Valuing Generation Assets: Overview and Spark Spread Option Valuation

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6 May 2009

For many participants involved in power trading such as energy merchants, utilities, banks, and other investment companies, accurate valuation of generation assets and their associated risk calculations is crucial. Not only does rigorous valuation provide a more accurate view of a portfolio's current value, it also affects the ability to properly manage and hedge the risks associated with generation assets. It is common to state that the flexibility involved in the operation of generation assets can be treated as a "real option" from a valuation perspective and as such this operational flexibility can be viewed as optionality that provides value. However, each plant also has certain operational constraints that affect how much flexibility the user has in operating the plant.

In this article, and subsequent articles that will follow we will detail a number of different ways in which industry practitioners typically value the flexibility of generation assets as real options whilst taking into account the constraints in operating the plant. As we will show, some of these methods can be relatively simple – for example, valuing the asset as a portfolio of spread options – while others are more complex, and take into account more of the asset's operational constraints. The level of complexity often depends on the type of generation asset that is being modelled. In this first article we will begin by summarizing many of the features of thermal generation assets, describe common techniques used to value them, as well as working through a simple example using analytic or closed form techniques. Some of the other techniques will be discussed at length in future articles in this series.

Properties of Generation Assets

Generation assets have many different properties. The following lists many of the most common properties that are commonly taken into account when valuing and measuring risk of generation assets.

- Maximum Capacity
- Minimum Stable Generation
- Heat Rate
- Variable Operational and Maintenance Cost
- Start Cost
- Ramp Up Rate
- Ramp Down Rate
- Minimum Up Time
- Minimum Down Time
- Emissions
- Outages
- Scheduled Maintenance
- Fuel Transportation Costs
- Power Transmission Costs

Of the properties listed above, maximum capacity is probably most familiar to the reader, representing the maximum amount of power that can be produced in an hour. The maximum capacity can change from month to month, with the fluctuation in the capacity occurring because the capacity is dependant on the thermal gradient between the generation unit and the ambient air temperature. The larger the gradient, the larger the maximum capacity can be. On the other hand minimum stable generation is the lowest generation level that the unit can operate at, and still produce power that can be sold to the grid. The ability to run at the minimum stable generation allows the operator to run the unit at a minimal loss if the unit is not, or can not be shut down.

The concept of the heat rate is also probably familiar to most readers with the value representing the efficiency of the unit. As is the case with maximum capacity, the heat rate can also vary through time. A larger thermal gradient between the generator and the ambient air temperature improves the unit's efficiency. The efficiency can also be improved by running the unit at maximum capacity. The unit is at its least efficient when generating at minimum stable generation. In models that more accurately model the operation of the generation unit, the unit can be dispatched at a capacity between the minimum stable generation and the maximum capacity, and in these cases a full heat rate curve needs to be provided. The heat rate curve can be described via a step function or it can be modeled as a continuous function.

Variable operation and maintenance (VOM) costs represent the non-fuel costs associated with running the unit.

Start costs are charges associated with starting the unit. Some of these charges are costs that actually occur such as the purchase of start fuel. This is the fuel consumed while getting the unit up to producing the minimum stable generation. Other start costs are included to account for the wear and tear on a unit caused by stopping and restarting the unit. As we will see later, it can be challenging to account for these costs in any analytic valuation solution. One of the things that make start costs particularly challenging is the fact that they may be dependant on how long the unit has been off. Units that have just come off line are usually cheaper to bring back on line than similar units that have been off for a considerable amount of time.

Ramp up and ramp down rates limit how quickly the unit can change its operating level of generation. Similar to start costs, ramp up rates are also frequently dependant on how long the unit has been off line.

Minimum up/down times require that if the unit is turned on/off that the unit remain in that state for a minimum number of hours. These constraints are put in place to minimize excessive wear and tear the unit would experience if it were constantly switched on and off.

Emissions costs associated with CO2, NOx, and SO2 are an important component to include in asset valuations. Since most emission markets are still relatively immature, it is often difficult to estimate reliable parameters for modelling their prices, and so these costs are often included as deterministic values and treated much like VOM costs. When parameters can be estimated, the incorporation of stochastic prices for emissions complicates the modelling process and typically requires Monte Carlo simulation methods.

Every unit has the possibility of suffering a forced outage. Forced outages are random outages that reduce the operating capacity of the unit or take it off line completely for an extended period of time. In addition to forced outages there are scheduled maintenance outages. Although schedule maintenance outages are planned, they may take at least several days if they are for major issues. Both of these kinds of outages can have significant impact on the valuation of the plant.

Since, typically, generation units are not located at the gas supply or the load centre, we have to account for costs associated with getting the gas to the plant and the power to the grid. These costs may show up in the form of adders, multipliers, taxes or losses.

