Equivalent Generation Complexity

Solomon Associates
M³ – Measure. Manage. Maximize.®

Our methodology helps accurately model the variable and fixed cost components of units in support of better decision-making.

Introduction

Power generators throughout the world have come to rely on Solomon's Comparative Performance Analyses™ (CPA™) to help them improve the operational performance of their generating assets. The unique methodology and metrics comprising CPA have shown their value over the years. One such metric—Equivalent Generation Complexity (EGC™)—has repeatedly proven itself invaluable to CPA participants, as they use this tool as a means to normalize costs and compare dissimilar assets.

However, as development of EGC has continued over the last several years, we have come to realize that it is much more powerful than we had initially thought. Beyond its value as a normalizing variable, EGC can be used to address problems that industry has struggled with for years, such as:

- Defining the impact of spending on future reliability—over- and under-funding?
- Predicting future operations and maintenance (O&M) spending.
- Allocating resources to a fleet of assets with varying technologies, fuels, and market missions.
- Determining the incremental cost of generation.

The following paper discusses the development of EGC followed by practical applications, leading to a better understanding of potential solutions to these problems.

Normalization

The theory behind EGC centers around normalization. Industry has traditionally normalized unit performance by comparing capacity and production to costs on a megawatt (MW) and MW hour (MWh) bases, respectively. However, variations between units make suitable comparisons difficult.

Figure 1 and Figure 2 illustrate this point, showing plots of operating costs versus installed capacity and production, respectively. Operating cost (OPEX) is defined as total costs less fuel. With a coefficient of determination (i.e., r^2) of 68%, as shown in Figure 1, the correlation between OPEX and installed capacity is low and the data distribution is broad, with a standard error of US $6,407,000/MW.

The correlation between OPEX and production, shown in Figure 2, is better, with an r^2 of 73% and a standard error of US $5,528,000/MWh, but it is still not as good as it should be to make robust comparisons.

There are too many differences between the units in these figures to allow adequate comparisons on a MW or MWh basis. Location, market mission, age, fuel type, etc. are variables that are simply not accounted for in these correlations.

Improved Approach

Recognizing the difficulty of comparing disparate assets, Solomon chose to tackle the problem by investigating operating cost drivers. In doing so, a database representing the operating costs of fossil-fired units with the following characteristics was developed:

- Installed Capacity: 10 to 1500 MW
- Net Capacity Factor: 5 to 95%
- Scrubbed and Unscrubbed Units
- Technology: Conventional Steam (Gas- and Oil-Fired), Coal-Fired, Combined Cycle Gas Turbine (CCGT)
- Unit-Years: 600

Results

Using a patented methodology, we developed a multi-variable non-linear algorithm to correlate OPEX and operating characteristics. It is important to note that, regardless of whether a company classifies major projects as maintenance or capital, for the purposes of the CPA and this analysis, any project that is significant in maintaining the plant design, condition, and operation—and has a duration of greater than 1 year—is annualized over the projected life of the project. Therefore, only a

