Consideration of the Appropriate Economic Measure for Evaluating Transmission Projects in ERCOT

ERCOT Regional Planning

I. Introduction

At any given moment, electricity is flowing from hundreds of generating units to thousands of distribution substations across ERCOT's 38,000 miles of high voltage transmission lines. Once the electricity is generated, the laws of physics dictate the path each electron takes. As customer demand rises, and generating units produce more energy in response, the energy flowing on certain lines can reach the limits of what the system can reliably support. In response, the output at specific generating plants must be changed in order to reduce the loading on stressed lines. This is the nature of congestion – when output from less expensive generating units is replaced by output from more expensive units in order to relieve loading on transmission lines. The cost associated with this congestion is the price difference between power generated by the expensive units and the power that could have been produced by the cheaper units.

Transmission planners work to relieve this congestion in order to make the electricity market more efficient. However, different parties that utilize the transmission system realize different benefits from transmission improvements. Transmission operators earn revenue requirements on new capital improvements in their systems. Some generators are harmed by congestion – when they cannot deliver their output to consumers. Other generators can benefit from congestion, when it limits the output of low-cost, more-efficient competition. Consumers pay for capital improvements to the transmission system, but consumers also benefit from reduced electricity prices when congestion is relieved. All of these market participants rely on an efficient, reliable and robust transmission system in order to sustain the economy and ensure our quality of life. It is the responsibility of the transmission planner to improve the transmission system to the benefit of all users.

Depending on the type of electricity market that is superimposed on the physical transmission system, the impact of congestion to customers and generators can be more complicated. This paper is a discussion of the impact of congestion on the electricity market in ERCOT, and, the appropriate economic measure for evaluating the benefits of transmission improvements.

II. Economic theory

A. Consumer and Producer Surplus

Diagram 1 shows the supply and demand curves for a generic product. The supply curve shows the prices at which the set of producers in the market are willing to produce different quantities of the product. The demand curve shows the quantities that potential consumers of the product would be willing to consume at different prices. The market is at equilibrium with a market clearing price equal to p and the quantity bought and sold at that price is q.

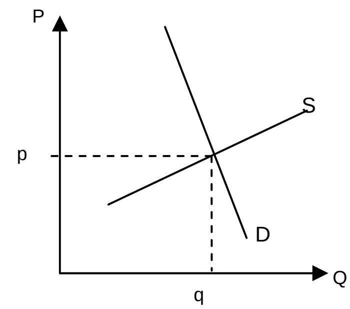

Diagram 1

The economic value (EV) of a product is equal to the sum of the Consumer Surplus (CS) and Producer Surplus (PS; these and other terms are defined in Appendix A). In other words, the total economic value of a product will be shared among consumers and producers. The economic value is also called the Societal Surplus.

The consumer surplus is shown graphically on Diagram 2 as the area (denoted CS) between the demand curve and the price axis above the equilibrium price p. The producer surplus is shown on Diagram 2 as the area (denoted PS) between the supply curve and the price axis below the equilibrium price p.

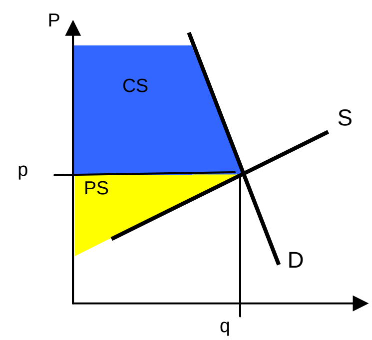

Diagram 2

To understand the meaning of these surpluses, consider the market for a product which has a market clearing price p, as shown in Diagram 3. Looking along the supply curve, there is a set of producers who would have been willing to produce the first quantity q1 of the product and sell it at a price of p1. These producers have a surplus, due to the fact that they are paid the market clearing price p for that quantity q1. Similarly, there is some subset of consumers that would have been willing to pay more than the market clearing price for a smaller quantity of the product. These consumers have a surplus, because they pay a lower price, q, than what they would have been willing to pay.