Financial Options vs. Generation Assets

One of the benefits of treating an asset as a real option is that we can make use of the many techniques that have been developed for the valuation of financial options. As we have seen, there are a number of constraints that we would like to take into account when valuing a generation asset. Consequently, it is worth understanding the difference between financial and real options so that we understand the limitations these techniques impose on us when we value generation assets.

Firstly, typically financial options are paid for 'up front' and there is no significant cost to exercising the option. As we have seen, there usually is a start cost associated with the generation asset. Since the start charge is accounted per start and not per hour run, it is more complicated to implement start costs in a closed form solution than in a Monte Carlo solution.

The second major difference between financial options and generation assets is that once the financial option matures, we can immediately exercise it. Generation assets, on the other hand, have a ramp rate which implies that we can't instantly go from having the unit off to running at maximum capacity. In other words, we need to decide to exercise the real option of the generation asset before its expiry.

Most financial options can have the payoff descried in a single payoff function that can be easily written down. This is even true for some path dependant options like Asian options. The operational constraints of a generation asset such as start costs, ramp rates, and minimum up/down times, require us to keep track of prior states of the unit.

This requirement makes it difficult to write out a simple payoff function for a generation asset with all the operational constraints. In order to make use of many of the standard techniques from financial options, many of the constraints of the generation asset are typically ignored or modelled in a less than ideal way.

Overview of Valuation Methodologies

There are a number of different ways of valuing a generation assets as a real option which we now go on to describe. As we will see there are advantages and disadvantages to each of the techniques.

Analytic Spark Spread Option

There is a long history of using spread options to value many different kinds of energy assets as real options. For example, refineries have been modelled as the spread between the input crude price, and the prices of the refined products (crack spread options); storage assets can be modelled as the spread between cheap – input – forward months and expensive – withdrawal – months (calendar spread options), and transportation/transmission systems can be modelled as geographic spread options. It is a natural step to treat a generation asset as a spark spread options. A spark spread option is an option on the spread between the power price and the input fuel price used to generate it[1]. The advantage of this approach is that it is very simple and easy to get a quick evaluation of the asset. The payoff function for a spark spread option maturing at time *T* is given by

$$Payoff = Q \times \Delta t \times Max(P_T - HR \times G_T - K, 0) \ ,$$

where Q is the maximum capacity, Δt is the time the unit is generating power, P_T is the power price at the maturity of the option, HR is the heat rate, G_T is the natural gas price, and K is a fixed strike. The fixed strike will be composed of the VOM as well as other costs from the other operational constraints. In order to value this type of spread option we can make use of the standard formula for a call option on a futures contract. The payoff for a European call option on a futures contract is given by

$$Call\ Payoff = Max(F_T - K, 0)$$

1 In the US spark spread refers to and spread between power and the fuel used to generate it. In the UK and Europe, often a distinction is made between the fuels used to generate the power. A spark spread is the spread between power and natural gas and a dark spread is the spread between power and coal.

where F_T is the futures contract price underlying the option at the maturity date. This is just Black's formula [Black, 1976] and the analytic expression for the value of the option is given by

$$c = e^{-rT}\left[F \times N(h) - K \times N(h - \sigma\sqrt{T})\right]$$

where *F* is the current forward price, *r* is the risk free interest rate, *T* is the maturity of the option, σ is the volatility, N( ) is the cumulative normal distribution function, and

$$h = \frac{\ln(F/K) + \frac{1}{2}\sigma T}{\sigma\sqrt{t}}.$$

We can rearrange the spark spread option payoff to be[2]

$$Payoff = Q \times \Delta t \times Max\left(\frac{P}{HR \times G - K} - 1, 0\right) \times \left(HR \times G - K\right).$$

In this formulation, the strike is 1 and there is only one stochastic underlying and its volatility is given by

$$\sigma = \sqrt{\sigma_P^2 + \left[\sigma_G \frac{HR \times G}{HR \times G + K}\right]^2 - 2\rho\sigma_P\sigma_G \frac{HR \times G}{HR \times G + K}}.$$

The volatility of the single stochastic variable is dependant on the volatility of power, σ_P, and gas, σ_G, as well as the correlation, ρ, between the two commodities. Simple substitution of these values into the formula for the value of a call option provides the value of the spark spread option.