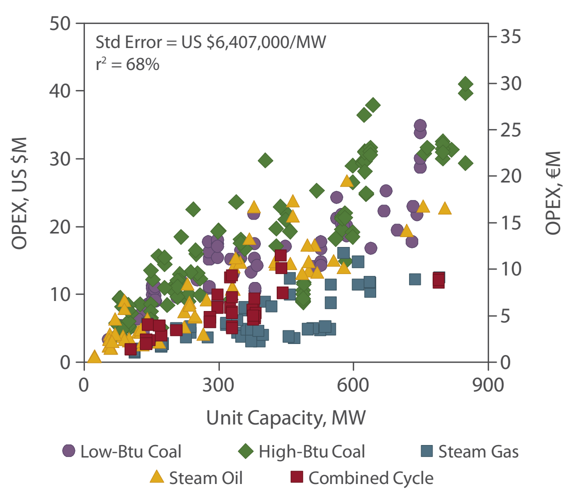

Figure 1. OPEX vs Installed Capacity

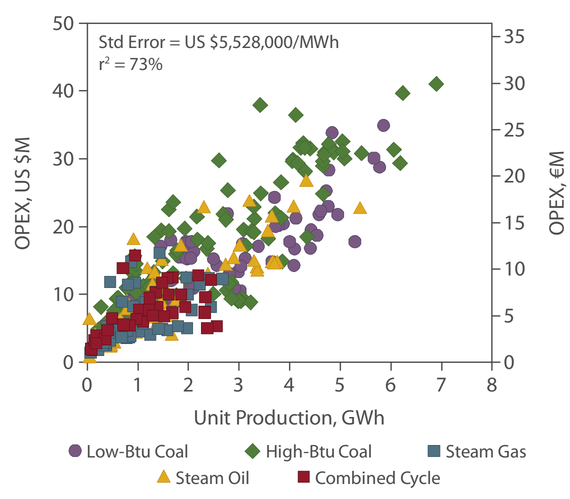

Figure 2. OPEX vs Production

portion of the total cost of each major project is attributed to the annual operating costs of a unit. Without treating overhauls and major projects in this manner, cost data would exhibit annual variations that could hinder the development of meaningful results.

Figure 3 plots OPEX versus EGC, which results in a vastly improved correlation, an r^2 of 93%, and a standard error of US $2,587,000/EGC. Using EGC, only 7% of the relationship is not explained by the algorithm.

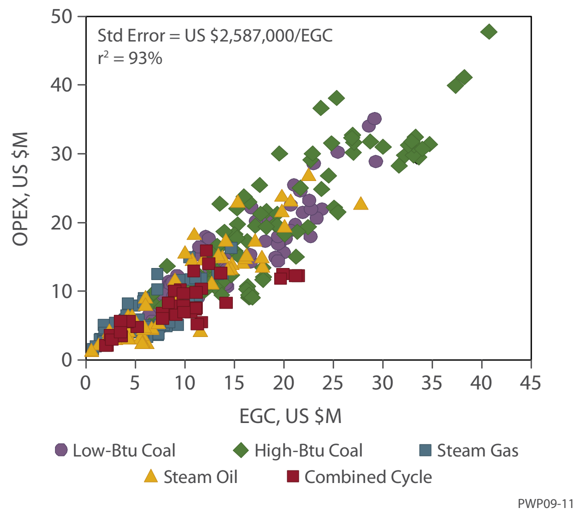

Figure 3. OPEX vs EGC

To better understand the correlation, you must have a good understanding of the methodology employed. Firstly, the drivers of cost are elements of configuration, utilization, and fuel characteristics. Industry experts (i.e., former plant managers and executives) plugged different combinations of drivers into the algorithm to determine which had the most impact on the correlation. The algorithm can be represented as follows:

$$EGC = A * [Capacity\ (MW)]^{n1} + B * [Production\ (MWh)]^{n2} + C * [Ash\ Content]^{n3} \ldots$$

Clearly, capacity and production have a large impact on cost, as evidenced in Figure 1 and Figure 2. Beyond that, ash content, age, whether or not a scrubber was installed, etc. was investigated to determine which engineering-based drivers had the most impact on cost. Using our experience and an iterative process, we systematically added those terms that made sense from a practical perspective to the above equation until the correlation was sufficiently high (i.e., >90%).

Application

There are many uses of this type of analysis, but one in particular is illustrative. Take for example a fleet of five units with the following characteristics operating in the PJM interconnection:

- Unit A – Combined cycle gas turbine (CCGT)
- Unit B – High net capacity factor (NCF), un-scrubbed coal
- Unit C – High-NCF, scrubbed coal
- Unit D – Older low NCF, un-scrubbed coal
- Unit E – New combined cycle cogeneration

To allocate a fleet-wide budget cut of 25% (approximately US $5 million in this example), a common approach would be to reduce the operating budget evenly across the fleet. Examine the impact that such a reduction would have on two generating units of similar size and similar OPEX, but with different capacity factors. The relevant characteristics, OPEX budgets, and budget reductions are shown in Table 1.