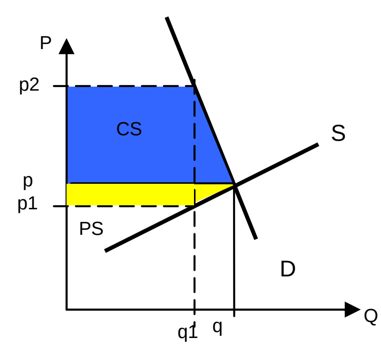

Diagram 3

B. Application to Transmission Upgrades

Suppose there is a transmission limitation between two areas of the power system, Areas A and B, both of which have load and generation. Further suppose that electricity can be produced at a lower cost in Area A than in Area B. A transmission upgrade, such as a new transmission line between the two areas, will allow more electricity to be produced in area A and transported to area B. Such an upgrade will increase the societal surplus of the product because after the upgrade the same demand can be served at a lower cost. This upgrade will also affect the distribution of the surplus among consumers and producers:

$$\text{Societal Surplus before the Upgrade} = SS0 = CS0 + PS0 \qquad (1)$$

$$\text{Societal Surplus after the Upgrade} = SS1 = CS1 + PS1 \qquad (2)$$

The incremental societal surplus due to a project:

$$ISS = SS1 - SS0$$

$$ISS = (CS1 + PS1) - (CS0 + PS0)$$

$$ISS = (CS1 - CS0) + (PS1 - PS0) \qquad (3)$$

Equation 3 shows that the change in the Societal Surplus resulting from a project is equal to the sum of the changes in the consumer and producer surpluses.

In many deregulated electricity markets, consumers pay the cost of electricity at their location (their zonal or nodal price), and producers are paid the value of electricity at their location. If there is congestion between the producers' and the consumers' locations, the two prices may not be the same.

However, these deregulated electricity markets also have transmission allocation procedures (such as transmission congestion rights or financial transmission rights) that allow market participants to manage their exposure to congestion. In an efficient market, these instruments will be appropriately valued at a price equivalent to the expected congestion cost between two points. If the proceeds from their sale are returned to the consumers, then the net effect on consumers of congestion costs and the proceeds from the sale of transmission rights, in the aggregate, is zero.

As a result, it is a reasonable simplification to assume that changes in consumer costs are equivalent to changes in producer revenue. Assuming the exact same demand (i.e., hourly load) is served before and after the project, the increase in consumer surplus due to the project will equal the difference in how much they paid for the product. Thus the first component on the right part of equation 3 can be rewritten as:

$$CS1 - CS0 = PR0 - PR1 \qquad (4)$$

where PR represents Producer Revenue. This equation states that the change in consumers' costs is the same as the change in generator's revenue.

The Producer Surplus is equal to the Producer Revenue (PR) minus Production (or Producer) cost (PC):

$$PS = PR - PC \qquad (5)$$

As a result:

$$PS1 = PR1 - PC1$$

$$PS0 = PR0 - PC0$$

Subtracting the two equations:

$$PS1 - PS0 = (PR1 - PC1) - (PR0 - PC0)$$

Which can be rewritten as:

$$PS1 - PS0 = (PR1 - PR0) + (PC0 - PC1) \qquad (6)$$

Equation 6 shows that the change in Producer surplus comes from two sources: changes in producer revenues and production costs.

Substituting equations 4 and 6 into equation 3 results in:

$$ISS = (CS1 - CS0) + (PS1 - PS0)$$

$$= (PR0 - PR1) + (PR1 - PR0) + (PC0 - PC1)$$

Or:

$$ISS = PC0 - PC1 \qquad (7)$$

Equation 7 shows that the incremental societal surplus, or in other words, the value of a project to the marketplace, is equal to the production cost savings due to the project, provided that the total demand served is unchanged.

In summary, the total project value (ISS) to the market is equal to the production cost reduction due to the project (equation 7). This project value is shared by the consumer and the producers (equation 3). The consumer's portion of the incremental economic value (CS) is equal to the reduction in producer's revenue (PR) (Equation 4).

C. Costs and Benefits of Transmission Projects

Improvements to the transmission system, whether they are driven by reliability or economics, have an impact on the efficiency of the overall system. Each transmission project has a construction cost, and each project in turn results in changes in the way generating units are committed and dispatched. Transmission upgrades will also affect energy losses incurred by the system. Transmission projects can have other benefits as well, including improving the system's resistance to sudden voltage swings, and increased flexibility to resolve emergency situations. To the extent that these additional benefits can be assigned costs or cost savings, they can be included in this analysis. The true cost of a transmission upgrade is the sum of its incremental construction and operating costs, as well as any savings (or costs) that result from changes in how the system as a whole is operated.

