physical uncertainty, including price simulations for major commodities and weather forecasts, which then drives load, wind generation, hydro production, and spot prices for gas. Spot power prices are a function of load, wind, hydro generation, and spot gas prices.
- These simulated variables, in turn, drive the economic optimization model of the hourly generation of NorthWestern's current and future resource options, leading to a cost-optimized dispatch schedule for each portfolio.

Stochastic Modeling

PowerSimm is a stochastic, rather than deterministic, model, which means that its outputs have a probability distribution or pattern, rather than simply a point estimate, which may be analyzed statistically. A stochastic simulation approach is superior to deterministic simulations of the expected values of input variables because deterministic models tend to miss out on the range of possible outcomes of portfolio costs.

PowerSimm's use of stochastic analysis allows for a full characterization of the expected costs and uncertainty for each portfolio that NorthWestern studies. Stochastic simulation methods capture key short- and long-term uncertainties that are fundamental to estimating fuel prices, market electricity prices, generating plant outages, production from renewable energy resources, and hydrological conditions. Stochastic analysis enables the model to explicitly capture the impact that uncertainty in key inputs has on the expected value, and likely range of values, for each portfolio. The stochastic approach used in PowerSimm estimates the value of alternative portfolios across a wide range of possible future conditions. Each simulation represents a unique combination of alternative model assumptions about commodity prices, weather, electric demand, market electricity prices and renewable resource generation.

The uncertainty or risk in the estimated values for different portfolios can be compared by calculating the "risk premium" associated with each portfolio. A portfolio's risk premium is measured as the probability weighted average of the costs between the median and 95th percentile of simulated costs (similar to a "value at risk" measurement as used in finance). This measure reflects the potential that costs above the expected values may be realized. By adding each portfolio's risk premium to its expected levelized annual cost of energy, the analysis quantifies risk using a single number that is more easily comparable across portfolios than traditional approaches. This simplifies the decision-making process because it allows cost and risk to be combined (because they are quantified on the same expected-value basis) and thus allows a direct comparison between portfolio options with different risk profiles.

Primary Inputs

The primary inputs to the PowerSimm model are as follows:

- Historical Daily Weather Data: Historical daily minimum and maximum dry bulb temperatures are used to fit a simulation model for hourly temperatures. Hourly temperature simulations are used (directly or indirectly) in nearly every simulation model in PowerSimm, including: Load, Hydro, Wind, Solar, Power Prices, and Gas Prices.
- Hourly System Load: System Load refers to the market or electrical region that has the largest impact on the utility's wholesale power and gas prices. The System Load drives the System Power Price because power prices respond to customer demand. The Western Electricity Coordinating Council (WECC) is the Regional Entity responsible for promoting the reliability of the Bulk Electric System in the Western Interconnection, which includes NorthWestern Montana. Historical demand data in the WECC region was used in PowerSimm for the System Load.
- Hourly Customer Load: NorthWestern dispatches its resources based on market price signals, but ultimately is responsible for meeting its own customer load. Simulating customer load allows us key insight into system reliability.
- Hourly System Power Price: PowerSimm simulates power prices at the Mid Columbia hub (MIDC) to use as a baseline for purchase and sale decisions. The driver of prices at MIDC is the WECC System Load.
- Hourly Power Nodes: Locational marginal pricing (LMP) is the standard for power markets, and each generator has a unique power sales price that accounts for the cost to sell the power it generates to the market, and small influxes in near-by customer demand. PowerSimm models each LMP as a basis off the system power price at MIDC.
- Daily System Gas Price: Daily gas prices are a key determinant of hourly power prices in the PowerSimm model. Alberta Energy Company (AECO) is the System Gas Price used in NorthWestern's simulation.
- Global Shapes: PowerSimm applies global shapes to power prices so that daily price profiles follow future expectations to account for changing dynamics in system power prices, caused by changing net-load dynamics, introduced through increasing levels of renewable penetration. In lieu of system-level (WECC) renewable data, the most reliable way to ensure that an evolving

marketplace accurately represents what we expect to see, rather than what we are accustomed to seeing, is by constraining the hourly power price shapes to be consistent with market forward expectations.

