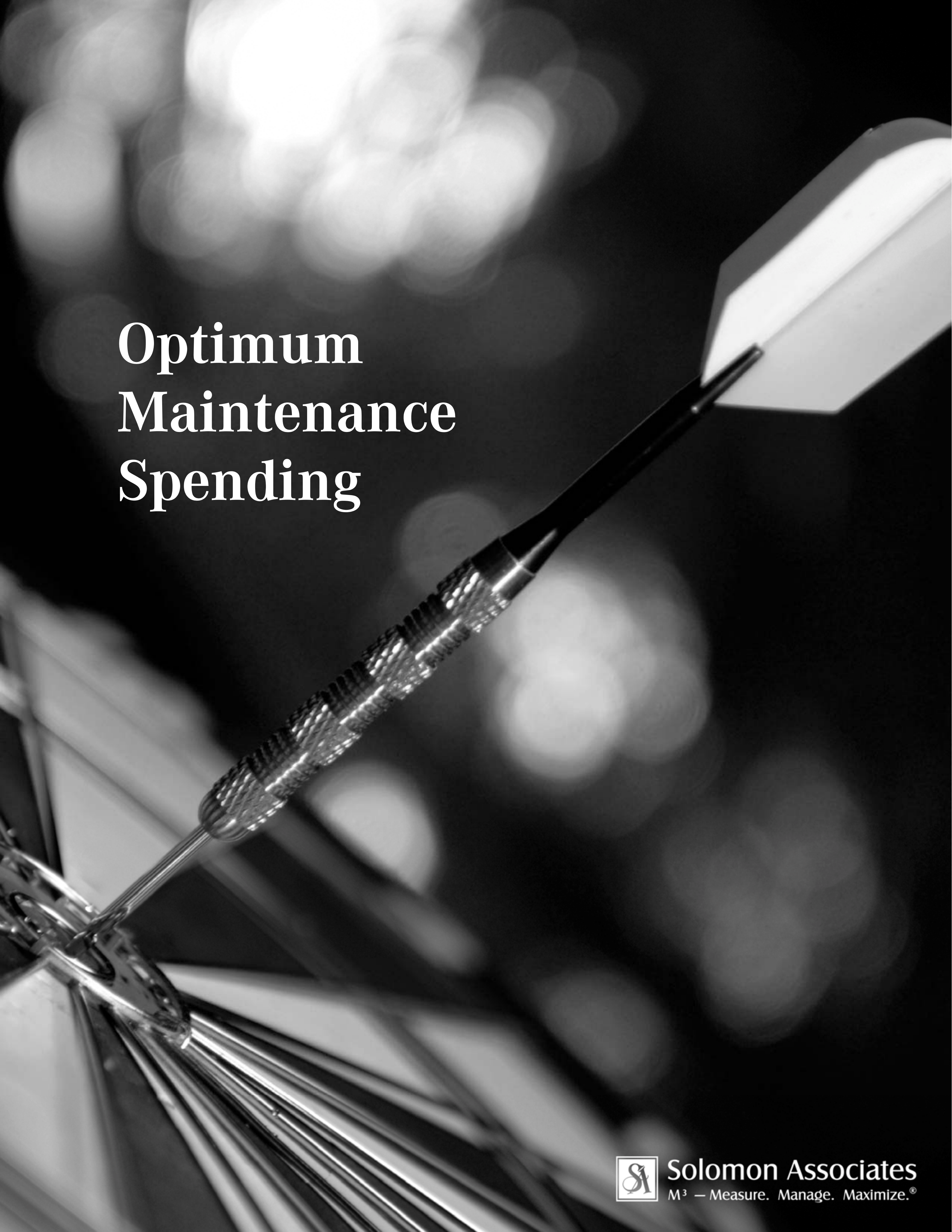
Optimum Maintenance Spending



Solomon Associates
M³ — Measure. Manage. Maximize.®

Our methodology helps you target your optimum availability and maintenance spending given your commercial circumstances.