Table 1. Characteristics and Budgets

Unit	Capacity, MW	2-Year Average NCF, %	OPEX, US $k	25% Reduction, US $k
C	500	60.2	20,246	5,062
D	485	37.1	20,320	5,080

The units operate in the same market but have different utilizations. Reducing the OPEX budget by the same percentage reduction would reduce funding without regard to utilization, thereby reinforcing inefficient resource allocation. Although intuition (and experience) would suggest that Unit D is less efficient because of its budget and lower NCF, the extent of this inefficiency is unknown. EGC can provide insight into operating efficiency and help provide guidance as to how and where resources should be allocated.

Predicting Cost and Reliability

EGC effectively models the cost of any fossil-fired operation based on certain drivers with good correlation. Consequently, given a specific generating unit with certain operating characteristics, the EGC algorithm predicts what the operating costs might be, assuming that conditions are representative of the database on which the model is based. As an illustration, consider Figure 4, which plots the ratio of actual OPEX to EGC against production.

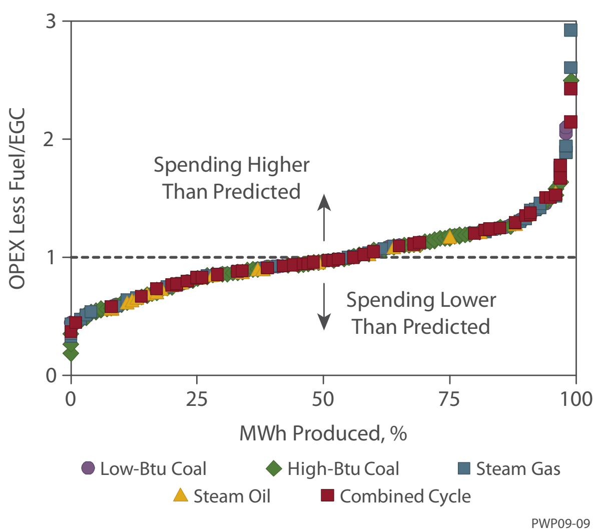

Figure 4. OPEX/EGC vs Production

If actual OPEX of a generating unit were identical to the EGC prediction based on operating characteristics, the ratio of OPEX/EGC would be 1.0. Assuming a normal distribution of differences between the model and actual data, there are an equal number of points above and below 1.0.

It is important to note that this does not suggest that 1.0 is an average level of OPEX, nor does it suggest that below 1.0 is under spending; it simply suggests that for a generating unit with an actual OPEX/EGC other than 1.0, circumstances may be different for the unit that would cause a departure from what the model would predict.

Using the same data set as that used for the derivation of EGC, the correlation between equivalent forced outage rate (EFOR) and OPEX/EGC was investigated. Experience suggests that high (or low) spending levels do not automatically equate to problems in reliability, but a relationship exists. If costs continue to be cut, at some point reliability will suffer.

To establish the relationship between spending and EFOR, the variation in reliability as opposed to reliability itself was investigated. Figure 5 presents a combination of the OPEX/EGC curve (i.e., Figure 3) and the normalized Coefficient of Variation (i.e., volatility) in EFOR that resulted 2–3 years after a change in spending.