- Hourly Hydro Generation: Generation for NWE's hydro resources is simulated as run-of-river fit to historical hydro generation and monthly forecasts. Regional hydro generation's influence on power prices is modeled using global shape constraints on the MIDC power price.
- Hourly Wind Generation: PowerSimm uses historical hourly wind generation data and monthly or annual forecasts.
- Hourly Solar Generation: PowerSimm uses historical hourly solar generation data and monthly or annual forecasts.
- Weighted Average Cost of Capital (WACC): NWE's WACC is used to discount future costs and revenues to calculate net present values.

Structural Relationships between Input Variables

PowerSimm captures important correlations and structural relationships between input variables and their uncertainties. For example:

- Commodity price forecasts are constructed from current futures prices for commodities.
- Variability in weather is modeled as the key driver of electric load, wind generation, hydro generation, and spot gas prices.
- Electric load, wind generation, hydro generation and gas prices are, in turn, modeled as the key drivers of electricity market prices.

Modeling Commodity Price Scenarios

A key feature of PowerSimm is that it captures meaningful uncertainty in the year-to-year and hour-to-hour dynamics of commodity prices over the time horizon modeled, rather than fixing the commodity price at specified "medium," "high," or "low" price trajectories for the entire study period. The forward price curves used in the model are consistent with the prices observed in current spot and futures markets for each commodity. The future price "paths" used in the model are produced by solving a system of simultaneous equations that (1) capture the uncertainty inherent in futures prices and (2) preserve the seasonality and relationships with other commodities observed in the historical data. The future paths used in the PowerSimm simulations also preserve the mean-reversion behavior (i.e., that "spikes" in commodity prices do not typically persist, but tend to regress towards the mean over time) exhibited in historical price paths.

Modeling Electricity Market Prices

The simulation of electricity market prices is developed from a statistical relationship between market prices and important stochastic variables, including weather, gas prices, and electric load. The simulation of market prices includes two stages. "Prior to delivery" simulation evolves current price expectations through the end of the simulation horizon. "During delivery" simulations capture the relationship of physical system conditions (weather, load, supply conditions) on spot market prices.

For "Prior to delivery", PowerSimm develops projections of on-peak and off-peak electricity prices based on forward price curves and the historical relationship between natural gas and electricity prices. PowerSimm develops simulations of market prices using a structural statistical relationship between market prices and important key variables that include weather, gas prices and electric load. The simulations use the historical correlation between market prices, weather and load. These correlations are also used to shape the monthly forecasts into an hourly shape.

Modeling Load

PowerSimm forecasts system electric demand at the hourly level for all years in the simulation horizon. In the model, load is the dependent variable and historical weather and seasonal, day-of-week, and hourly load patterns are the independent variables. The model explicitly captures relationships between each of the independent variables, as well as their relationship to load. For example, while modeling uncertainty in temperature, a statistically valid relationship is maintained between temperature and load.

Production Simulation

Each simulation represents a unique combination of uncertain model inputs such as temperature, electric load, gas prices and market electricity prices. PowerSimm uses its stochastic engine to perform a set of simulations of the operation of NorthWestern's electricity generation system. The simulations are run under the assumptions defined by the specific scenario. The key characteristics of each simulation include:

- Hourly operational analysis: The simulation uses an hourly time step level of detail to capture the flexibility of generation resources as they respond to changes in load, intermittent renewable generation, or plant outages.
- Market-based dispatch: Resources whose output level can be controlled ("dispatchable" resources) are dispatched economically, which means that they are operated when the market price of electricity is greater than the variable costs of operating the resource.
- Renewable generation: Renewable resources, such as solar and wind, are not dispatchable because their output cannot be controlled. The dispatchability of NorthWestern's hydro resources is limited by weather and environmental constraints. Generation produced by renewable resources is driven by the weather conditions specific to the simulation.