Introduction

Owners of fossil-fired generation facilities have always struggled to find the best balance between maintenance expenditures with plant availability. Few companies can determine this balance themselves because of the need for years of unit-specific historical data. Even when many years of data are available, rapid changes in plants and the market place render data more than a few years old virtually irrelevant. Additionally, to define an optimum point, operating data across all ranges of availability are required. Generation owners are not granted the luxury of being able to "experiment" with a series of conditions to develop cost/availability relationships, as short-term demands of the business must be met.

To address this challenge, Solomon developed a methodology to determine a target optimum point where availability meets maintenance spending for Powder River Basin (PRB) coal-fired units. Using a database of sufficient size and composition across various operating ranges, we generated an algorithm that predicts the relationship between maintenance spending and availability. Coupling this generalized algorithm with a unit-specific market-loss curve determines the optimum spending for a facility.

This paper presents the results of our analysis, which includes the details surrounding operating points, how this methodology can be applied to develop optimum operating and financial targets for specific units and markets, and a process to achieve those targets. Additionally, we describe how this methodology can be used for other types of fossil-fired technologies and future enhancements to the analysis.

Concept

Understanding the cost of achieving certain availability levels is crucial in optimizing the total cost for a plant. Total costs are considered to be maintenance costs plus the opportunity cost of not being available when there is a positive spark spread. Evaluating the total cost of a generation unit at various degrees of unavailability provides insight into the optimum operating levels for the plant.

First, consider the elements of maintenance cost. For the purposes of this conceptual discussion, *reactive maintenance* is defined as actions or efforts taken as the result of unplanned outages or durations; *proactive maintenance* is defined as preventive actions aimed at the source of potential failures to extend the life of the equipment and avoid failures. Figure 1, presents a conceptual illustration of both proactive and reactive costs versus varying levels of availability.

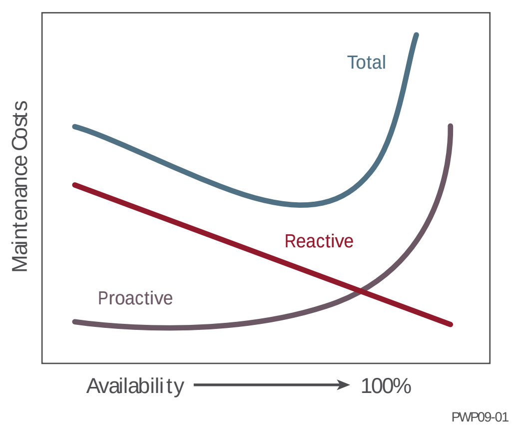


Figure 1. Maintenance Cost Components

Generally speaking, the cost of reactive maintenance decreases toward zero as the asset approaches 100% availability, whereas the cost of proactive maintenance increases exponentially with increasing availability. That is, it is more difficult and costly to attain increasing levels of availability because of the amount of proactive maintenance that needs to be performed. The combination of the reactive and proactive costs produces the total maintenance cost curve, which is depicted as the blue line in Figure 1. It is important to note that the inflection point of this curve is associated with the lowest maintenance costs. As availability increases past this point, so does total maintenance cost.

The point at which minimal spending occurs for maximum availability does not suggest an optimum operating point, as the asset is generating electricity for which the company is being compensated—a key component that must be taken into consideration when determining an optimum operating point. A commercial perspective provides the context for which the best balance of maintenance cost and availability is achieved. In other words, integrating a market dimension into the analysis establishes the value associated with a given level of maintenance cost and availability.

To quantify the market dimension, consider Solomon's Lost Revenue Opportunity (LRO™), which is an opportunity cost for the amount of generation lost due to the unit being unavailable. For example, if the market is paying US $60/megawatt-hour (MWh) and the variable cost of generation is US $25/MWh (fuel, auxiliaries, etc.), if the unit is unable to produce, the LRO is US $35/MWh (i.e., US $60/MWh minus US $25/MWh). Including this economic factor into the analysis, the total cost describing the operations of the unit is the sum of the total O&M costs developed in Figure 1 plus the plot of LRO as shown in Figure 2.

