David Daniels Recommendations to the Committee on the Future of the Electric Power in the United States

2/10/2020

Washington, DC

Dear Prof. Morgan and the Committee on the Future of Electric Power in the U.S.,

Thanks again for inviting me to present at the NAS workshop on models to support electric infrastructure planning in Irvine last week. As I said then, modeling the future power grid is an extremely important topic, befitting of NAS examination. The workshop itself highlighted some of the challenges. Joe Eto's timescale chart was illustrative. Viewed at different timescales, the challenges are quite different; and, the communities, techniques, and tools used to address the challenges are almost entirely disjoint. Although there are many technical (technical defined expansively to include economics, policy design, and individual and social behavior) challenges involved in modeling the future grid, the non-technical challenges are, in my opinion, much more insidious. The opinions in this note are entirely my own, not those of the U.S. EIA.

Where practitioners define system boundaries around the problem can end up dictating the solution. While the real-world grid is expansive and inclusive (it is analog, real-time, interconnected with other sectors, and global), models are constructed to narrow scope, ignore dynamics and feedback from outside that scope, and simplify dynamics within it. Naturally, practitioners seek problems that fit their skills and tools; yet the problem of "the grid" incorporates device modeling, reliability modeling, distribution modeling, transmission modeling, capacity investment modeling, demand modeling, macroeconomic modeling, policy modeling, etc. There is no single "model of everything."

There are several potential solutions to this problem, and grid modeling is not the only domain that has similar issues. But, there are several philosophical differences between models and practitioners that make working together exceedingly difficult. For example, some classes of models incorporate only physical phenomena (e.g., device response, failure rates, Kirchhoff's Laws), while others focus on human behavior (e.g., demand response, policy). Economic and financial investment models have elements of both. Most models that focus on physical behavior tend to ignore human behavior, and vice versa. And, it turns out, so do the designers and operators of the models. Thus, in my personal opinion, modeling the grid is more a human factors problem among the various modeling communities and disciplines than it is a technical one.

I would recommend, therefore, that rather than trying to add features to existing models or integrate disparate models together, the heterogeneity of existing models should be leveraged to collectively cover all aspects of the problem. This means that an ensemble of heterogeneous models should be assembled and, rather than force them to interoperate with each other, which would be challenging, they can each model the aspect of the future grid that they are designed to examine in detail: capacity expansion models could look at the conditions that might or might not lead to a particular future state, dispatch models could look at how the operation of that future state might affect electricity prices, reliability models could flag conditions that would lead to systemic failure, etc. This would not be a typical EMF-style model intercomparison effort, in which the outputs of different models of similar type are compared with each other; rather, this is more like a parallel "proof by contrapositive" effort, in which a heterogeneous collection of models examines the same proposed system sate and each one makes a statement about that system's viability. To be successful, such an effort would need tight coordination and careful definitions, while the technical capabilities of the individual models might become only secondarily important.

There is a precedent for this (and not only the parable of the blind men and the elephant). EMF 34 used a heterogeneous collection of energy models, each of which had different insights into the North American energy system, to draw conclusions about potential changes to the system. While no single model represented all of the North American energy system in detail, collectively they yielded more insights than any individual model could alone. The important thing for that effort was to identify common system boundaries and then find the appropriate bases for comparisons. (In that study, it ended up being trade across the national borders.)

Finally, as I mentioned last week in response to a question from the audience, it will be important not to misuse models to explore extreme deviations from historical precedent. Models all make BAU-type assumptions, especially outside their own self-identified system boundaries. Some of these assumptions would not hold in a future system that deviated significantly from history, yet it would take another model with broader scope, perhaps, to perceive this. So, ideally, this heterogeneous ensemble of models (the HEM – quick, NAS should coin that term!) could first explore the ways in which the power system would evolve (or would need to evolve) under a very minor perturbation from either history or the expected future. Where feedbacks occur in one model that challenge ceteris paribus assumptions in another, all models in the ensemble can be updated to incorporate this new knowledge. Then, the ensemble could be used to model successively larger perturbations, updating assumptions after each increase until the desired future state is reached. This process is very (very!) similar to a Bayesian updating process, with the functions being updated being the models in the HEM. To be clear, the HEM is not the same as an IAM (although IAMs could and probably should be included in the HEM), since the models in the HEM would not necessarily be soft- or hard-linked with each other. Coordinating this updating process would be exceedingly challenging, legitimately being "big science." But, modeling the future of the power system is also becoming exceedingly important, as the United States starts exploring a future power system that looks very different from the past and with emerging threats and vulnerabilities that are not similar to past ones. Big science has been the norm in high energy physics for over 40 years and in genomics for 20; there is no reason power system modeling cannot also adopt similar organizational and process techniques that these other fields did.

I hope my comments here are helpful. I would be happy to discuss further, if necessary. And, I apologize for failing to keep my remarks to a single page.

Regards,

David Daniels