Operating Hydroelectric and Pumped Storage Units In A Competitive Environment

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In recent years as restructuring has gained momentum, both new generation investment and efficient power plant operation have taken on greater strategic significance. The time during which energy was a monolithic product is now past. Recently, California, ISO-New England, New York ISO, PJM and Ontario IMO have created distinct energy and ancillary service products. These new products offer additional sources of revenue to energy suppliers. The market prices of the energy and the ancillary services are interrelated and the suppliers have the choice of

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participating in the market that returns the highest profit.

In such a multi-commodity market, generator operators will seek to maximize income by pursuing profits across all available markets. In order to achieve the full earnings potential of the asset, operators must actively participate in the lucrative ancillary service and spot markets. The price swings that characterize the power markets are so significant that market participants will be reluctant to forego the profits potentially available in the various markets.

In this paper, we examine how the ancillary service markets affect the operation and the revenues of hydroelectric plants and pumped storage units.

Operating Hydro Units Solely to Provide Energy Ignores Potential Sources of Revenues

In the past, during the days of regulatory price determination, hydro and pumped storage units were mainly dispatched to replace high-cost thermal energy during the high-load periods. The earnings of these units were calculated on the basis of the cost of the energy they replaced. The method of valuation usually employed a peak-shaving algorithm applied to a single energy market production cost simulation. However, this method severely underestimates the income of the storage and pumped hydro units, by failing to recognize the profit potential from the ancillary service markets.

In the next section, we present a case study of the operation of a hypothetical hydro and pumped storage unit in a multiple-product market and compare the revenues earned by these units to their counterpart earnings through conventional operation in an energy-only market. In an earlier paper,[2] we have discussed the impact of volatility and the presence of multiple-product markets on the valuation of thermal generators in a competitive environment.

Case Study: Simultaneous Bidding in Energy and Ancillary Service Markets

The case study presented in this paper is based on hourly simulation of energy and ancillary services in a day-ahead electricity market like California involving a Power Exchange (PX) and an ISO. For an internally consistent forecast of all the markets including energy, ancillary services and real-time imbalance, a structural model is needed. In this study we use UPLAN Model[3], a proprietary multi-product, multi-

[2] Rethinking Asset Valuation in a Competitive Environment, Public Utilities Fortnightly, February 2000.

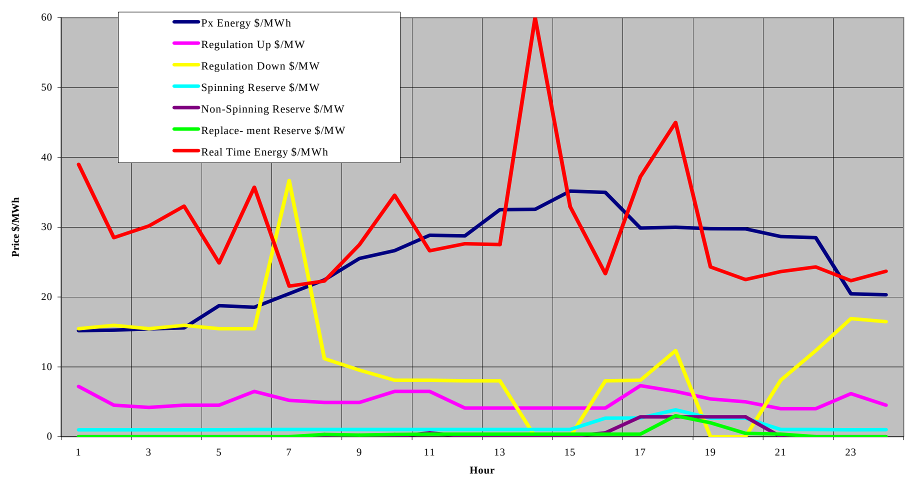
[3] UPLAN's Market Simulation Model is based on Rational Expected Equilibrium Prices (REEP) in the presence of multiple forward markets. The REEP methodology treats the problem of determining competitive equilibrium prices in the presence of multiple markets as a non-linear game between the suppliers, maximizing their profit and buyers minimizing their payments. It uses a state-of-the-art decomposition methodology to solve the non-linear game using successive linear programs. The algorithm starts with estimates of the initial equilibrium prices in the energy, ancillary services and real-time energy market. Then the program determines the bids that maximize the marginal profit of each seller and uses the optimized bids to determine the equilibrium prices of energy and ancillary services. The successive linear

area structural model with an Optimal Power Flow (OPF) dispatch for real-time pricing.

A typical hourly forecast of the model is displayed in Table 1 and consists of prices for energy, regulation-up, regulation-down, spinning and non-spinning reserves, replacement reserve and real-time energy. These prices will be now used to find the optimal bidding strategies of the Storage and Pumped Hydro units whose characteristics are displayed in Table 2.