Comparing Alternative Portfolios

In comparing alternative portfolios, PowerSimm evaluates each portfolio over the same combination of simulated conditions. Generating the results across all simulations produces a probability distribution of costs for each portfolio for each year of the planning horizon, as well as a probability distribution of the portfolio's net present value. The portfolios can be summarized and compared in terms of these distributions as well as their expected values and risk premia. The expected value of the cost of each portfolio is the probability-weighted average cost of operating the NWE system across all simulations considered in the analysis. The risk premium is the probability-weighted average of costs between the median and 95th percentile of costs. For both the expected value and the risk premium calculations, the final results are summarized in terms of net present value across the planning horizon.

Detailed Outputs

PowerSimm performs a full system dispatch for each portfolio for each hour of each simulation. These results can then be aggregated up to weekly, monthly or annual summaries. The primary detailed reports include:

- Net Position Report: Contains the annual generation of each generating resource, total load obligations, and net position between total system generation and load.
- Generating Stations Report: Contains detailed dispatch results for each generation resource, including generation output, capacity factor, fuel consumed, revenue and key operating cost elements (such as fuel, emissions, variable O&M).
- Portfolio Supply Costs Report: Includes annual portfolio-level results for market purchases, power sales, fixed costs and operating costs for each portfolio.

Validation of Model

The following section describes how the PowerSimm model is validated. Please reference the Appendix for example validation plots:

- Weather: Weather simulations are compared against historical weather patterns to ensure that the simulated variability in temperatures across the year is consistent with historical variability.
- Commodity prices: Prices for commodities such as natural gas and coal are calibrated to both the averages and uncertainty reflected in forward (futures) contracts for each commodity. In addition, the commodity simulations are tested to ensure a realistic correlation to market electricity prices, and to ensure that the time series of forecast prices demonstrate realistic reversion-to-mean behavior.
- Electric load: Simulations of load are compared with historical load data and weather simulations to ensure that the historical relationship between load and weather is preserved.
- Electric spot market prices: Simulated market prices are checked to verify that simulated results for historical periods match actual historical electricity prices, both in terms of mean values and the range of uncertainty. As with electric loads, the calibration is performed for monthly and hourly time intervals.
- Gas spot market prices: Simulated gas prices are examined to ensure that monthly variability is consistent with the range of variability in historical gas prices.
- Renewable generation: The model produces estimates of monthly variability in wind and hydroelectric generation. This variability is compared to the historical variability in the output of

these resources.

Appendix: Validation Plots

Weather:

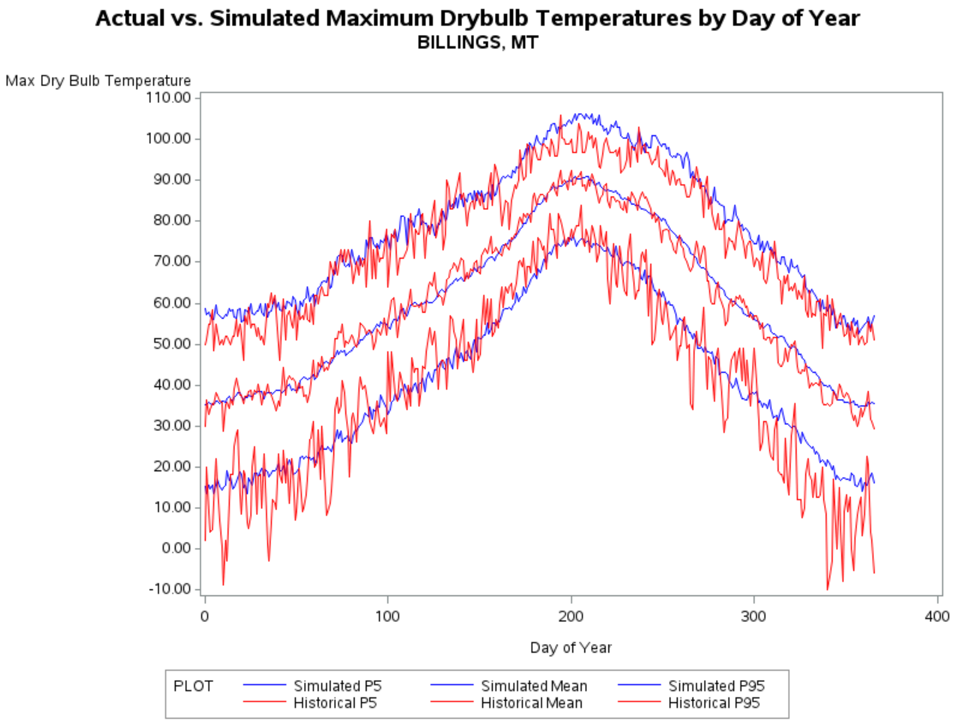

Figure 1. Backcast simulated (blue) Max Dry-bulb temperatures follow a similar pattern to historical (red), but with more observations, thus less variability.

Commodity Prices:

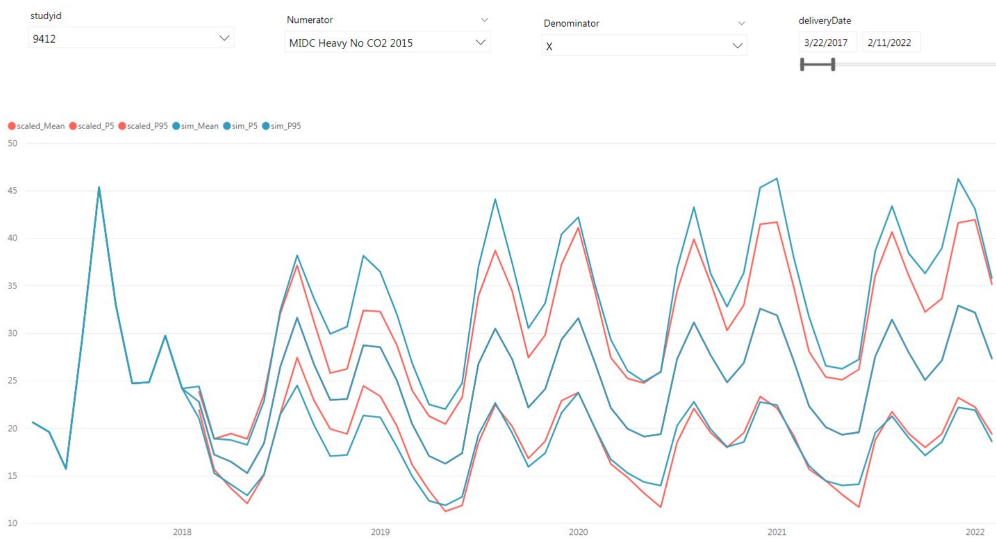

Figure 2. Forward simulations (blue) follow a similar, yet enveloping, spread to equivalent historical (red) confidence intervals.

Load:

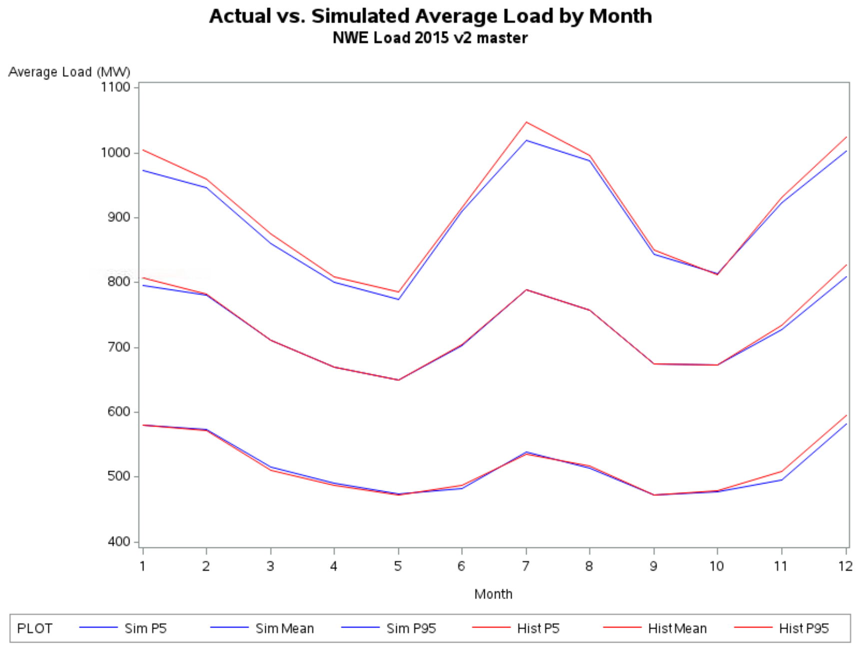

Figure 3. Backcast simulated (blue) load compared to 2015 NWE customer load (red). Simulated load closely follows the shape and distribution of load probabilities.

Electric Spot Market Prices:

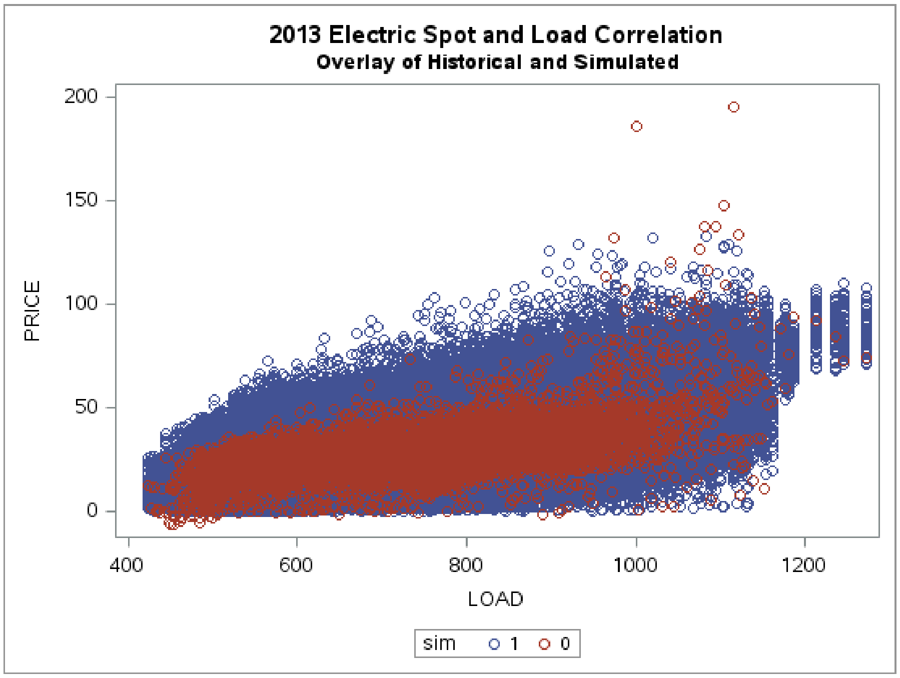

Figure 4. Backcast simulated (blue) power prices behave similarly, but enveloping, to 2013 historical (red) given the same load inputs.

Gas Spot Market Prices:

