# *STOCHASTISTIC VERSUS DETERMINISTIC GRID-EVOLUTION MODELS- A CASE STUDY ON MISO*

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## Overview

Most of the current electrical grid evolution models do not account for the variability or sudden shifts in fuel prices, capital costs, demand growth, etc intrinsically (EIA, 2017; North et al., 2002; NREL, 2012). They are deterministic models which compensate for this uncertainty through scenario analyses. E.g., National Energy Modelling Systems (NEMS) by EIA is a deterministic value model which partially incorporates uncertainty using scenarios of variations in inputs of economic growth, fuel prices, and policy interventions (EIA, 2017).

While a deterministic simulation captures the average behavior of a system, it evens out the natural randomness of critical inputs (e.g. fuel prices or carbon taxes). Consequently, a full range of possible outcomes akin to reality is not explored with representations very often containing a sub-optimal inclusion of input variability. This study explores the possibility and cost trade-off of including stochasticity in input variables to account for variability in the system. Results of grid portfolios using deterministic inputs and stochastic inputs are compared to understand if the deterministic model is a more suitable representation when large value variables are in consideration; or if the stochasticity in input variables such as fuel prices, capital costs, electricity demand, etc., are better predictors of the optimal grid build-out. Forecasted values from EIA and EPA are used to determine the outcomes under different subsidy/tax policy scenarios and economic growth. The distributions of input variables are varied from narrow widths-for determinstic analysis to very wide widths for highly sotchastic analysis. Monte-Carlo analysis of carefully constructed input distributions is used for stochasticity. These outcomes are shown for Midcontinent ISO (MISO) in the U.S. Prior work on stochastic grid models is scarce. One prior paper exploring stochastic models however indicates that in generator portfolio planning, deterministic analysis overestimate the achievable carbon emissions reductions by ~33% (Hart & Jacobson, 2011), which means an underestimation of renewable energy capacities to be added to the grid.

## Methods

Our model simulates the future build-out of grid infrastructure in MISO using both deterministic simulations and stochastic simulations. This is explored by varying the distribution widths of the input variables from very narrow (nearly deterministic) to very wide (highly stochastic) widths.

The grid infrastructure planning model iteratively runs the optimized generation build-out portfolio and economic dispatch model over a 20 year time horizon (2020-2040) with an objective to meet the electricity load demand and policy requirements at the lowest cost possible. A genetic algorithm optimization is used to search for generation build-out plans that minimize discounted expected total costs of meeting electricity load. Monte-Carlo simulation is used with the dispatch model to integrate the uncertainty in the inputs variables. The outcome from the dispatch model is a distribution of expected daily variable cost, renewable energy, and emissions which are fed to the optimization algorithm (genetic algorithm) to determine the generation build-out plans. These iterations continue over the time horizon of 20 years and generate an outcome of grid build out plans each year.

Probability or variance of the distribution of input variables is considered for stochastic simulation. The data for the existing power plants is taken from the EPA e-Grid database (US EPA, 2014), annual hourly load demand from MISO (MISO, n.d.), and average fuel prices from EIA (EIA, 2016). In order to model uncertainty, we run an Auto Regressive Integrated Moving Average (ARIMA) for the fuel prices. ARIMA estimates the "noise" of a variable by subtracting the mean and calculates maximum likelihood estimation. The normal distribution is used for simulating synthetic electricity load demand in each Monte-Carlo simulation, and for other costs such as carbon prices where historical data is not available.

All the simulations are run using the software Matlab R2016b version.

## Results

Initial dispatch model results based on the current generation fleet show that MISO electricity supply is largely coal-based (more than 50% of total demand) in all three seasons. Transformation of the grid towards low carbon emitting technologies is one of the greatest challenges faced by MISO in the coming years. Concurring with low natural gas prices forecasts (EIA, 2017), expected results of the deterministic model are likely to indicate adoption of natural gas based generation as a primary source through 2040. Yet, this reconfiguration may not be an optimal solution given the volatility in the natural gas prices, uncertain policy constraints and declining prices of the wind energy. Thus, the transition is highly exposed and prone to shocks from the sudden shifts in the input variables. Stochastic simulation easens these problems and provides a better range of outcomes. It is expected that with stochasticity inclusion grid build-outs will transition towards a gradual adoption of natural gas, wind energy (abundant potential), and solar energy technologies over the next 20 years. However, simulation trials are yet to be completed and these will determine the actual capacities of each technology adopted as well as the cost trade-offs for the adoption as against deterministic approach.

## Conclusions

Electricity infrastructure in the real world is largely a stochastic problem. The uncertainty analysis will not only clarify the expected distribution of outcomes but also explore relationships in how sudden shifts in critical inputs would affect the outcomes of grid build-out. This will help the policy makers to reshape and modify the current and future resource planning models to meet the electricity demand growth and other constraints (Renewable Portfolio Standards, for example) at the lowest cost. Also, stochasticity in the model aids in a smoother transition of technologies as compared to deterministic models. This is particularly relevant in MISO which is heavily reliant on coal-based power generation and eventually needs to shift to cleaner technologies. On the downside, running Monte-Carlo on dispatch model over a horizon of the 20-year time period is a computationally intensive process. Therefore, there is a trade-off between realism and deterministic models and depends upon the planning horizon and type of electricity grids.

## References

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