Transmission Investment Assessment Under Uncertainty about Fuel Prices, Technology, Renewables Penetration and Market Responses using a Multi-Stage Stochastic Model Approach with Recourse (Year 2)

Project Lead: Hobbs *Co-investigators:* Schuler, Zimmerman

July 20, 2012

1. Project objective

To develop and apply a methodology for evaluating the impact of market, technology, and policy uncertainties upon transmission planning on a regional and multi-decadal time scale. The methodology will integrate transmission capacity expansion decisions and OPF methodologies in a decomposition scheme in order to rigorously capture operational constraints such as security constraints, ramp limitations, and transmission flow limits, as well as longer term investment issues. The methodology would address questions such as the identification of robust transmission investments, the cost of disregarding uncertainty, the value of information, and option values. Response of generation investment and operations to transmission investment is to be accounted for. The intent is to model likely market response over time to transmission investment, taking into account future responses when current uncertainties become known, and to factor those choices into the current investment plans.

2. Major technical accomplishments to be completed this year (FY2012, Oct 2011-Sep 2012)

This year's efforts have been focussed on final model formulation and case study development.

(a) *Finalization of Benders' and successive hedging-based decomposition schemes.* Alternative modified decomposition schemes for coordinating investment and operations will be evaluated using simplified case studies and OPF models based on the CAISO 17 zone systems developed in year 1. Larger-scale testing will be initiated at the Sandia National Laboratory using their Red Mesa 42,000 processor facility, in collaboration with Dr. Jean-Paul Watson of Sandia. We will collaborate with the SuperOPF developers at Cornell to define interfaces that will allow use of the SuperOPF as the subproblem, including development of Benders' cuts based on dual variables in the SuperOPF. Coordination with the two-period generation planning simulations of the Eastern Interconnection that are being conducted by CERTS investigators W. Schulze, et. al., at Cornell, using the SuperOPF, is on-going in anticipation of future integration of methodologies.

(b) *Testing with extensive case study.* For further testing of the decomposition schemes with discrete transmission additions, we will develop a coupled transmission-generation planning problem under uncertainty for the 240 equivalent bus system developed for the WECC by Dr. Jim Price of the CAISO. It is necessary to elaborate the database by defining the characteristics of potential new renewable and thermal generation, opportunities for transmission investment, and scenarios. The linearized OPF models will be reformulated to consider ramp constraints and linearized versions of unit commitment constraints, based on approximations we applied in collaboration with researchers at KU Leuven.

(c) *Assessment of the properties of the successive linearization scheme for continuous transmission capacities, and application testing.* In particular, the convergence and optimality properties will be investigated analytically. We will examine the scheme's possible application to the Eastern Interconnection States' Planning Council study of interregional transmission additions (http://communities.nrri.org/web/eispc) and the European Union 27 model of transmission additions based on the ECN COMPETES model (in cooperation with Ms. Ozge Ozdemir of ECN), showing the impact of considering transmission losses and demand response upon optimal additions.

(d) Test cases based on a simplified version of the study region's system will consider the characterization of the rapid dynamic system impacts of substantial wind penetration, and of how that can be offset by strengthened transmission and/or rapid response storage or conventional generation. The implications of greater system volatility for reserves and ramping capability economics will be explored. We will also explore how realistic representations of transmission constraints in transmission planning affect, in general terms, the costs of compliance with renewable portfolio standards.

3. Deliverables and schedule for activities to be completed under FY2012 funding

(a) A technical report documenting modifications of Benders and successive hedging decomposition schemes and their performance on test systems; the formulation and testing results for the successive linear programming scheme for continuous transmission approximations; and results of test cases examining effect of increased variability and ramp needs associated with high renewable penetration.

(b) Journal and proceedings papers prepared for publication on the results of the project activities. These will include, at a minimum, two submissions to the *IEEE Transactions on Power Systems*, two submissions to the *Journal of Regulatory Economics*, a submission to the HICSS46 conference, two papers presented at the IEEE Power Engineering Society 2012 general meeting. In addition, presentation of project results have been made at the Nov. 2011 INFORMS annual meeting, as well as seminars at MIT and FERC, and a general discussion of potential improvements in planning methodologies which was presented at the Carnegie-Mellon Eighth Annual Conference on the Electricity Industry in March 2012.

The technical report will be prepared in Sept. 2012, while the papers will be submitted during the FY as they are completed.

4. Risk factors affecting timely completion of planned activities

None foreseen.

5. Early thoughts on follow-on work that should be considered for funding in FY2013

Proposed tasks in this year would include model testing and execution. Testing of the Benders or successive hedging coordination schemes would take place using, if feasible, a more sophisticated OPF model (SuperOPF) using its linearized DC version as the subproblem. If this is not feasible, and simpler OPF subproblems must be used, those solutions will be verified by comparison and, if appropriate, calibration against more detailed load flows based upon the Super OPF modelling effort. Application of the methodology to test cases will address questions of the value of information and flexibility in transmission planning, whether future uncertainties significantly affect near-term investments, the cost of disregarding uncertainty in coupled transmission-generation models, and the flexibility and option value of alternative transmission investments.

Another potential effort in FY2013 could address the issue of model aggregation. In particular, we would propose comparing the impact of adding more detail to the WECC network representation, based on work by CERTS investigator D. Tylavsky at ASU, relative to adding additional time periods for a finer grained representation of intertemporal variability of load and renewable production. Additional aggregation issues that could be addressed include number of planning decision stages and number of long-term scenarios. The ultimate criterion is the effect of aggregation on near-term transmission investment decisions, with additional indices of aggregation errors being errors in flows, costs, and generation.