



Analytical Methods for the Study of Investment Strategies in Compliance with Environmental Policy Requirements

Final Project Report

Power Systems Engineering Research Center

*Empowering Minds to Engineer
the Future Electric Energy System*



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PSERC Publication 13-43

September 2013

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Power Systems Engineering Research Center

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Acknowledgements

This is the final report for the Power Systems Engineering Research Center (PSERC) research project titled “Analytical methods for the study of investment strategies in compliance with environmental policy requirements” (project M-28). We express our appreciation for the support provided by PSERC’s industry members and by the National Science Foundation under the Industry / University Cooperative Research Center program.

We wish to thank our industry advisors, who have provided strong support and constructive feedback to our work: Ron Chu (Exelon), Jeff Fleeman (AEP), Liang Min (EPRI), Kip Morison (BCTC), Mahendra Patel (PJM), Mike Swider (New York ISO), and Tongxin Zheng (ISO New England). We are grateful to Jim Price (CAISO) for providing the data for our case study.

Executive Summary

Investment in new generation capacity is critical to maintain the power system's capability to provide reliable and economic electricity to meet the growing demand. For individual generation companies, correctly-timed investment into the appropriate generation technology located at the appropriate site will yield a future stream of beneficial returns over many years to come. Conversely, a misguided investment could lead to unforeseeable and undesirable consequences that not only negatively impact the profitability of the company but also may compromise the reliability of the power system. The pursuit of an effective strategy to formulate profitable investment plans has been one of long interest, yet many existing strategies have limited capability to address some significant challenges. A particularly good example is the inability of many current approaches to explicitly consider the compliance requirements imposed by various environmental policy legislative and regulatory initiatives so as to reduce the environmental impacts of electricity operations. Moreover, uncertainty on both demand side – short-term load variations and long-term growth patterns – and supply side due to the deeper penetration of the variable and intermittent outputs of renewable energy resources introduces major complications in the quantitative measure of the risk and return associated with the investment. The additional sources of uncertainty in the competitive environment further complicate the analysis due to the interactions of the independent decisions of the various market participants and their impacts on grid congestion and the outcomes of transmission constrained electricity market. The objective of this project is to effectively address the many complicating factors in the investment decision-making area with the explicit consideration of the impacts of environmental regulations and of key sources of uncertainty. To meet this objective, we constructed an appropriate analytical framework to facilitate the analysis of the issues so as to lead to the selection of improved investment decisions.

The proposed analytic framework provides the capability to assess the profitability of the investment decision over a longer period by taking into account the ramifications under the considered sources of uncertainty and directly incorporating the compliance requirements of environmental restrictions. The framework makes detailed use of probabilistic and scenario analysis so as to quantify the uncertain outcomes. For example, the methodology can quantify the returns on an investment in intermittent wind generation turbines as well as those on a coal-fired generation unit investment under the various environmental restrictions that impact its operations. Furthermore, the framework is effective in the analysis of *what if* questions to study the impacts of a large number of issues, such as various transmission expansion alternatives, implementation of significant wind generation projects by a competitor generation company, and termination of production tax credits for renewable energy generation.

The modeling framework has a three-layer structure. The decision maker interfaces with the optimization layer through the input of a set of candidate investment plans. The information flow among the three layers allows the comparison of the various alternatives on a consistent basis in line with the decision maker's preferred tradeoff criteria between risk and return in terms of expected value, or worst scenario or maximal regret. The assessment layer analyzes comprehensively each investment plan under the represented sources of uncertainty. The computational engine in the operations and market layer simulates the clearing of the hourly transmission-constrained markets by solving the DCOPF formulation for the market clearing problem. In this way, the analysis explicitly accounts for temporal and spatial correlation among the loads and renewable resource outputs under transmission network constraints. Also, the analysis considers the impacts of the retirement of generation capacity, addition of new capacity, transmission expansion, and load growth. Indeed, the framework allows the ranking of the various alternatives in terms of specified metrics on a meaningful basis. The framework is a practical decision tool to help both planners and investment analysts to make better-informed decisions by explicitly taking into account various sources of uncertainty and the requirements of compliance with environmental regulations.

We illustrate the application of the framework with numerical results from representative case studies carried out on the 240-bus WECC test system. Our studies indicate the effectiveness of the analysis of the decision alternatives by the three-layer framework so as to effectively construct an investment plan in line with the decision maker's preferences. The studies show the sensitivity of alternatives to the technology type, implementation timing, siting location, and generation capacity addition. Results using the proposed framework, with proper visualization, reveal insights into the consequences of an investment plan that could not have been available without the framework. The case study results are particularly useful to understand the impacts of each individual investment company's strategy on the power system's overall generation adequacy in meeting the forecasted loads and in the resulting market performance. The report discusses in detail the analytical basis for the framework, analyzes the case study results and provides an interpretation of the ramifications of investment decisions made with the developed framework. The report also provides directions for future work.

Student Theses: Yanyi He, "Analysis of investment decision making in power systems under environmental regulations and uncertainties," PhD dissertation, Iowa State University, expected September 2013.