For reliability-driven projects, if there is more than one acceptable alternative, the costs of all solutions (both the construction costs and the resulting changes in production costs) must be determined in order to select the option that has the lowest cost (or greatest benefit) to society. For economic-driven projects, there is one additional alternative than for reliability-driven projects: no change to the system. As defined, a proposed transmission system upgrade is economic if the transmission system can be operated reliably with changes to the output of generation units. The costs associated with the no-change alternative are the additional generation production costs required to relieve the excess loading on the affected lines. The total additional production costs of the no-change alternative can be compared with the net benefit of each proposed solution to determine the project that provides the maximum societal benefit.

III. ERCOT Regulatory and Market Environment

ERCOT has a "postage stamp" system for recovery of transmission investment. All load-serving entities in ERCOT pay at the same rate, equal to the sum of the Transmission Cost of Service (TCOS) of all transmission service providers (TSPs) multiplied by the ratio of the LSE's four-month summer average coincident peak and divided by the total ERCOT four-month summer average peak. TSPs can request that new in-service transmission investments be added to their TCOS on an annual basis. As a result, the costs of the transmission system (including all approved transmission improvements) are paid by all electricity customers throughout ERCOT.

The Public Utility Commission of Texas Substantive Rules state that TSPs shall "…endeavor to construct and place into service sufficient transmission capacity to ensure adequacy and reliability of the network to deliver power to transmission service customer loads. The TSP will plan, construct, operate, and maintain facilities that are needed to relieve transmission constraints…[1]" These rules make the TSPs responsible for constructing and maintaining an adequate transmission system. Payment for the resulting system is the responsibility of the electricity customer.

These rules do not contain a provision for a group of market participants to pay for improvements to the transmission system. Although some transmission improvement projects in ERCOT may be shown to benefit certain

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1 P.U.C. SUBST. R. 25.195(b)

market participants, such as generators or customers in specific geographic regions, there is no provision to require these market participants to compensate other parties for their share of the benefits, or to allow these market participants to develop and fund improvements that serve their own interests.

IV. Project Analysis Methodology

A. System Modeling

Timing is an important issue in transmission planning. Large transmission projects, especially ones that involve establishing new rights-of-way, can take as long as six years to complete. In the meantime, factors that have a significant impact on the usage of transmission facilities are likely to change. These factors include: customer demand (loads), generation locations, and generation commitment and dispatch (as a result of changes in fuel prices, environmental regulations, or other factors). Given these changes in system usage, it is not appropriate to rely solely on current ERCOT operational system data to quantify the expected economic benefits resulting from future transmission upgrades. Current system conditions may be very different from conditions six years from now. Instead, economic benefits must be evaluated using a simulation that incorporates all the planned changes in the electric system, i.e., one that represents the expected state of the electric system when the proposed transmission project will be completed.

The lead-time required to complete large transmission projects also means that if congestion is already present in the system, it will likely be several years before it can be alleviated. Planning models allow analysts to proactively study the expected impacts of transmission projects and to develop projects that will cost-effectively reduce system congestion in a timely manner.

System modeling has limitations. Long-range models are heavily dependent on input assumptions, such as forecasts of customer loads, generation capacities (additions, modifications, and retirements), fuel costs, availability of new technologies, and regional economic growth. However, using sensitivity analyses, the societal benefits of transmission projects can be determined under a range of likely future input scenarios.

The economic benefits of transmission projects in ERCOT are evaluated using a simulation of an efficient "marginal-cost" dispatch, one in which generating units bid their variable marginal costs and all customers are served by the least expensive available supplier, subject to security transmission constraints. Real electricity markets, due to contractual capital costs and other reasons, do not behave exactly as simulated. However, economists generally concur that efficient mature markets should motivate producers to bid close to their marginal costs.

In addition, even though there is no such thing as a perfectly efficient electricity market, consumers are likely to take advantage of cost-savings opportunities. As such, transmission projects that provide societal benefits in a market with security-constrained unit commitment and economic dispatch are likely to provide similar benefits regardless of market design.

B. Annual Economic Benefits

Once a transmission project is completed, the benefits from reduced production costs can be expected to be realized for many years. However, the actual benefits from transmission projects may be more or less than predicted. In order to ensure that economic transmission projects are cost-effective, it is important that the expected long-term benefits from a project significantly outweigh the construction costs, to compensate for inherent modeling uncertainties. So, even though the benefits from transmission projects can be expected to continue for many years, ERCOT only recommends projects that provide sufficient production cost savings to compensate for construction expenses within six years.