This valuation method is easy to implement and straight forward to understand. However, it doesn't account for many of the constraints that we listed earlier in this article. For those that can be handled, they are only handled in a very crude fashion. For example, emissions costs can be treated as a fixed cost that is incorporated in the strike term. The cost per start can be incorporated similarly. However, the start gas needs to be handled in an alternative way because the gas price is stochastic. Typically, start gas is incorporated by adjusting the heat rate input. We demonstrate this in the example presented near the end of this article. The only way to handle outages, forced or scheduled, in this analytic framework is by de-rating the volume, where the volume is

[2] See for example Kirk, 1995

given by the product of maximum capacity, Q, and hours run, Δt. If the unit is expected to be forced out for 10% of the hours run then the hours run should be scaled down by a similar percentage. Unfortunately, this does not capture the real risk of a forced outage. We are also completely unable to capture the affects of ramp rates and minimum up/downtime constraints in this methodology.

Monte Carlo Simulation

Because forward power prices are usually quoted for blocks of hours, it is very common to use those same blocks of hours, and the associated forward prices, when applying the analytic spark spread option methodology. There are a number of problems with doing this. The first is that the prices for these blocks do not describe the hourly variability in observed prices – this hourly variability is crucial to the valuation of peaking units. Secondly, regardless of the granularity, the analytic spark spread option technique is unable to connect the dispatch of the plant in one time block with its dispatch in an adjoining time block, making it impossible to handle the constraints such as ramp rates, and minimum up/down times.

A solution to both of these issues is to implement hourly simulations of the spot power price which gives us the granularity in prices to determine how the plant should be run each hour. Although this allows us to incorporate ramp rate and minimum up/down time constraints with simulation, we no longer have a simple equation that we can write for the payoff. In order to determine when the plant will run, we need to develop a dispatch algorithm which not only takes into account the economic situation but also meets the physical constraints. As part of these constraints we are able to simulate emissions prices and outages, greatly improving the accuracy of the valuation.

There are many ways to determine how to dispatch the generation asset. One can develop sophisticated algorithms like linear or dynamic programming. However, both these approaches require a substantial amount of time to design the algorithm. In the case of a linear programming approach, we need to determine all the equations that will be used to model our constraints. The dynamic programming approach requires states and transitions to be defined, with the number increasing as the number of constraints increases. Both the linear and dynamic programming approaches are guaranteed to determine an optimal solution, but can be difficult to implement.

Although they are not guaranteed to determine the optimal solution, heuristic algorithms are often satisfactory. As heuristic algorithms are a collection of simple rules, they are often easier to design and implement. Additionally, if new constraints are added, it is fairly simple to add extra rules for the inclusion of the new constraint. The differences between an optional solution and a suboptimal solution are usually insignificant when compared to the difference between implementing a realistic power price model and an unrealistic power price model, on the valuation of a generation asset.

A solution from a good heuristic model may turn the generator on an hour too late or too early from time to time. This will have less affect on the value of a plant than an unrealistic model for hourly power prices. The unrealistic price model will ultimately affect the valuation of the generator on all hours. Furthermore, most Monte Carlo solutions assume perfect foresight and this generally more then compensates for any loss due to a suboptimal solution.

Perfect foresight with Monte Carlo solutions is achieved because the spot prices that are simulated are used to dispatch the plant and to calculate the profit and loss. In reality a plant operator would never know exactly what the spot prices will be in the future – instead relying on experience and expectations of future prices. This means that if there is an unexpected spot price realisation the generator may lose out on extra profit or run at a loss. One way around this shortcoming is to dispatch the plant on simulated forward prices and then use the spot prices to calculate the profit and loss. Although this is not that much more complicated than the normal Monte Carlo it does require extra time due to the extra calculations. There are other techniques, such as trees and least squares Monte Carlo which do not assume perfect foresight.

Trinomial Trees and Least Squares Monte Carlo

Trinomial trees and least squares Monte Carlo (LSMC) methodologies avoid the issue of perfect foresight. Tree models do this by implementing a process called backward induction. This process starts at the last time step of the tree and determines the cashflows of the plant at each of the terminal nodes. We then step back to the penultimate time step and determine the value of the plant at each possible node, which is based on the optimized level of generation at that node. These steps are repeated back through the tree determining the operating cashflows and the discounted expected future value of the plant until the initial time step.

In tree models, dynamic programs are usually used to determine what state the generation asset is in and which state it can transition to in the next time step. Tree methods tend to be very computationally intensive. This is especially true when we build a tree with hourly level granularity. As a consequence, tree based models at an hourly level of granularity tend to take too long to provide results. A further shortcoming of tree models is that we are limited to certain price processes. The implementation of jumps in a tree model increases the computation significantly such that it is impractical. Since real world power prices exhibit jumps more than any other commodity, this limitation is often considered to be a very severe limitation.