A. Bidding for Energy-only Note from Tables 1 and 2 that the capacity of the storage hydro unit and the Pumped Hydro (PH) unit are 120 MW and that they can be discharged in 10 hours at full capacity with a daily scheduled energy of 1200 MWh. In the traditional mode, the units will operate for 10 hours between 11 AM to 8 PM at the highest PX energy prices. Both the storage and the pumped hydro unit will receive all revenues, a sum of $37,469 for each, from

Figure 1. Hourly PX and Ancillary Prices for One Day



Tables 3 and 4 show the optimal bidding strategy and expected revenues earned by the storage and pumped hydro unit respectively. These revenues are obtained by optimizing hourly and daily decisions over an extended planning horizon.

the energy market. To enter the market, the storage unit might bid its water value, the lowest profit it earns during the 10 hours of operation, which is $28.77/MWh in hour 11. The unit could also bid zero dollars for the 10 hours as a price taker.

programs alternate between minimizing the buyers' payment, and maximizing sellers' profit until they determine arbitrage-free Nash equilibrium prices for the multi-commodity market. The UPLAN Network Power Model uses an optimal power Flow (OPF) algorithm to dispatch the resources cleared by the Market Simulation Model to determine the real time imbalance prices. The OPF also calculates the security-constrained load flows, manages congestion and calculates transmission costs.

1	2	3	4	5	6	7	8	9	10	11	12
Hour of the Day	PX Energy Price $/MWh	Reg-Up Price $/MW	Reg-Down Price $/MW	Spinning Reserve Price $/MW	Non-Spinning Reserve Price $/MW	Replace-ment Reserve Price $/MW	Real-Time Energy Price $/MWh	Expected Income from Reg-Up $/MWh	Expected Income from PX & Reg-Down $/MWh	Hydro Reg-Up Bid Qty MW	Pumped Storage Reg-Up Bid Qty MW
1	15.19	7.20	15.47	0.99	0.01	0.01	39.00	38.02	28.61	120	0
2	15.26	4.50	15.95	0.99	0.01	0.01	28.49	33.21	31.27	0	0
3	15.45	4.20	15.47	0.99	0.01	0.01	30.17	33.25	30.64	0	0
4	15.58	4.50	15.95	0.98	0.01	0.01	33.00	34.12	30.68	0	0
5	18.77	4.50	15.47	0.98	0.01	0.01	24.88	32.49	35.02	0	0
6	18.53	6.50	15.47	1.02	0.01	0.01	35.73	36.66	32.61	0	0
7	20.47	5.20	36.68	1.03	0.01	0.01	21.56	32.53	58.59	0	0
8	22.47	4.90	11.20	1.03	0.01	0.31	22.30	32.38	34.96	0	0
9	25.54	4.90	9.55	1.03	0.01	0.24	27.50	33.42	35.34	0	0
10	26.64	6.50	8.10	1.03	0.01	0.31	34.57	36.43	33.58	120	120
11	28.77	6.50	8.10	1.03	0.55	0.37	26.62	34.84	37.30	0	0
12	28.74	4.10	8.00	1.04	0.05	0.37	27.62	32.64	36.97	0	0
13	32.50	4.10	8.00	1.03	0.13	0.37	27.52	32.62	40.75	0	0
14	32.55	4.10	0.00	1.05	0.05	0.37	60.00	39.12	26.30	120	120
15	35.15	4.10	0.00	1.04	0.05	0.37	32.95	33.71	34.31	0	0
16	35.00	4.10	8.00	2.66	0.55	0.37	23.35	31.79	44.08	0	0
17	29.87	7.30	8.10	2.68	2.83	0.37	37.22	37.76	36.28	120	120
18	29.97	6.50	12.33	3.87	2.83	3.00	45.00	38.52	39.05	0	0
19	29.80	5.40	0.00	2.66	2.83	2.00	24.30	33.28	30.69	0	120
20	29.77	5.00	0.00	2.66	2.83	0.49	22.50	32.52	31.02	0	0
21	28.66	4.00	8.10	1.03	0.01	0.37	23.66	31.75	37.78	0	0
22	28.50	4.00	12.33	1.03	0.01	0.01	24.30	31.88	41.72	0	0
23	20.46	6.15	16.92	0.99	0.01	0.01	22.33	33.63	38.67	0	0
24	20.32	4.50	16.47	1.00	0.01	0.01	23.70	32.26	37.80	0	0
Avg	25.17	5.11	11.07	1.41	0.54	0.39	29.93	34.12	36.00	0	0

Column 9 = Expected Income from Reg-Up + Income from Real-Time Dispatch + Next Day Income from Carry-Forward
Column 10 = Income from PX + Income from Reg-Down - Payback for Unused Energy + Next Day Income from Carry- Forwa

Table 1. PX, A/S and Regulation-Up Market Clearing Prices

	Storage Hydro	Pumped Hydro
Hydro Capacity (MW)	120	120
Charging Size (MW)	N/A	300
Charging/ Discharging Ratio	N/A	1.5
Daily Energy Allocation (MWh)	1200	1200

Table 2: Characteristics of Pumped Hydro and Storage Hydro

The PH unit, however, will charge 1800 MWh of energy between hours 1 through 6 at a cost of $29,634, thus storing 1200 MWh energy-only bid are summarized in columns 2 and 3 of Table 3 and Table 4.