A six-year payback standard also ensures that each approved economic transmission project will compensate for the increased capital costs uplifted to the customer. Depending on the Transmission Service Provider involved, the first-year incremental revenue requirement from capital upgrades currently ranges from 15% to 17% of the construction cost of a project. A six-year payback requirement is equivalent to annual production costs savings of 17% of the construction costs of the project.

C. Determining the Distribution of Benefits

As shown in Section IIB above, the benefits to society (incremental societal surplus) from transmission improvements are equivalent to changes in total production costs less the project construction costs. This surplus is shared by market participants, i.e., consumers and producers (generators). The term “benefits to producers” resulting from a transmission project is defined as the change in generator operating income (the difference between generator revenue and costs). The term “benefits to consumers” is defined as the change in consumer costs and is equivalent to the change in producer revenue, i.e., the costs paid to generators to produce electricity. Determining the allocation of benefits from transmission upgrades can be complicated, and the results are highly dependent on starting and ending conditions, generator bidding behavior, and other issues. In actual electricity markets, it can be difficult, if not impossible, to predict which market segments will benefit from specific transmission improvements. However, the overall societal benefit (the projected reduction in production cost less the cost of the transmission improvement) is more consistent and can be calculated with available production costing tools.

D. Economic Project Justification

There is general industry consensus that changes in production costs are the appropriate primary justification for economic transmission projects. Economic theory dictates that production cost changes represent the benefits of transmission improvements to society as a whole. By using production-cost changes as the primary criteria for transmission project cost-benefit analyses, ERCOT procedures are consistent with those of many other Regional Transmission Operators and Independent System Operators in the United States (including the California ISO[2], the Southwest Power Pool[3], and the New York ISO[4]).

Other organizations conduct further analyses to determine the market segments that are likely to benefit from transmission improvements, in order to allocate costs to specific entities. In ERCOT, load serving entities and their customers pay the costs of all transmission improvements. There is no mechanism for ERCOT to allocate costs for new transmission projects to specific market participants.

Since the customer pays for all transmission improvements in ERCOT, it may seem reasonable to require that economic-driven transmission improvements result in sufficient savings to the customer (i.e., reductions in generator revenue) to cover the cost of the improvement. Such reasoning is inappropriate. Because there is no mechanism in ERCOT to allow generators to fund specific network improvements, applying this additional criterion would likely lead to reduced investment in new generation. An example may help to illustrate this concept. Consider the situation in which a new, efficient generating unit is constructed in an unconstrained part of the system. A short time later, another new, slightly more-efficient generator is constructed nearby, and due to a limitation in the transmission system, the two generators cannot simultaneously generate at their maximum capacity. Presuming that the generators are not large enough to significantly affect the prevailing prices on the other side of the constraint, improving the transmission system to eliminate the constraint would result in decreased production costs but would not reduce consumer costs. The application of an additional consumer savings criterion would rule out such an upgrade, and as a result, the older, yet relatively low-cost generator would be curtailed in the market – even though the upgrade would have a positive savings from a societal standpoint.

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2 See discussion of societal benefits from transmission projects in: Transmission Economic Assessment Methodology (TEAM), California Independent System Operator, June 2004. http://www2.caiso.com/docs/ 2004/06/03/2004060313241622985.pdf

3 Southwest Power Pool Planning Documents available at: http://www.spp.org/Objects/Engineer.cfm

4 Measures of congestion costs defined in: NYISO Congestion Cost Metrics, April, 2005. Available at: http://www.nyiso.org/public/webdocs/services/planning/congestion_costs/misc/congestion_ metrics_042505.pdf

Producers must have a reasonable expectation that they will have fair and efficient access to consumers in order for them to justify investments in new generation. As shown in this example, requiring that all economic-driven transmission upgrades provide not only sufficient societal benefits, but also sufficient consumer savings, could lead to efficient generators being constrained, and could reduce investment in new generation. In the long-term, this reduced investment would lead to increased wholesale electricity prices.