LSMC methods combine the backward induction principal of tree based models with Monte Carlo simulation of power prices. LSMC was originally developed to value American style options, which allow for early exercise, within a Monte Carlo framework but can be extended to general valuation problems where the optimization covers the cashflows that arise from making a decision now (such as operating the plant at a certain level) and which in turn affect the expected future value of the option. Since LSMC does not make use of a tree or lattice, it can use any price process to evolve the underlying uncertainty. The downside to LSMC is that it requires many linear regressions to be run at each time step. This requirement means that LSMC takes very much longer than any of the methods to calculate the value of a plant. As a consequence, LSMC is often not seen as a practical way to value generation assets.

Types of Generation Assets

We can group generation assets in to three broad categories based on how they are expected to serve load:

- Baseload
- Mid-merit
- Peaking

Baseload units, as the name implies, handle the base load of the grid. They tend to be efficient units with low heat rates and consequently, typically operate in the money with most of their value being intrinsic value rather than extrinsic. On the negative side, they have high start costs and have very long minimum up and down times. It also takes a long time to ramp the unit up to the maximum capacity. These constraints tend to minimize the amount of optionallity that we have for baseload units. Since baseload units tend to be in the money and have some significant operational constraints, the use of an analytic spark spread option to value them is often seen as a good approximation.

Mid-merit units on the other hand tend to be less efficient than baseload units and/or use a costlier fuel which often puts mid-merit units at the cusp of being used. In terms of moneyness these units are considered to be at the money and as such have the largest amount of extrinsic value. Consequently, it is very important to properly value the optionality of a mid-merit unit. Mid-merit units typically to have lower start costs, shorter minimum up/down times, and less time to ramp up to maximum capacity than baseload units. This implies that the constraints do not constrict the optionality of the mid-merit unit as much as they do for baseload units. Consequently, using an analytic spark spread option model for a mid-merit unit would be less than ideal. The preferred method to value mid-merit units would be to make use of the Monte Carlo techniques that we discussed earlier.

Peaking units tend to have very high heat rates and as such are seen as out of the money options with all of their value seen as extrinsic value. Peaking units are designed to be able to meet sudden peaks in demand and consequently have low start costs, short minimum up/down times, and can quickly ramp up to maximum generation. Since peaking units are very flexible and have only extrinsic value, the ideal way to value them is to use Monte Carlo techniques.

Analytic Spark Spread Example

Although an analytic spark spread option approach isn't the best approach for all types of generating units, it can be a reasonable method for valuing baseload and intermediate units. In this example, we will demonstrate how we can value a unit with start costs over a 24 month period beginning on January 1st 2009. The evaluation date for the generation unit is October 1st 2008. The properties of the unit are as follows:

- Maximum capacity 100 MW
- Heat rate at maximum capacity 7 MMBTU/MWh
- Variable O&M \$1.50/MWh
- Start Cost \$5,000/start
- Start Gas 700MMBTU

For this example we will assume that the generator will only sell "on peak" power.

Figure 1 shows the monthly forward power price and the heat rate adjusted forward gas price that we will use in this example. In this figure we see the seasonal patterns in the power prices which peak during the summer months and the gas price which peaks during the winter months. We can also see that the power price is greater than the adjusted gas price during the spring and summer months and consequently we would expect to see a non-zero intrinsic value for this power plant in those months.

In addition to the forward curves we also need relevant volatility information. For markets that have liquid option markets, an implied volatility can be calculated. For markets that do not have liquid option markets, an annualized volatility can be estimated from historical forward and spot price data. In our example we assume that both the power and gas markets have liquid option markets and we were able to back out implied volatilities. Figure 2 plots these volatilities. Similar to the forward prices, volatilities also exhibit seasonality with power volatilities reflecting the peak power prices during the summer months. The volatility level of both power and gas decay over time, representing the term structure of forward volatility. The gas volatility peaks during the winter months, which is when the gas price also peaked.

