TRANSFORMING ELECTRIC GENERATION PLANNING MODELS TO MEET SUSTAINABLE ENERGY POLICY GOALS

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Overview

Today's electric power generation planning models and methods rely on decades-old practices of minimizing costs in order to optimize investment in new generation. These models make rough approximations that have been adequate in a world in which thermal generation was dispatched to meet forecast loads. However, as policies expand to incorporate multiple objectives, including the integration of intermittent renewable resources and targeted customer demand response, those models are rendered obsolete. Without modelling improvements, policy goals seeking to increase sustainable resource options may not be achieved effectively. There is a need to improve model formulations and industry practices to fully capture the need for, and benefits of, system flexibility in the face of short-run variations and forecast error, and long run policy, regulatory, technical, and economic uncertainties.

The paper explores what aspects of existing models need to be updated and the consequences of both maintaining the status quo and improving model capabilities. Current research into improved models will be reviewed for best practices and challenges are identified. Recommendations will be made on how to overcome the challenges in order to develop models that will better optimize mixes of renewable generation, thermal generation, demand response, energy storage, and transmission.

Methods

Through the authors' own professional experiences in modelling and seeking regulatory approval for new generation resources and a survey of recent literature, several gaps have been identified in terms of the ability of generation planning models (1) to provide answers to crucial questions facing planners, investors, and regulators for systems with ambitious renewable energy targets and (2) to represent the features of power systems that are necessary to address those questions. Researchers have proposed planning model formulations that include some of these features, which have been incorporated in some commercial software packages, yet a fully integrative model that can be used for large systems and solved within a reasonable time frame still needs work.

We summarize the new types of questions that are being asked, the model features that are needed to respond to those questions, and the state of the art of academic and commercial planning models. The existing literature is systematically reviewed and critiqued, including mathematical formulations and solution methods, and needs for new modelling developments and better data are identified.

Results

Based upon our review, the following are some conclusions we draw about available and proposed models and their responsiveness to the needs of users.

The operation and planning of systems with high penetrations of intermittent resources is uncharted ground. Although theoretical studies suggest that 80-100% renewable energy is possible, it is not necessarily economical or reliable. Detailed system operational and reliability studies have only been conducted to reach 30% intermittent renewable energy and many electric systems must rely predominantly on intermittent wind and solar resources to meet renewable energy goals. Without improved representations of how the electric system will be operated, the planning and investment models are limited in their ability to assess system performance under high intermittent renewable penetration. The broad brush methods used to advocate ambitious policy goals of 80-100% renewable resources are inadequate for capturing and evaluating system cost and reliability performance in the actual system. Existing models do not fully capture the variability and flexibility characteristics of traditional dispatchable generators, newer renewable resources and customer response alternatives – each of which impacts the overall portfolio of required resources to meet customer demand.

To improve models, it is necessary to rely on formulations that are more faithful to the detailed physical and economic characteristics of resources; use high quality data including interdependencies; and take advantage of increased computational power. Data improvements are needed particularly in assessing costs associate with thermal unit cycling and in determining price elasticity for customer response options. As data availability and use expand in some areas (such as incorporating unit commitment variables or transmission constraint), model approximations in other areas may be needed to provide computational solutions within reasonable time frames.

Existing models underestimate the operating cost implications of intermittent resources (and likely undervalue the contribution of customer demand response and wind curtailments). This is in part due to the subhourly need for system regulation to maintain frequency that is not captured in modelling, as well as inadequate representation of the need for ramping capabilities, increased maintenance due to thermal unit cycling and the implications of wind and solar forecast errors. The cost of required incremental transmission reinforcements can also be underestimated.

Higher amounts of intermittent resources must be accompanied by an increase in system flexibility which needs to be sufficiently captured in modelling such that appropriate resource selection is accomplished. A spectrum of customer demand response is one potentially important source of flexibility, but is rarely represented realistically (in terms of cost and operating characteristics) in comprehensive planning models. Flexibility can also come from fast start, fast ramp, relatively small natural gas generating units; however, these are often the highest cost units and the simplistic modelling parameters neglect to capture their full benefits. Wind curtailments may be modeled in response to transmission congestion, but are rarely modeled as a potential means to reduce high cost frequency regulation.

Regulatory policies requiring least-cost additions may not choose necessary flexible resources as wind penetrations rise, because planning models that use representative system hours do not capture the necessary operating characteristics of fast ramping and actual repeated starts and stops. Incomplete systems of market pricing that rewards the lowest cost producers rather than flexibility may not result in additional flexible resources that have higher energy costs; for instance, markets with long averaging periods (one hour) will suppress within-hour price spikes that would reward resources that can respond to those signals with short notice. Possible market fixes based, for instance, on capacity payments for flexible capacity face difficulties in commensurating resources with very different operating characteristics (for instance, demand response limited to hot seasons and which can only be called on for short periods of time, versus peaking generation without operating hour limitations).

Although maximizing renewable energy output and minimizing system operating costs might seem to be consistent objectives, they actually can be competing, resulting in inefficient outcomes. Subsidized wind development, along with market price support or take-or-pay penalties, along with penalized fossil development can result in over-investment in variable renewable technologies because necessary system operating characteristics are disregarded. Investment decisions should consider the full range of operating services that a resource provides or requires; capturing the entire costs and benefits experienced on the system not just in primary energy markets. To the extent that energy production requires supporting ancillary services, these cost impacts should be factored into the decision to dispatch the offered resource which in-turn will influence the overall investment decisions. This is no more than accurately accounting for the true life-cycle cost of the investment including the system externalities.

Conclusions

The future of electric generation resource investment planning relies on clear policy and more realistic yet practical models that accurately capture the variables needed for optimal decision making. Without clear policy, the models will not optimize the right set of objectives and without improved models, the policy will not be achieved in a cost effective manner. The integration of a greater variety of weather and consumer-dependent resources requires more sophisticated modelling than currently exists. Generation and transmission parameters must be supplemented with weather forecasts and consumer behaviour models. Resource availability must also consider meteorological uncertainty and price elasticity of consumers, as well as their response to non-price incentives and cues. As the electric generation system transforms to include a greater variety of resources, long-term planning models must also keep pace in modelling the necessary operating characteristics and inherent uncertainties of a wider diversity of resources.