A COMPREHENSIVE COST BENEFIT ANALYSIS OF TRANSMISSION PROJECTS

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Overview

The paper describes an engineering economic methodology underlying the cost benefit analysis of regional transmission projects. The primary emphasis is placed on the benefit side of the analysis since the cost side is typically much less uncertain. In general terms, the benefit is defined as the change in social welfare due to the transmission upgrade. Since demand is assumed to be inelastic, the increase in social welfare equals the decrease in total supply cost.

What makes economic analysis of transmission expansion projects in high voltage transmission systems so interesting and challenging is that they often affect a wide geographical footprint. Moreover, the project benefits vary significantly with the change of geography and/or regulatory jurisdiction. Adding a transmission line to the existing grid system does not only increase the transfer capability between two newly connected points, but makes a more complex indirect impact on transfer capabilities between other points on the grid, leading to changes in patterns of flow and congestion. Short term changes in flow patterns are accompanied by changes in generation dispatch and prices. These changes in the longer term lead to shifts in generation capacity expansion, fuel consumptions and environmental impacts.

Practical experience indicates that no single analytical tool presently exists that would allow to address all the above discussed complexities at once. Instead, a complete and comprehensive analysis could only be carried out with the use of a set of analytical tools and models.

The described methodology is illustrated using the case study of the_Wichita to Reno County transmission project within the Westar Energy Company's service territory in Kansas.

Methods

Using a case study of the Wichita to Reno County transmission project within the Westar Energy Company's (Westar) service territory in Kansas, the paper discusses an application of a set of analytical tools including MAPS Workbench, GE MAPS, PowerWorld, and NEEM. Benefits are assessed by comparing results of long-term market simulations for the two scenarios, the Base Case with no transmission upgrades and the Change Case incorporating transmission upgrades being analyzed. Westar service territory is a part of Southwest Power Pool (SPP). Thus, benefits were assessed for three expanding footprints, starting from the Westar service territory to the State of Kansas and further to the SPP system. Simulations were conducted for the entire Eastern Interconnection. Given the life of a transmission project, the analysis was done for years 2009 through 2019.

The primary benefit criterion used is the change in Total Supply Cost between to the two cases developed for Westar territory and for the entire SPP footprint. This criterion measures the change in the cost of generation installed within the footprint plus costs of imported power from outside the footprint minus revenues from exports outside of the footprint. Given the regulatory structure in Kansas, the change in Total Supply Cost accurately reflects the benefit that consumers will receive from the transmission project, as the change in the regulated cost of generation adjusted by revenues from net off-system sales. At the same time, change in Total Supply Costs is a correct theoretical economics indicator, because it could be shown that it is precisely equal to the Change in Social Welfare within the footprint.

Other metrics used to supplement the Total Supply Cost were the Cost Impact on the Loads measured as the change in the cost of served energy, Generating Revenue Impacts on Producers measured as the change in generators' margin, Surplus Congestion Revenue (impacts on cost of congestion in terms of change in electricity wholesale prices), and the Impact on Social Welfare. The latter is measured as the difference between the change in generators' margins and the cost of served load and adjusted by the change in Surplus Congestion Revenues and as stated earlier is exactly equal to the change in Total Supply Costs.

The above metrics are calculated hourly and aggregated annually. Annual results are then used to compute the net present value benefits over an eleven year period 2009-2019. Benefits are then compared to estimated cost of the project.

Hourly computation of benefit metrics and their annual aggregations were carried using MAPS Workbench (CRA International). MAPS Workbench is an analytical framework for post-processing of the hourly generation dispatch, power flow, cost and price information produced by GE MAPS.

Other metrics analyzed are congestion patterns across major flowgates in the system.

GE MAPS (General Electric) is a least-cost security constrained unit commitment and dispatch model used to conduct hourly chronological simulations of the Eastern Interconnection for each year of the study period. The output of GE MAPS essential for this analysis include locational marginal prices at every generator node, every load center and every monitored tie-line between neighboring control areas, hourly generation, costs, revenues, fuel use and emissions by unit, hourly load by control area, hourly flows across tie-lines. Critical inputs to GE MAPS are transmission topology in the form of the solved load flow, generation expansion forecast and projections of fuel and emission allowance prices. These inputs are derived from other models as discussed below.

