PSERC

Economic Impact Assessment of Transmission Enhancement Projects

Final Project Report

Power Systems Engineering Research Center

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Final Report

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PSERC Publication 09-07

September 2009

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Power Systems Engineering Research Center

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Acknowledgements

The Power Systems Engineering Research Center sponsored the research project titled "Economic Impact Assessment of Transmission Enhancement Projects (M-14)." We express our appreciation for the support provided by PSERC's industrial members and by the National Science Foundation under grant NSF EEC-0119301 received under the Industry / University Cooperative Research Center program. Some of the work described in this report was partially supported by the Department of Energy through the Center for Electric Reliability Technology Solutions (CERTS).

Special thanks go to Jim Price at CAISO for his contributions to the research, and for his careful reading and thoughtful comments on this report.

Executive Summary

In this project, we propose a new methodological framework for assessing the economic impact of transmission investment. This framework improves on the current state of art by explicitly modeling strategic responses of generators to transmission investments. Using an economic measure of social benefit, results show that transmission planning should lead rather than follow generation investments. As a result, transmission investments should be treated as infrastructure development in the same general way that roadway investments are used for regional development. An example of such a policy is the Competitive Renewable Energy Zones in Texas for providing transmission that attracts wind generation investment to specific geographic areas. The project developed a game theoretic framework employing a three-stage game for assessing economic value of transmission projects. A paper resulting from this project won the Best Paper in Energy 2008 Award from the Institute for Operations Research and the Management Sciences.* Illustrations in the report help explain the motivation for model development and explain the results.

Development of a general analytic framework for the transmission network investment problem

We introduced a set of appropriate metrics to quantify the improvement attained from transmission investment in terms of welfare for all the participants. The use of these metrics in the evaluation of the impacts of new transmission investments under competition provides meaningful measures of the effects of a modification in the grid over a planning horizon. These measures are particularly useful in transmission planning because they allow for comparison of different transmission investment projects and enables prioritization of the projects. A key element of the proposed framework is the use of an optimization scheme to maximize the social welfare with and without the transmission asset investments under various bidding behaviors of the market players and contracting conditions. We illustrate the application of the proposed framework on the IEEE 24–bus RTS network.

Distributional Impacts, Market Power, and Alternative Economic Criteria for Transmission Investment

In general, transmission investment results in welfare transfers from load pocket generators and generation pocket consumers to load pocket consumers and generation pocket generators. However, load pocket consumers and generation pocket generators cannot simply decide to build a transmission line linking them. Their decision will be subject to scrutiny not only by a regional transmission operator (RTO) and possibly its stakeholder groups, but also by state and federal energy and environmental regulators. In this situation where there are winners and losers, the losers from the transmission investment might block the transmission investment even if it is socially beneficial. In this report, we present illustrative examples showing the diverse distributional impacts of transmission investments and the potential conflict between alternative economic criteria for investment decisions, such as consumer surplus maximization, effectiveness in curbing market power, and social surplus maximization. Furthermore, such decisions are very sensitive to a variety of parameters that could change over time. They also depend on the fuel cost advantage that some generation technologies have over other generation technologies.

The effect of market power on the market outcome of transmission expansion is a critical aspect often ignored in transmission planning. What might be a beneficial transmission project under the old regulated monopoly paradigm may not be so in a competitive environment where generation

* Enzo, Sauma; and Shmuel Oren. "Proactive Planning and Valuation of Transmission Investments in Restructured Electricity Markets." *Journal of Regulatory Economics*, Vol. 30, (2006), pp. 261-290.

and production decisions by profit-seeking generation companies may circumvent the potential economic benefits of a transmission project. We demonstrate with a simple two node examplehow interconnecting a cheap generation area with an expansive generation area may result in flow that is opposite to the expected direction (i.e., from the high cost to the low cost area) which reduces social welfare due to strategic response of generators with market power. The basic lesson from the above analysis is that transmission planning must account for stakeholder incentives and strategic interactions among market participants. The subsequent analysis and proposed methodologies are motivated by the above observations.