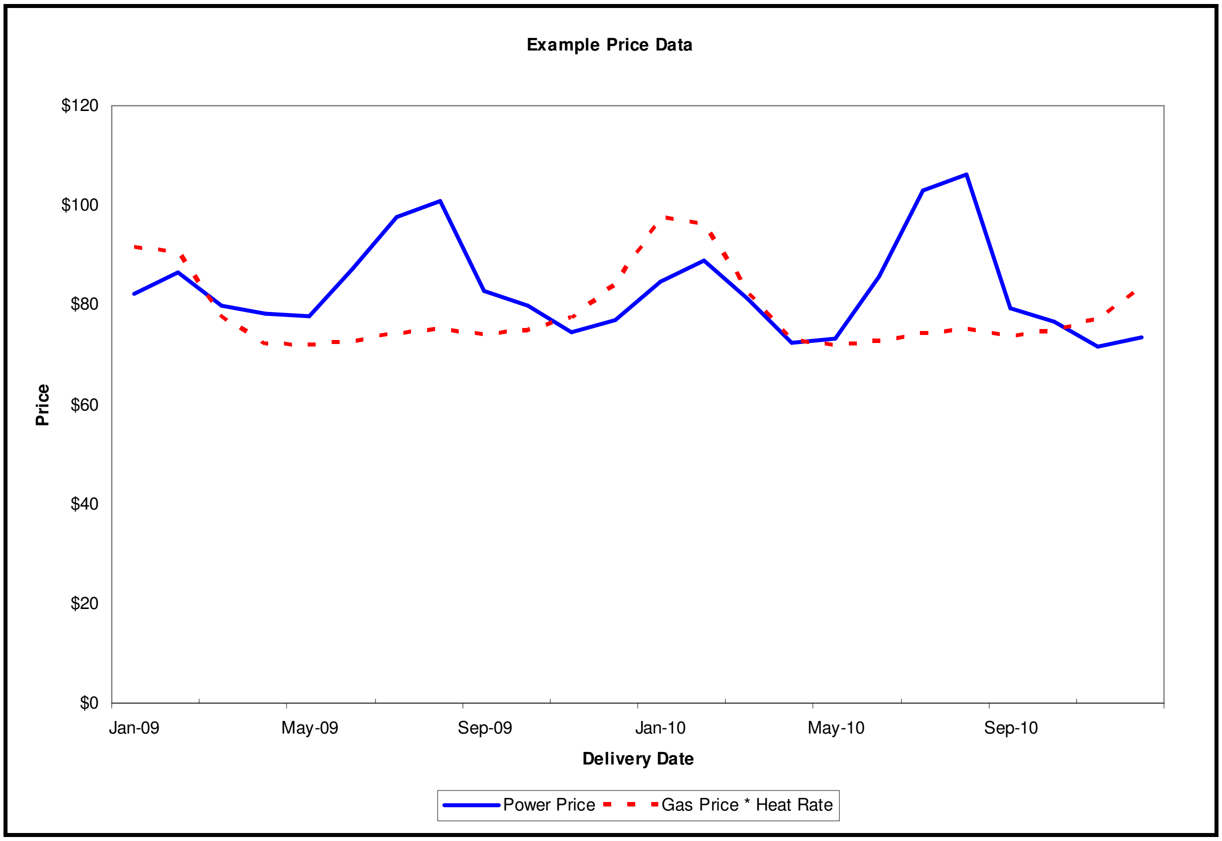

Figure 1: The power forward curve and the heat rate adjusted gas forward curve

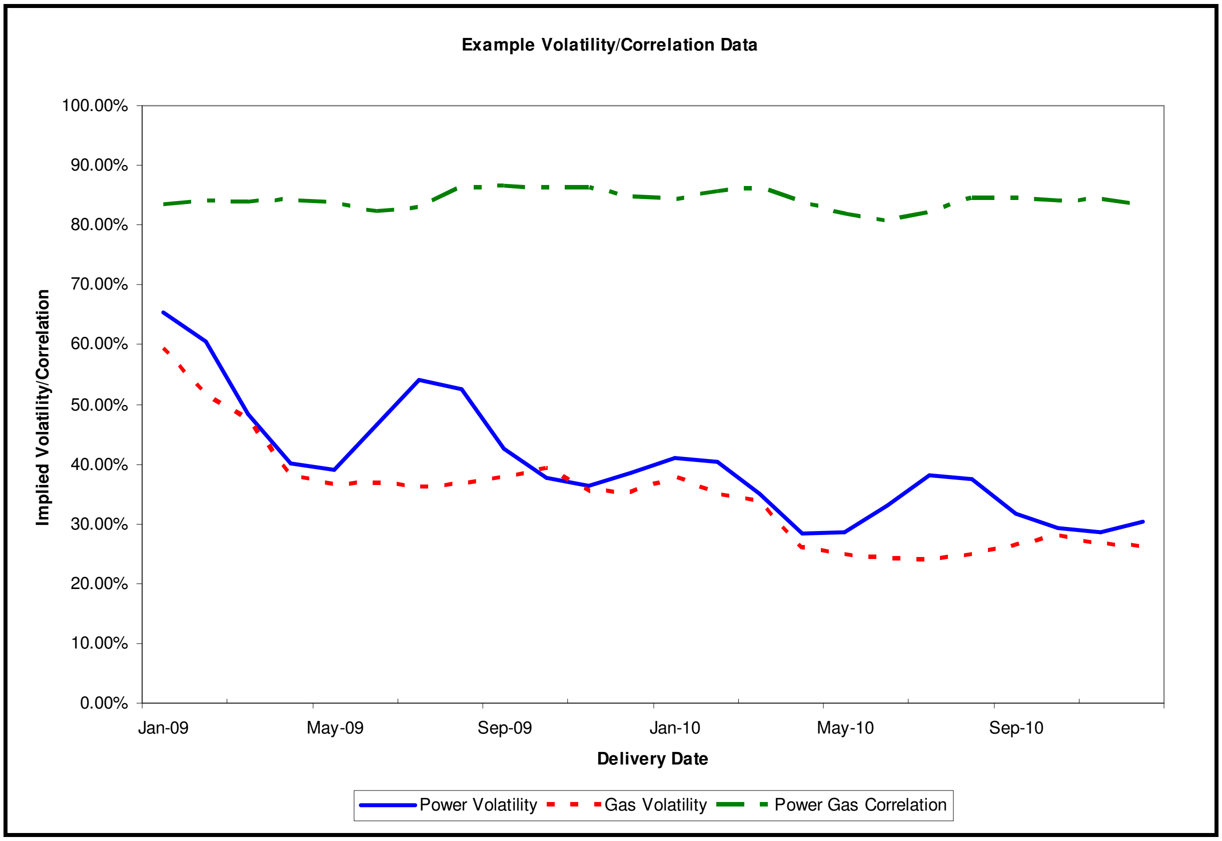

Figure 2: Volatility curves for power and gas and correlation between power and gas...

In addition to the forward prices and the volatility, we also require an implied (terminal) correlation. The correlations used in this example are also implied from market data, and are also plotted in figure 2

With the parameters of the unit and the data for the forward prices, volatilities, and correlation, we can value the generation asset. Figure 3 shows the calculations for the analytic spark spread model.

Delivery	Expiration	Time to Maturity	Power	HR * Gas	VOM	HR * Gas Adder	Start Cost	Total Strike	Intrinsic Value	Extrinsic Value	Total Value	MWH	Intrinsic Value	Extrinsic Value	Total Value
1/31/2009	1/14/2009	0.29	$82.10	$91.52	$1.50	$0.70	3.13	$5.33	$0.00	$1.87	$1.87	33,600	$0	$62,839	$62,839
2/28/2009	2/13/2009	0.37	$86.40	$90.38	$1.50	$0.70	3.13	$5.33	$0.00	$3.49	$3.49	32,000	$0	$111,627	$111,627
3/31/2009	3/13/2009	0.45	$79.75	$77.79	$1.50	$0.70	3.13	$5.33	$0.00	$4.21	$4.21	35,200	$0	$148,037	$148,037
4/30/2009	4/14/2009	0.53	$78.25	$72.11	$1.50	$0.70	3.13	$5.33	$0.80	$4.46	$5.25	35,200	$28,119	$156,857	$184,976
5/31/2009	5/14/2009	0.62	$77.75	$71.86	$1.50	$0.70	3.13	$5.33	$0.56	$4.82	$5.38	32,000	$17,900	$154,277	$172,177
6/30/2009	6/12/2009	0.70	$87.25	$72.65	$1.50	$0.70	3.13	$5.33	$9.09	$3.55	$12.64	35,200	$319,880	$125,130	$445,010
7/31/2009	7/14/2009	0.78	$97.77	$74.27	$1.50	$0.70	3.13	$5.33	$17.75	$3.36	$21.11	36,800	$653,212	$123,809	$777,021
8/31/2009	8/14/2009	0.87	$100.73	$75.11	$1.50	$0.70	3.13	$5.33	$19.77	$2.62	$22.40	33,600	$664,408	$88,164	$752,572