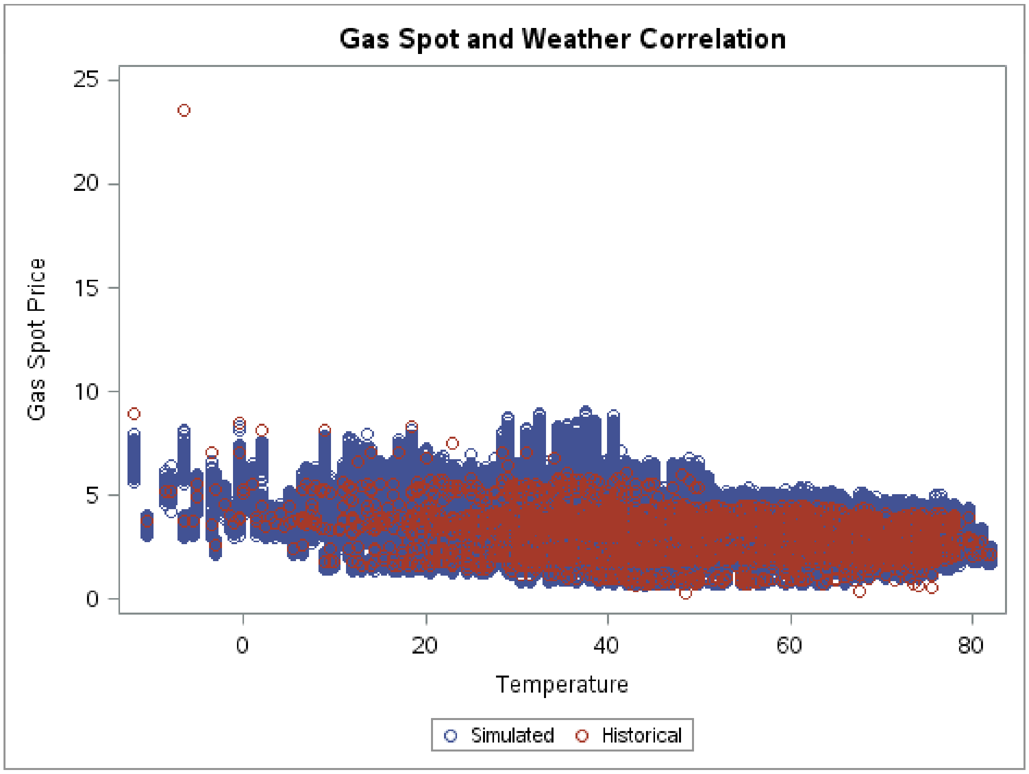

Figure 5. Backcast Gas price simulations (blue) behave similarly, yet enveloping, to historical (red) given the same temperature inputs.

Renewable Generation:

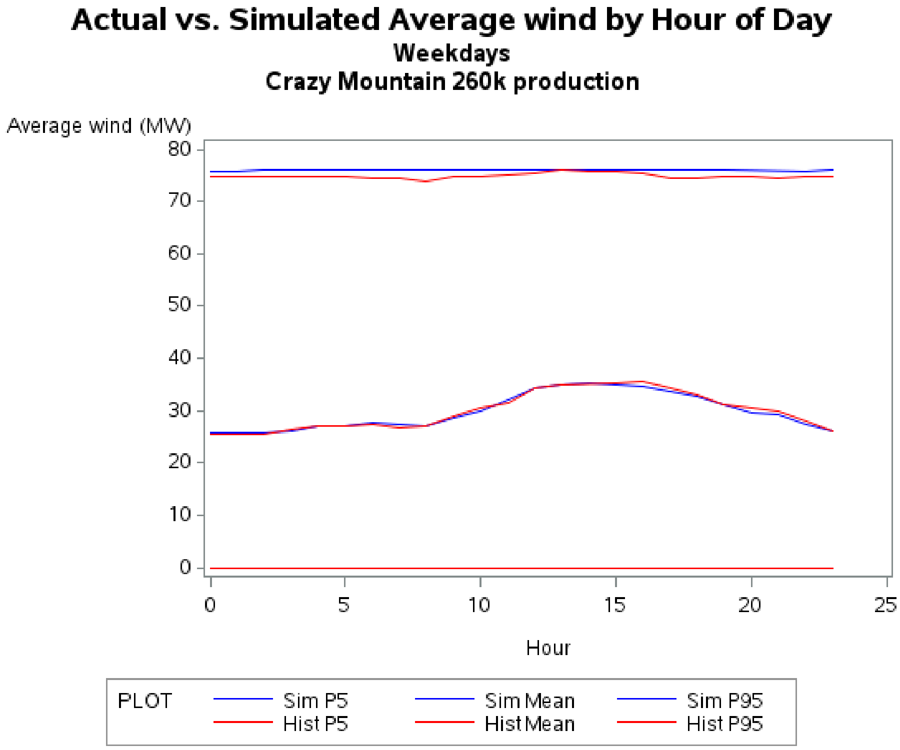

Figure 6. Wind Simulations (blue) show a similar hourly generation pattern to history (red) over the course of a year.