The preparation of the loadflow was done using PowerWorld (PowerWorld Corporation). The impact of the change in transmission topology due to upgrades in question on power flow in Eastern Interconnection was analyzed by adding the projected line(s) to a solved loadflow and resolving the loadflow, assuming no changes on the supply and demand side of the system. Every physical detail of the project starting from line characteristics (voltage level, impedance etc) to related equipment upgrades (transformers, capacitors etc) and changes (opening of an existing circuit or retirement of existing equipment) is implemented into the new loadflow. The addition of the line, when the new loadflow is solved, results in different transmission topology and flow patterns that lead to different transfers between various regions.

Capacity expansion forecast, emission allowance prices, and coal price projection is prepared using NEEM (CRA International). NEEM is a unique long-term capacity expansion and emissions impact analysis tool. In general, it could be used to assess the impact of the transmission upgrade on environmental allowance prices, fuel prices, and new generation expansion, including mothballing, retrofitting, and retirements of generation units. In this case, however, no major impact of transmission upgrade on these factors was identified and the same capacity expansion forecast was used for the Base and Change cases. NEEM, which looks into the economics for a long term (over 30 years) derives the most economically efficient solution for capacity expansion needed to satisfy reliability standards and other regulatory requirements such as the Clean Air Interstate Rule, Renewable Portfolio Standards or local emission restrictions. The long run cost to be minimized includes those related to short term operation such as fuel switching and emission control, and longer term capital decision such as new builds, retirements, mothballing and retrofits due to environmental compliance. The output of NEEM is allowance prices, new capacity additions and retirements (including mothballing), retrofits including change in variable operation and maintenance cost (VOM), and delivered coal prices.

A fuel forecast needed for NEEM and GE MAPS is developed using GASCAST and OILCAST (CRA International). GASCAST is a model that calculates forward gas prices on a monthly-locational (often state or utility level) basis. It takes available forward data such as NYMEX clearings for Henry Hub and regional trading hubs for the short to mid term, and the forecast from EIA’s Annual Energy Outlook for the long term. By combining forward prices and CRA derived regression models , GASCAST calculates forward gas prices on a monthly-locational (often state or utility level) basis. OILCAST forecasts both fuel oil #2 and #6 prices in a similar manner.

It is important to recognize that all input data for these different types of models are synchronized. For example, if the load projection used in NEEM do not match that in MAPS, the NEEM results cannot be used in MAPS. The need to synchronize the different models is one of the major difficulties of this comprehensive modelling excersize.

Results

The study identified substantial economic benefits of the Wichita to Reno County Project transmission upgrade project and formed a foundation of the testimony of Dr. Richard D. Tabors on behalf of Westar Energy Company before the Kansas Corporation Commission (KCC). KCC subsequently approved the project.

Conclusions

The US power industry faces numerous challenges created by the dynamics in the quality, level and geography of incremental demand for power, by changed in the economics of existing generation technologies related to market fundamentals in generation fuels and environmental control policies, by emerging generations technologies, and by the variety of power markets already in place and in the making. Substantial upgrades to the U.S. transmission system are needs in the next decade and beyond. Transmission expansion planning moves from the relatively local domain of the utility planning level toward a broadly regional geographical scope often crossing multiple regulatory jurisdictions and market structures. Robust and unambiguous methods are needed to assist planners, regulators and other stake-holders in developing sound transmission expansion strategies. The methodology discussed above meets these requiresment. It adequately addresses the complexity of the system and provides a combinations of tools and analyses using these tools which lead to solutions grounded in engineering economics of power systems, it correctly captures long-term benefits created by transmission expansion projects and traces these benefits across geographical and administrative boundaries such as control areas, states and broad market regions. At the same time, it measures the impact of transmission upgrades on various market segments within each footprint.