Impact of Market Prices on the Economic Feasibility of Transmission Expansions

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Abstract-- **The economic viability of transmission expansion is a function of market prices throughout the impacted region. Various methods have been utilized to simulate market prices. This article summarizes an empirical approach developed by the California Independent System Operators (CAISO) using dynamic bids that change hourly based on system conditions and the relative influence of critical suppliers.**

Index Terms— **Economic transmission expansion, transmission benefit, nodal prices, congestion costs, residual supply index, LMP.**

I. INTRODUCTION

Transmission expansion has generally been evaluated from either a "reliability" or "economic" perspective. Most of the existing transmission system has been justified using reliability criteria (i.e. the transmission line is required to deliver generation to load or to meet reliability criteria set by NERC, the regional reliability council, or the applicable ISO). In fewer cases, the transmission expansion has been justified using economic criteria. For economic evaluations, the benefit of the proposed transmission expansion is compared against its expected capital and operating cost. If the present value of benefits exceeds the present value of costs, the project is considered economically viable.

Traditionally, these economic studies have employed a production-costing simulation solution to determine the total system costs before, and after, the transmission upgrade. This difference in systems costs represents the value of the transmission project. The shortcoming of using production costs is that the market bids are frequently greater than the underlying marginal costs, thus potentially underestimating the value of the proposed upgrade and misallocating the benefits to the various market participants. This paper will focus on the development of market prices for the evaluation of transmission upgrades. Specifically, the paper will briefly discuss: (a) the value of including market prices in the analysis; (b) alternative methods for developing the market price forecast; and, (c) an example of simulating market prices prepared by the California Independent System Operator (CAISO). The authors were directly involved in the CAISO study as the Project Manager and supervising CAISO Director respectively.

II. VALUE OF SIMULATING MARKET PRICES

The use of marginal costs as a proxy for generator bids can be an important starting point for the economic evaluation of potential transmission additions. Considerable insight can be gained regarding the benefit of the upgrade by understanding its use and value in a perfectly competitive market. If the transmission upgrade is economically viable using only marginal costs, then the upgrade would generally become more attractive if market prices were simulated.

There are several primary reasons why market prices are simulated. First, there is often a significant difference between marginal costs and market prices. In those cases where the upgrade may not be economically compelling in a cost-based simulation, the economics may be more favorable in a market-based simulation. Second, understanding the value of the upgrade to various potential participants may be important in order to determine an appropriate sharing of costs and benefits.

For example, a methodology developed by the California Independent system Operator (CAISO Methodology) analyzed the economic viability of proposed transmission upgrades from the multiple perspectives including the following:[1]

- Societal (in this case, WECC)
- CAISO ratepayers (or consumers)
- CAISO participants (includes all market participants)

In an example study performed by CAISO and submitted to the California Public Utilities Commission (CPUC), the societal or WECC benefits for a potential transmission upgrade increased almost 500 percent as the market assumptions were changed from a perfectly competitive market to one where there is significant market power.[2]

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[1] The CAISO spent several years developing and refining a methodology to evaluate the economic viability of proposed upgrades. This analytical approach is referred to as the "Transmission Evaluation and Assessment Methodology" or TEAM. The methodology was filed in a report to the California Public Utility Commission in June, 2003, and can be found on the CAISO website at: http://www2.caiso.com/docs/2003/03/18/2003031815303519270.html, see presentation entitled Transmission Economic Assessment Methodology Report (CAISO TEAM Report).

[2] CAISO presentation at July 15, 2004 CPUC Workshop, "Supplement– Updated Results and Recommendations", J. Chen, E. Toolson, p. 29 (CAISO Supplement). Presentation can be on the CAISO website at: http://www2.caiso.com/docs/2003/03/18/2003031815303519270.html, see

This change was even more dramatic for the CAISO Ratepayer and Participant perspectives, where the benefits changed from being negative to a significant positive amount that was comparable to the annual fixed and capital costs.[3] Thus, it can be crucial to simulate market prices instead of marginal costs to determine a more accurate measurement of total benefits and the benefit allocation among participants.

III. Alternative Methods for Developing Market Price Forecast

The evolution of simulating market prices in regional fundamental models started with "marginal-cost" generator bids, moved forward to "static" bids, and ultimately advanced to "dynamic" bids. Static bids involve developing a bid strategy for each generating unit in based on perceptions about that unit's market power opportunities. These bids do not change throughout the course of the day, and they may not change during the month, season, or even year. The advantage of this technique is that it is more accurate than a marginal-cost bid and it reflects some market power opportunities. The disadvantage with the static bid is that it does not reflect the hour-to-hour changes in system parameters such as load, generator availability, transmission capability, and dominant suppliers that play a tremendous role in setting market prices. Many models today employ some type of static bid that changes infrequently.