9/30/2009	9/14/2009	0.95	$82.75	$73.92	$1.50	$0.70	3.13	$5.33	$3.40	$5.00	$8.41	33,600	$114,404	$168,087	$282,492
10/31/2009	10/14/2009	1.04	$79.71	$74.78	$1.50	$0.70	3.13	$5.33	$0.00	$5.91	$5.91	35,200	$0	$208,126	$208,126
11/30/2009	11/13/2009	1.12	$74.46	$77.34	$1.50	$0.70	3.13	$5.33	$0.00	$2.79	$2.79	32,000	$0	$89,136	$89,136
12/31/2009	12/14/2009	1.20	$76.83	$83.96	$1.50	$0.70	3.13	$5.33	$0.00	$2.70	$2.70	35,200	$0	$94,988	$94,988
1/31/2010	1/14/2010	1.29	$84.64	$97.55	$1.50	$0.70	3.13	$5.33	$0.00	$2.81	$2.81	32,000	$0	$89,883	$89,883
2/28/2010	2/12/2010	1.37	$88.86	$96.10	$1.50	$0.70	3.13	$5.33	$0.00	$4.10	$4.10	32,000	$0	$131,124	$131,124
3/31/2010	3/12/2010	1.44	$81.06	$82.81	$1.50	$0.70	3.13	$5.33	$0.00	$4.01	$4.01	36,800	$0	$147,669	$147,669
4/30/2010	4/14/2010	1.53	$72.44	$72.96	$1.50	$0.70	3.13	$5.33	$0.00	$3.16	$3.16	35,200	$0	$111,405	$111,405
5/31/2010	5/14/2010	1.62	$73.18	$71.96	$1.50	$0.70	3.13	$5.33	$0.00	$4.21	$4.21	32,000	$0	$134,788	$134,788
6/30/2010	6/14/2010	1.70	$85.67	$72.64	$1.50	$0.70	3.13	$5.33	$7.32	$4.91	$12.23	35,200	$257,707	$172,876	$430,583
7/31/2010	7/14/2010	1.78	$102.95	$74.20	$1.50	$0.70	3.13	$5.33	$22.21	$3.08	$25.29	33,600	$746,204	$103,404	$849,608
8/31/2010	8/13/2010	1.87	$106.05	$75.02	$1.50	$0.70	3.13	$5.33	$24.31	$2.45	$26.76	35,200	$855,562	$86,370	$941,932
9/30/2010	9/14/2010	1.95	$79.32	$73.79	$1.50	$0.70	3.13	$5.33	$0.19	$6.99	$7.18	33,600	$6,347	$234,995	$241,342
10/31/2010	10/14/2010	2.04	$76.70	$74.69	$1.50	$0.70	3.13	$5.33	$0.00	$5.24	$5.24	33,600	$0	$176,107	$176,107
11/30/2010	11/12/2010	2.12	$71.58	$77.16	$1.50	$0.70	3.13	$5.33	$0.00	$2.55	$2.55	33,600	$0	$85,840	$85,840
12/31/2010	12/14/2010	2.20	$73.55	$83.43	$1.50	$0.70	3.13	$5.33	$0.00	$2.44	$2.44	36,800	$0	$89,669	$89,669
											Total		$3,663,745	$3,095,207	$6,758,952