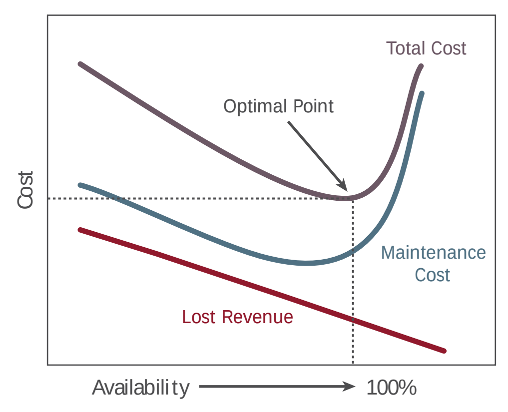


Figure 2. Total Cost vs Availability

Such a conclusion assumes that bi-lateral contracts or the ability to cover market shortfalls through another means does not exist.

The inflection point of the total cost curve represents the optimum balance between maintenance spending and unavailability losses. As availability approaches 100%, total costs increase exponentially, possibly beyond market value. That is, the incremental cost to run the unit at higher availabilities is greater than the associated increase in incremental revenue.

Methodology

To bring the analysis from a conceptual discussion to an empirical application, Solomon considered a set of 30 generating units that burned PRB coal. Each of the units exhibited the following characteristics:

- Installed Capacity: 360–750 MW
- Base Load with Net Capacity Factor: 61–89%
- Scrubbed and Un-Scrubbed
- 80 Unit-Years of Data

As this data set was homogeneous with regard to fuel and utilization, the results and conclusions cannot be generalized to other peer groups.

Metrics

The salient metrics used in the analysis and their relevancy are presented below.

Maintenance Index

Solomon's Comparative Performance Analysis™ (CPA™). Maintenance costs and Solomon's Maintenance Index from the CPA were used for this work. Maintenance Index is defined as a 2-year average of non-overhaul expenditures plus the annualized portion of the most recent overhaul and major project expenditures for the major pieces of equipment divided by the current and previous years' average production in megawatt-hours (per generating unit).

It is important to note that the elements of maintenance cost (i.e., proactive and reactive maintenance) depicted in Figure 1 were not used in favor of total maintenance cost simply because of the ease of data collection. Separating proactive and reactive components is addressed subsequently in this paper.

Solomon's Maintenance Index and how overhauls and major projects are treated are crucial to this analysis. 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 in the same design, condition, and operation—and has a duration of greater than 1 year—is annualized (over the life of the project). In this regard, only a portion of each major project is attributed to the operating costs of a unit. Without treating overhauls and major projects in this manner, cost data would exhibit such variation that would hinder the development of meaningful results.

Annualized Equivalent Availability Factor

As a measure of availability, we initially used Equivalent Availability Factor (EAF). This factor represents the maximum production a unit can generate, accounting for derates and full outages as defined by North American Electricity Reliability Corporation (NERC) Generating Availability Data System (GADS). Later, we determined that a time-averaged EAF over a longer period was more appropriate.

Lost Revenue Opportunity

LRO was used as a representation for economic opportunity costs, as previously described. From Solomon's CPA, LRO is determined by calculating the difference in market clearing price and plant variable cost at the time of the lost opportunity (i.e., outage or derate) and applying any positive difference (i.e., spark spread) to the megawatt-hours lost due to the incident. This effectively establishes a curve of lost market opportunity that is added to the maintenance cost to determine total cost of unavailability.