Incentives for Investments in Transmission Expansion/Enhancement

1) A Cooperative game approach to cost allocation and incentive design

The thrust of the work on this topic was to explore the development of an incentive mechanism for transmission asset investment. Incentives were designed to address the major challenges of underinvestment in transmission. The sluggishness of transmission construction is because mismatches between those benefitting from the new facilities and those paying for them often deter investment. We formulated the transmission investment problem in a cooperative game framework. Aaddition of new transmission assets can produce improvements in the network, such as congestion relief, that change the market efficiency. Cooperative game theory allows participants to jointly create added value and to receive compensation based upon the individual contribution to the welfare of the system. We proposed an incentive mechanism where the players of the cooperative game were the investors in transmission assets. A planning authority reimbursed these investors by offering them all or part of the social welfare increase brought by their investment. If their return requirements were below the incentives, then they were invited to invest. The entire process was iterative until there were no more investors willing to invest in new transmission assets. We tested the proposed methodology on two systems – the Garver 6-bus system and the 24-bus IEEE Reliability Test System. The results provided useful insights and a solid basis for further testing on larger networks.

2) The effect of FTR allocation on transmission investment incentives

We studied whether generators have the incentive to fund or support incremental social-welfare-improving transmission investments. In particular, we examined how such incentives were affected by the ownership of financial transmission rights (FTRs) by generators. In the context of a two-node network, we showed both (i) that the net exporting generator has the correct incentives to increase the transmission capacity incrementally up to a certain level and (ii) that, although a policy that allocates FTRs to the net exporting generator can be desirable from a social point of view, such a policy would dilute the net-importer-generator's incentives to support transmission expansion. Moreover, if all FTRs were allocated or auctioned off to the net exporting generator, then it is possible to increase both consumer surplus and social welfare while keeping the net exporting generator revenue neutral.

Proactive Planning and Economic Impact Assessment of Transmission Expansion

The interactions between the transmission and the generation systems are a crucial element in the analysis of the optimal way to expand a network. In principle, the true value of transmission is reflected by the gain from trading among interconnected regions. Yet, due to the physical laws of electricity, there are both operational and investment complementarities and substitutabilities between generation and transmission assets. If a generator creating congestion in a line were to expand its generation capacity in order to gain more of the equilibrium market share, this would aggravate the congestion over the line and would increase the value of additional transmission capacity. At the same time, if a generator providing counterflow to the previous line were to expand its generation capacity, then this would result in a decreased transmission value. Market power plays a key role in this context since it will affect how generators respond to transmission investment while seeking to maximize their profit. Such responses may enhance or negate the contribution of transmission investment to social welfare.

We proposed a three-period model to examine how the exercise of local market power by a generator affects both the generating firms' incentives to invest in new generation capacity and the equilibrium investment between the generation and the transmission sectors. The model structure was a social welfare maximization problem subject to market equilibrium constraints characterized as a two-stage equilibrium problem. Under this paradigm, the network planner optimizes the expansion plan while accounting for subsequent generation capacity expansion and the energy spot market outcome.

As a benchmark, we used an idealized (but impractical) integrated resource planning process that co-optimizes investment in transmission and generation so as to maximize social welfare. We considered both a fully vertically integrated social planer (FVISP) who both optimized investment in transmission and generation, and operates the resources in real time to maximize social welfare versus an integrated resource planner (IRP) who optimized investment while anticipating the strategic interaction of the privately owned generation firms in the energy market.

We then show that a "proactive" system operator - PSO (who plans transmission investments in anticipation of generation investments so that it is able to induce a more socially-efficient Nash equilibrium of generation capacities) can recoup some of the welfare lost due to the unbundling of the generation and the transmission investment decisions by proactively expanding transmission capacity. Conversely, we show that a "reactive" system operator - RSO (who plans transmission investments only considering the currently installed generation capacities and, in this way, ignoring the interrelationship between the transmission and the generation investments) foregoes this opportunity and may make suboptimal investment decisions.

The results are illustrated using a 30-bus test case. The results suggest that transmission planning should be done with a centralized regional planning perspective that accounts for all subsequent decentralized decisions by stakeholders in the investment and operations stages of a market and attempts to influence these decisions. This view represents a departure from the "generation centric" approach that favors decentralized merchant driven transmission planning and view the role of transmission expansion to provide interconnection services in response to investment decisions by generators.