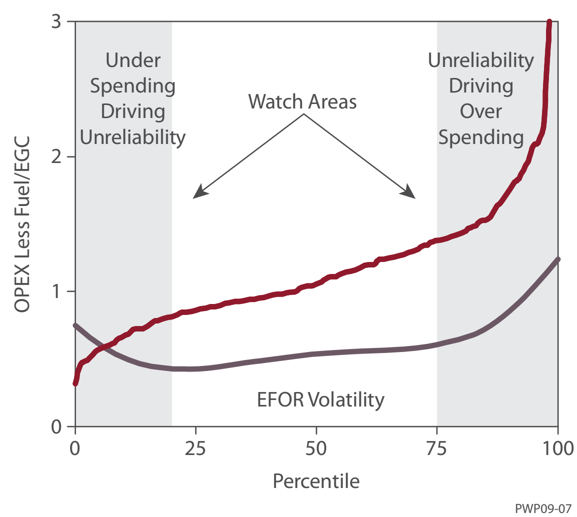

Figure 5. OPEX/EGC vs Production

This time frame was selected because operating power plant experience suggests that reliability impact typically occurs between 2 and 3 years after a change in spending.

The shape of the normalized EFOR volatility curve changes dramatically below the 20% and above the 75% percentile levels, defined by the gray shaded regions. In these regions, for a given level of spending as compared to EGC, we cannot conclude that increased EFOR will definitively occur but, rather, there is an increased risk of unreliability. As actual spending trends away from what EGC predicts based on the configuration, utilization, and fuel factors of the unit, there is a greater likelihood that the unit will exhibit reliability problems.

These "watch areas" are also intuitive. As OPEX continues to decrease, reliability issues eventually occur. Similarly, at the other end of the curve, correcting reliability problems will require additional spending.

It is possible to operate in these unreliability regions with respect to cost and not have a change in reliability, which is why the focus of this analysis is on the increased risk of reliability. Quantifying the facility's position along this risk continuum can help balance reliability and cost.

Application

Revisiting the fleet of five units used in the previous example and plotting OPEX/EGC of these units along the study curve results in the efficiency of spending points shown in Figure 6. Units D and E are in the higher range of the OPEX/EGC curve and Units A, B, and C are in the mid range. Such a scatter suggests that Units D and E are spending more than the EGC analysis would predict, and Units A, B, and C would be about the amount predicted.

These results provide some insight into possible reliability issues in the fleet—there is risk for continued or increased reliability problems with Units D and E.

Also note that Unit C represents the 500 MW, scrubbed coal unit with a high NCF and Unit D represents the 485 MW, low NCF un-scrubbed unit. The EGC analysis indentifies what intuition and experience indicate; Unit C is relatively more efficient than Unit D. It also illustrates the magnitude of the efficiency of the units and how much potential improvement is available.

Reverting back to the example of a 25% fleet-wide budget cut, spreading the reduction in OPEX over the two units would move the units' EGC from their current position exhibited by Figure 6 to the new position indicated by Figure 7. Unit D would move from an area that is just in the watch area for over-spending to a position that is more centric. However, Unit C would move from a central operating range to a region of potential unreliability.

Although it is possible for Unit C to operate in this area, such cuts increase the risk of future reliability issues. By cutting the budgets in equal proportion, a unit that is spending relatively efficiently is required to make cuts that can potentially impact reliability while inefficient spending is reinforced with Unit D.