Analytical Method

Frontier Analysis is a numerical technique used to estimate the boundary or limits of a data set. Using validated operating and financial data, the technique envelops rather than intersects the data, thus creating a "frontier" of performance that represents what is achievable as opposed to what is theoretical. In terms of this analysis, the frontier points are defined as the values that have the lowest Maintenance Index for a given average EAF interval. We used these points to develop an analytical curve that represents the "frontier" of Maintenance Index as a function of average EAF.

Results

We began the analysis considering Maintenance Index versus a 1-year EAF as presented in Figure 3.

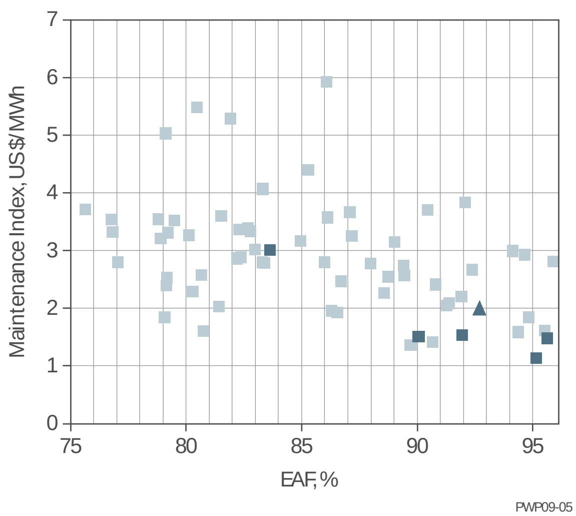


Figure 3. Maintenance Index vs EAF

However, a 1-year EAF does not account for units that ran continuously (i.e., those that did not experience an overhaul). A unit on which an overhaul is performed is going to have a reduced EAF in a given year. Therefore, in the context of determining a sustainable operating point, a time-averaged EAF over a longer period is more appropriate, which is more consistent with the manner in which Solomon's Maintenance Index is used. To determine the average value, the EAF for each year was averaged over the period for each unit. An example is highlighted in Figure 3 with the dark-blue points. During the 5 years of operation, EAF for the unit ranged from 83–96.5% and the average Maintenance Index ranged from US $1.5–$3.0/MWh. The averaged EAF for this period is 92.5% and corresponds to an average Maintenance Index of US $2.0/MWh, as is represented with the large dark-blue triangle.

Averaging each of the units in the data set, which ranged from 3 to 7 years, produces a plot of average Maintenance Index versus averaged EAF, which is presented in Figure 4.

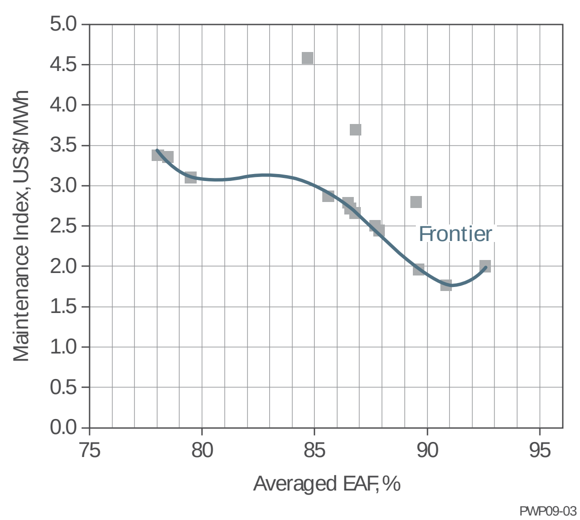


Figure 4. Frontier Development

The frontier of averaged EAF performance for the data set is shown as a curve in this figure. As one would expect, the Maintenance Index decreases as averaged EAF increases because less reactive costs are incurred and there is simply no opportunity to incur costs as the unit is operating more. Additionally, at approximately averaged EAF = 91%, the curve shifts upward, suggesting that more costs are incurred at higher availabilities; thus, an optimum point. Since EAF is an average value over a significant time period, this optimum point is the target where units should strive to operate as it is sustainable over a multi-year period. To achieve an increase in availability beyond this point, additional maintenance will be required that is going to cost incrementally more.