The customer ultimately pays for all aspects of the energy market: for the costs of plant operations, for the transmission system, and for profits for market participants. It is in the long-term interest of customers that power producers earn a suitable rate of return on their capital investments, so that customers can continue to benefit from investments in new generation technologies.

In some ways, the fact that there is no mechanism for ERCOT to allocate costs to specific market segments makes the process of transmission planning easier in that ERCOT can rely solely on production costs as the justification for economic transmission projects. However, this over-simplifies the issue. Over the long-term, ERCOT has an obligation, since costs cannot be allocated to individual parties or market segments, to ensure that the transmission system is improved to the benefit of all market participants.

V. Conclusions

ERCOT uses the expected change in generation production costs to determine the economic benefits from transmission improvements, since this is the measure of the incremental benefits of the project to society. For all proposed system improvements, the construction costs of the project are compared to long-term changes in production costs in order to select the most cost-effective projects to maintain the reliability and efficiency of the ERCOT transmission system. In order to ensure that the expected economic benefits will be realized by market participants, only economic projects that have an annual production cost savings greater than the annual carrying cost of the project will be recommended by ERCOT. ERCOT does not use economic benefits to specific geographic areas or market segments as criteria for recommending proposed transmission improvements. Instead, the economic justification of a transmission improvement is based on the benefits of the improvement to society, which should result in the greatest benefits to consumers over the long term.

APPENDIX A - DEFINITIONS

A. Congestion

Any state where the optimal security constrained dispatch is more expensive than a pure economic system dispatch (in other words, an optimal unconstrained system dispatch). Transmission system congestion causes generating units in the system to be dispatched differently from the most economic solution, and, as a result, increases total system production cost.

B. Congestion Price

The difference in nodal prices between two buses in a transmission system.

C. Consumer Surplus

The difference between the maximum amount that consumers are willing to pay for a product and the actual amount consumer pay for the product. The maximum amount that the consumer is willing to pay is called the product's value to customer; the actual amount that consumers pay is called the market clearing price or market price.

D. Customer Cost

The cost paid by customers for electricity. This cost is equal to or greater than generator revenue. The difference between customer cost and generator revenue is the result of congestion in the transmission system.

E. Economic Transmission Project

A transmission upgrade project that solves a reliability criteria violation which could otherwise be solved through redispatch of generation units. The cost-effectiveness of economic transmission projects must be determined to ensure that only projects that save more in generation redispatch costs than the cost of the project are approved.

F. Marginal Congestion Cost

The difference between consumer cost and producer revenue. The marginal congestion cost (MCC) for a transmission system can be calculated in two ways: The MCC is equal to the sum of the flow on each transmission line times the difference in the nodal prices at the buses on each end of the line; the MCC also equals the sum of each line's capacity multiplied by the shadow price of the line.

G. Marginal Cost

At any given moment, the cost of producing one more megawatt-hour of electricity at a generating unit.

H. Megawatt-hour

A unit of electricity equal to one-megawatt used or produced for the period of one hour.

I. Nodal Price

The minimum change in the total system hourly production cost if one more megawatt-hour of electricity were required at a specific location (node or bus) on the transmission system.

J. Producer Revenue

The revenue received by producers (i.e., generators) for the electricity produced. The difference between production cost (what it costs to produce electricity) and generator revenue (what the generators are paid) is generator income or producer surplus.

K. Producer Surplus

The difference between producer revenue (what the generators are paid for the electricity they produce) and the cost to produce the electricity.

L. Production Cost

The actual cost to produce electricity summed over some time period. Includes fuel cost, variable unit operations and maintenance, and unit startup costs.

M. Reliability-Driven Transmission Project

A transmission upgrade project that is designed to solve reliability criteria violations which cannot be solved through any feasible changes in generating unit outputs, regardless of cost.

N. Shadow Price (of a transmission line)

The maximum reduction in the total system hourly production cost due to one MW increase of capacity of a transmission line.

O. Societal Surplus

The total value to society of a product. This value equals the maximum amount the consumer is willing to pay for the product minus the production cost of the product. By definition, Societal Surplus is equal to the sum of the Consumer Surplus and Producer Surplus.

P. Variable Cost

The hourly electricity production costs that are directly tied to the level of unit operation. Variable cost does not include fixed costs, which are costs that would be incurred whether the unit generates electricity or not (such as the cost of financing a unit, property tax, the cost of security and custodial staff, etc.). The sum of variable costs over time is the production cost.