Figure 3: Analytic spark spread option calculations.

Each row in Figure 3 represents a calendar month. In this representation we value the spread option for a single hour and then scaling the value by the number of MWhs we expect to generate for the month. As each hour has a different time to maturity – the dates near the end of the month will have a longer time to maturity and a higher option value while the days near the beginning of the month will have a short time to maturity and a lower option value – we have chosen the expiration to be around the middle of the month as this should even out the difference between the.

The 'Power' column represents the on peak power forward price. We need to take some care with the heat rate adjusted gas price. The reason for this is that we have start gas that the unit requires and, since gas price is stochastic, we can't just incorporate the price of the start gas at the current forward price as a fixed part of the strike, as this would ignore all the risk associated with the uncertain gas price. In this example then, we scale up the heat rate to account for the start gas. To calculate the modified heat rate we add the start gas to the amount of gas the plant will use for running at maximum capacity for 16 hours, and then divide that total number of MWhs produced.

$$\frac{16 \times Heat\ Rate \times Maximum\ Capacity + Start\ Gas}{16 \times Maximum\ Capacity} = \frac{16 \times 7 \times 100 + 700}{16 \times 100} = 7.4375$$

The heat rate we used to account for the start gas is 7.4375 and heat rate adjusted gas price is represented in column 'HR*Gas' of Figure 3.

The fixed strike component of the spark spread model is composed of the variable O&M, the gas adder, and the fixed star cost of $5,000 per start. The variable O&M cost is just the cost defined for the generation unit under consideration and is in the column labelled 'VOM'. The gas adder is a product of the unadjusted heat rate and the gas adder. In this case it is 7[MMBTU/MWh]*0.10[$/MMBTU] or $0.70. The cost associated with the

$5,000 per start is tricky to handle. In order to handle it, we need to spread that charge over the MWhs we will generate over each day's 16 hour block. This means that the start charge needs to be divided by 16x100 and translates to a cost of $3.125/MWh that can be placed into the fixed strike. Consequently, the total fixed strike *K* for the generator is the sum of the variable O&M, the heat rate times the gas adder and the start cost. The fixed strike is calculated to be $5.3250/MWh.

We can now use the relations derived above for the analytic spread option to calculate the value for each month on a per MWh basis. The formula provides the total option value. We can also calculate the intrinsic value of the generation unit which we define to be $Max(P - HR \times G - X, 0)\, e^{-rt}$ where r is the risk free interest rate – assumed in this example to be 3%, and *t* is the time to maturity. The total option value is discounted implicitly. We can then calculate the extrinsic value to be the difference between the total value and the intrinsic value.