The curve illustrated in Figure 4 represents an algorithm for units that burn PRB coal. It describes the optimum point where maintenance costs meet availability.

This curve, however, is a generalization and does not represent a specific unit's cost structure and market conditions. The applicability of this curve to an individual unit is provided in the subsequent section.

Application

Consider, for example, a nominal 700 MW unit that burns PRB coal and has a net capacity factor (NCF) of 75%. The unit operates in the Western United States and participates in Solomon's *Power Generation Performance Analysis (Power Study)*. Using the algorithm represented by the blue line in Figure 4 and superimposing the unit-specific LRO curve yields the total cost curve presented in Figure 5.

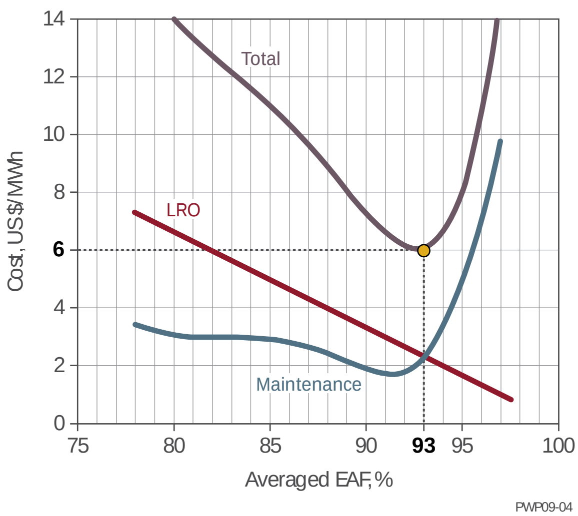


Figure 5. Optimum Operating Point

It is important to note that LRO results can vary significantly year-to-year depending on market conditions. To be consistent with the other variables in the analysis, not only does the LRO value applied here have to be specific to the unit under analysis, it also has to be computed over a multi-year period.

Given the unit-specific curve, the target for this unit should be an averaged EAF of 93%, which is associated with a Total Cost of US $6/MWh. This position represents the optimum balance between availability and maintenance spending considering the LRO when this unit moves to the frontier of best performance. At this point, the associated Maintenance Index would be approximately US $2–3/MWh, a target that is slightly more than a minimized Maintenance Index. However, achieving this frontier may not be practical within a short period of time. Intermediate goals may be needed to work programmatically toward reaching the frontier. Using this analysis will yield these targets regardless of whether the goal is to achieve best performance or an intermediate level of performance.

Future Work

The results of this work are significant in that the conceptual relationship between maintenance spending and availability has been quantified such that an optimum point can be determined. Moreover, we have demonstrated a methodology to identify a long-term operational target for a specific generating unit. However, we recognize that many unanswered questions remain. To address these questions, future work will involve the following:

- Conducting analysis on other technologies and fuels (lignite, hard coal, CCGT, cogeneration, etc.).
- Using Solomon's patented Equivalent Generation Complexity (EGC™) methodology to normalize the algorithm across technologies, capacities, fuels, etc.
- Investigating elements of the maintenance cost curve, the appropriate spending level for overhaul/non-overhaul costs, and defining/describing reactive/proactive maintenance.
- Determining intermediate targets such as median performance or 75th percentile as a short-term or interim goal towards achieving the frontier of best performance.

Establishing the most appropriate targets is not the only feature of this work. Understanding the gaps in performance and the practices needed to be improved are just as important. Solomon is currently developing a consulting program that focuses on "how" to improve the practices in a generating unit to help achieve these optimum targets.

> We are developing a program to help you achieve the optimum target.

Contact Information

For additional information, please contact:

William "Ed" Platt
Vice President Power Generation
13455 Noel Road, Suite 1500
Dallas, TX 75240-6634
Phone: 972.739.1757
Email: Ed.Platt@SolomonOnline.com