Dynamic bids can change hourly (or more frequently if the time step is less than one hour) based on the system parameters and market dynamics. The advantage is that the dynamic bids are much more reflective of the actual marketplace. The disadvantage is that they can be more difficult to define and implement than static bids.

There are several options for developing dynamic bids. These include:

- Game theory models
- Empirical models based on historical market information

Game theory models simulate future strategic bidding and do not rely on historical observations. Generally these models consist of several strategic suppliers with each player seeking to maximize its expected profit by changing its bidding strategy in response to the bidding strategies of other players. The advantage of game theory models is that they can simulate market power under a variety of future market conditions that have not been historically observed.[4]

Game theory models such as Cournot, Bertrand, and Supply Function Equilibrium have been implemented in some commercial market simulation models.[5] These models need to be structured so that they can converge to a solution. In order for a game theory model to solve in a timely manner, the model must be fairly simple in terms of network representation and the type of bidding strategies represented. Often, a basic network model of no more than 3 or 4 network nodes is used. The game theory approach faces significant technical challenges in terms of modeling supplier behavior in a full-network model.[6]

Empirical models rely on the observed historical relationships between specific market variables and the resulting level of market power (i.e. the difference between competitive and observed prices, or competitive and actual bids). The advantage of this empirical approach is that it has a strong historical basis and that it can be applied to a more detailed transmission network representation. An empirical approach is described in more detail in the following section since it was the methodology selected for the example study.

IV. Example Study Using an Empirical Approach for Simulating Market Prices

The CAISO developed an example study to illustrate its methodology for forecasting nodal market-clearing prices and evaluating the economic feasibility of proposed transmission expansions. The example study evaluated the expected benefit, as well as the distribution of benefits, for a proposed upgrade of a major interconnection between Central and Southern California (Path 26).[7]

The CAISO Methodology is built on several "key principles". One of these principles is that the benefits be based on from market prices and not marginal costs. A second key principle is that the model be able to accurately forecast physical flows and nodal prices for the WECC transmission network. And a third key principle is that all economic v iability assessments consider uncertainty and risk by performing a number of sensitivity studies, instead of relying on a single "base case". After an initial review of available models, the CAISO concluded that the software

presentation entitled July 13, 2004 Supplement – Updated Results and Recommendations.

[3] This example study is described in greater detail in subsequent sections of this paper. Although it is generally not possible for a transmission upgrade to have negative benefits from a societal perspective, it is possible that individual participants to have negative benefits. In this example study, the utility-owned generation in California is less profitable with the upgrade as it allows for more imports into California and an overall reduction of market price.

[4] CAISO Team Report, p. 4-2.

[5] Blake, Michael "Game Theory Models of Imperfect Competition in the PLEXOS Software", Drayton Analytics Research Paper Series, Adelaide, South Australia, http://www.plexos.info/kb5/.

[6] CAISO Team Report, p. 4.2.

[7] Path 26 has frequently been congested in the north-to-south direction. Various upgrades have been considered to relieve this congestion. The upgrade considered in this example is the re-conductoring of the third 500 kV Midway-Vincent line. The upgrade would increase the north-to-south capability from 3400 to 4400 MW, and the south-to-north capability from 3000 to 4000 MW.

model PLEXOS™ best met the above criteria and other requirements.[8]

The CAISO decided to implement an empirical approach since this methodology could be adapted to a detailed transmission network representation and could also be validated through historical experience. Although a detailed description of the development and implementation of the selected empirical approach is beyond the scope of this paper (the reader is urged to read the detailed write-up in the CAISO Report, Chapter 4), a few summary statements can be made.

The first step involved developing a historical relationship between selected system variables and the price mark-ups. Two time periods were selected – 2000 and 2003 – in which significantly different conditions existed. In 2000, there was little forward contracting, a tight reserve margin, and extensive price markups for a number of hours existed in the California market. By 2003, a much higher percentage of the load was covered by forward contracts, reserve margins were higher, and price-cost markups were lower in terms of magnitude and frequency.

The regression equation forecasts the Price-Cost Markup (PMU) for the three California zones for each hour of the year. The price-cost markup is equal to the percent the market-clearing price is above the estimated marginal cost. The price-cost markup is a function of two primary variables – the Residual Supply Index (RSI) and the percentage of unhedged load (PLU) and can be summarized as follows:

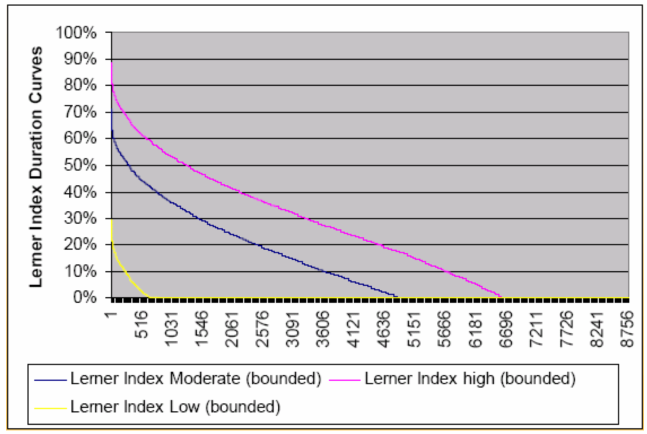
- PMU = function of (RSI, PLU)

The residual supply index and the price-cost markup is calculated hourly based on different hourly demand and supply conditions. RSI measures the extent to which the largest supplier is "pivotal" in meeting demand, and PLU is the percent of load which has not been secured by utility-owned generation or forward contracts. The regression results for 2000 and 2003 indicated that there was a statistically significant relationship the the price-cost markup and the residual supply index, percent of load unhedged, and other explanatory variables. This regression was built into the PLEXOS model and used in the example study.[9]

Since sufficient hourly market data were not available for regions outside of California at the time of the study, only the California market data and resulting regression equations were developed and used. Also, bidding data for the California generators were not available in the public domain, so the regression equation forecast the price-cost markup and not the bid-cost markup. The price-cost markups were then used as a proxy for the underlying bid-cost markups. In other words, if the derived price-cost markup for a given zone and hour were 50 percent (the market price is 50 percent higher than the computed competitive price), this same factor would be applied to the bids of the largest merchant generators in that zone.

In Figure 1, the forecast price-cost markup for is shown for the Southern California Edison (SCE) zone, for all hours of 2008, for three different market price sensitivity cases. In the moderate case, there is a price-cost markup approximately 60 percent of the time. The markup ranges from zero to about 60 percent.

FIGURE I
DURATION CURVES OF PRICE-COST MARKUP SENSITIVITY CASES FOR THE SCE ZONE IN 2008[10]



These price-cost markups were then applied to the bids of the largest merchant generators in the zone. As mentioned in Section II, the benefits of the proposed transmission line changed significantly for the various market price sensitivity cases as summarized in Table 1 below:

TABLE I
IMPACT OF MARKET PRICING ON THE 2008 BENEFITS FOR PATH 26 (MIL. OF 2008 $)[11]

Market Pricing	Societal	CAISO Ratepayer	CAISO Participant
None	$1.0	($1.5)	($0.2)
Low	$1.3	($0.4)	$1.9
Moderate	$4.6	$7.5	$17
High	$5.6	$9.6	$22

Several observations are apparent from the single-year Path 26 results summarized in Table 1. First, it is clear that the Path 26 upgrade benefits can change considerably as one moves from a perfectly competitive market to one in which market power exists. Second, since it is difficult to forecast any future variable with much precision (including

[8] For more detail regarding the model selection process, please refer to the CAISO Team Report, p. 7-2. Data for the study was from the SSG-WI regional transmission working group (http://www.ssg-wi.org/) with enhancements from the CAISO.
[9] CAISO Team Report, Chapter 4.

[10] CAISO Supplement, slide 28.
[11] CAISO Supplement, slide 29.

market prices), it is important to understand the uncertainty of the Path 26 upgrade value resulting from the market price forecast. Since the annual costs for Path 26 are estimated to be roughly $10 million, the economic viability of the project is very sensitive to the resulting market prices. Third, the benefits of the upgrade are not a linear function with respect to market prices.

V. Conclusion

The simulation of market prices is not critical if two conditions exist: (a) the transmission upgrade demonstrates strong economic benefits compared to expected capital and operating costs in a simple production costing simulation; and, (b) there is a single owner of the transmission facility. However, if the economics are not convincing in a cost-based simulation, or if the allocation of benefits will be a determining factor in the ownership and cost allocations, then it is important to perform a series of market price simulations that quantify the benefits for a range of possible future market prices.

These market prices should be simulated by employing some type of “dynamic” bid capability that can change hourly in response to system and market conditions. It is unlikely that game theory models will be developed sufficiently in the next few years to be valid in a network configuration. Therefore, research efforts should continue to improve and refine empirical methodologies.

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VII. Biography

Eric Toolson is an independent consultant and the CEO for PLEXOS Solutions LLC. Eric has 25 years of experience in resource and transmission planning working for investor-owned and municipal utilities and consulting firms. Eric is a professional engineer and has an MBA from the University of Washington.

Anjali Sheffrin is Director of Market Analysis at the CAISO. She is responsible for managing market monitoring activities for California’s deregulated energy markets. She has over 20 years of managerial and technical experience in utility deregulation, market design, generation and transmission planning and load and market research. Anjali has a Ph.D. in Economics from the University of California, Davis.