The last step is to scale the total value by the MWhs that are generated in each month, which is calculated as the product of the number of hours in the on peak block, the maximum capacity of the unit, and the number of business days in the month. The monthly intrinsic, extrinsic, and total values are displayed in last 3 columns of Figure 3. The monthly intrinsic and total values are graphed in Figure 4. The difference between the total and intrinsic value is the extrinsic value. The highest values occur during the summer months. This is expected since it is where the power prices are high and the gas prices are low. We can also see from the plot that the total value for the summer months is largely made up of intrinsic value. Most of the total value in the shoulder months is from extrinsic value.

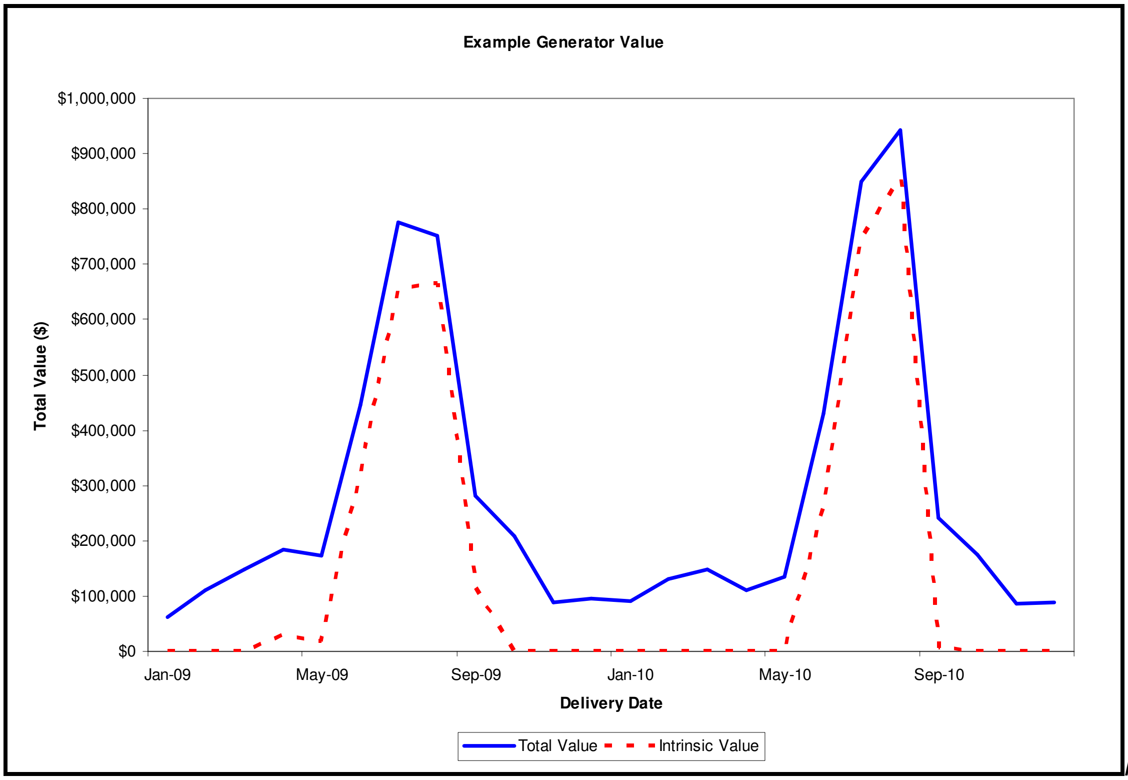

Figure 4: Total and intrinsic value for the generation unit.

Although the spark spread option presented here is a very simple model, it provides a good basis for a rough estimate. As we mentioned earlier, generator assets have many complicated constraints that need to be modelled correctly. We can only handle a limited number of them in the spark spread model. There are other techniques that can be used to correctly handle these other constraints. We will discuss these methods in subsequent articles.

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About Lacima Group

Lacima Group is a specialist provider of energy and commodity pricing, valuation and risk management software and advisory services. Based on its internationally acclaimed research in energy risk modelling, Lacima's solutions help energy trading organisations to effectively quantify and manage risks associated with structured contracts and physical assets across multiple commodities and regions. For further information, visit www.lacimagroup.com.

References

Black F, 1976, “The Pricing of Commodity Contracts”, Journal of Financial Economics, Vol. 3, Jan-Mar, pp 167-179.

Clewlow, L, and C. Strickland, 2000, “*Energy Derivatives: Pricing and Risk Management*”, Lacima Publications.

Kirk, E. 1995, “Correlation in Energy Markets”, in Managing Energy Price Risk. London: Risk Publications and Enron, pp 71-78