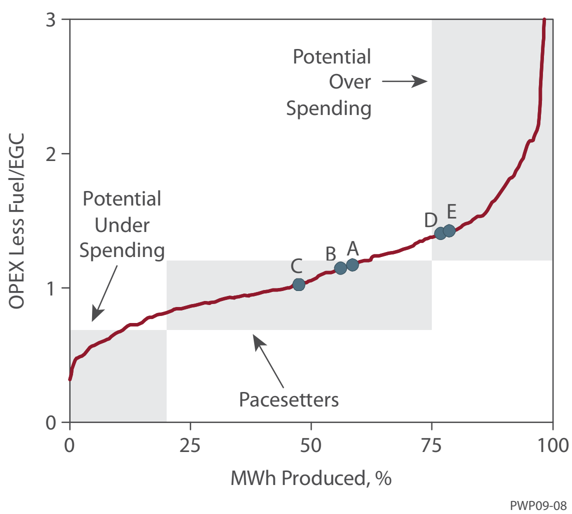

Figure 6. OPEX/EGC vs Production - Example

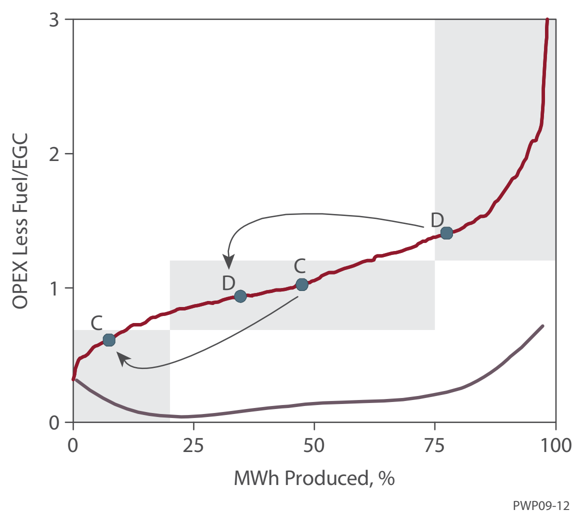

Figure 7. 25% Budget Reduction

Alternatively, with the same budget reduction mandate and cuts weighted more toward the inefficient unit, a more desirable outcome is likely to result.

By reducing the Unit C budget by US $3,700 and the Unit D budget by US $6,400, the OPEX/EGC curve shifts such that both units would be predicted to operate with relatively low reliability risk, as shown in the central region in Figure 8. By allocating the budget cuts in this manner, the performance of both units will likely be preserved without increased reliability risk.

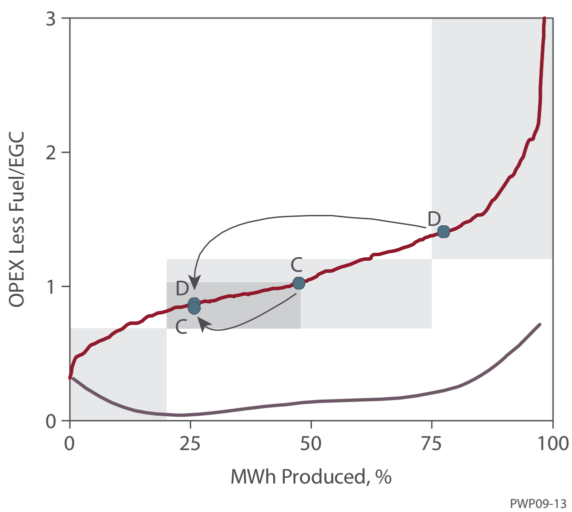

Figure 8. 25% Budget Reduction using EGC

These analyses do not suggest indiscriminate cutting of budgets with the assumption that performance will somehow magically reflect EGC predictions. Rather, EGC is a powerful tool that can help guide decision-making. In the preceding examples, intimate knowledge of unit programs and constraints is assumed so that budget cuts can be made logically. Plants must have the capability of absorbing the cuts while achieving operating goals.

Other Applications

The usefulness and accuracy of the EGC tool continues to expand. Numerous applications have been identified; two of which are briefly described as follows:

- *Pro Forma* – Given actual design data and site-specific information, EGC provides a realistic and accurate estimation of the operating costs of a unit that has not yet been built. Such an estimate allows for optimizing unit design and establishing effective operating and maintenance programs.
- *Planning Model* – Since EGC determines incremental costs of generation, it can be used to model the cost structure of a system of units that are supplying electricity to a common grid. In this capacity, Solomon provides a planning tool that can be used to optimize generation. Used in conjunction with (and as inputs to) dispatch models, Solomon's Planning Model can be used to optimize system costs.

Because the value of EGC is being more fully developed through client participation, only current CPA participants have access to EGC as part of Solomon's work.

Contact Information

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