As will be illustrated, these incomes are

Hour of the Day	Traditional Operation of Hydro Units		Competitive Bids for Ancillary and Energy Markets																
			Regulation-Up Market						Regulation-Down Market						PX Energy Market		Real-Time Market	Next-Day Market	
	Capacity Accepted by PX (MW)	Revenue Earned[1] $/MWh	Bid Price $/MWh	Bid Qty (MW)	Qty Accepted by PX (MW)	Revenues from Accepted Reg-Up Market ($)	Real-Time Qty Exercised by ISO (MW)	Carried Forward to Next Day (MW)	Bid Price ($/MWh)	Bid Qty (MW)	Qty Accepted by PX (MW)	Revenues from Accepted Reg-Down Market ($)	Real-Time Qty Exercised by ISO (MW)	Carried Forward to Next Day (MW)	Capacity Accepted by PX (MW)	Rev. from PX Energy ($)	Real-Time Energy Revenue (Payback) ($)	Rev. from Energy Carried to Next Day ($)	Total Estimated Revenue from All the Markets ($)
1	0	0	0.00	120	120	864	24	0	0.00	0	0	0	0	0	0	0	936	0	1800
2	0	0	0.28	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
3	0	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
4	0	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
5	0	0	3.89	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
6	0	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
7	0	0	7.21	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
8	0	0	6.47	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
9	0	0	1.27	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
10	0	0	0.00	120	120	780	24	0	0.00	0	0	0	0	0	0	0	830	0	1610
11	120	3452	2.15	0	0	0	0	120	0.00	0	0	0	0	0	0	0	0	3480	3480
12	120	3463	1.15	0	0	0	0	120	0.09	0	0	0	0	0	0	0	0	3480	3480
13	120	3900	1.25	0	0	0	0	0	3.73	120	120	960	24	0	120	3900	(661)	0	4199
14	120	3906	0.00	120	120	492	24	0	3.78	0	0	0	0	0	0	0	1440	0	1932
15	120	4218	0.00	0	0	0	0	0	6.38	120	0	0	0	0	120	4218	0	0	4218
16	120	4200	5.42	0	0	0	0	0	6.23	120	120	960	24	0	120	4200	(560)	0	4600
17	120	3584	0.00	120	120	876	24	0	1.10	0	0	0	0	0	0	0	893	0	1769
18	120	3596	0.00		0	0	0	0	1.20	120	120	1480	24	0	120	3596	(1080)	0	3996
19	120	3576	4.47	0	0	0	0	0	1.03	120	0	0	0	0	120	3576	0	0	3576
20	120	3572	6.27	0	0	0	0	0	1.00	120	0	0	0	0	120	3572	0	0	3572
21	0	0	5.11	0	0	0	0	120	-0.11	0	0	0	0	0		0	0	3480	3480
22	0	0	4.47	0	0	0	0	24	-0.27	0	0	0	0	72		0	0	2784	2784
23	0	0	6.44	0	0	0	0	0	0.00	0	0	0	0	0		0	0	0	0
24	0	0	5.07	0	0	0	0	0	0.00	0	0	0	0	0		0	0	0	0
	1200	37469			480	3012	96				360	3400	72			23063	1798	13224	44496
Avg $/MW		312				25						28				192	15	110	371
1. Revenue Earned = Capacity accepted by PX (col. 2, Table 3) * PX Energy Price (col. 2, Table 1)																			

Table 3: Storage Hydro Bids and Revenues

of energy at a charge-to-discharge ratio of 1.5. The total net incomes of the storage hydro and PH unit are $37,469 and $7,835 respectively, in the traditional way of dispatching. In terms of the capacity of these units, the income turns out to be $312/MW-day and $65/MW-day, respectively for the storage hydro and the pumped hydro units. The results of the substantially below the units' potential earnings from participation in the ancillary service markets.

B. Bidding for Energy and Ancillary Services: From the PX, A/S, and real-time market prices in Table 1, we can estimate the profits for a day from bidding hydro into the PX and regulation-down or regulation-up markets. Taking hour 1 for example, if the hydro unit participates in the PX and day-ahead regulation markets, it will receive $15.19/MWh from the PX and $15.47/MWh from the regulation-down market. Assume that the unit operates at full capacity 80% of the time and the remaining 20% of the time the ISO exercises its option to back-down the unit. Since the operator has already received payment for the entire amount of energy, it has to pay the ISO back for the unused portion of energy at the real-time market price of 39.00/MWh. However, the unit can sell the unused energy the following day at the hydro water value of $28.77. To simplify the example we assume that the next day PX prices and hydro water value are the same as today's. The total expected earning of this unit from the PX energy and the regulation-down market, taking into account the refund for unused energy and recovery from next day's sales is equal to $28.61/MWh (=$15.19+$15.47-$39*.2+$28.77*.2) as shown in column 10 of Table 1.

Suppose the hydro unit bids its entire capacity into the regulation-up market, it will receive $7.20//MWh, which is the clearing price of the regulation-up market. Now, assume 20% of the time ISO requires the unit to deliver energy in the real-time market. For the remaining 80% of the time, the unused energy can be carried forward to the next day and sold at its water value of $28.77/MWh. The total earning from the regulation-up market, real-time energy market and sale of the saved energy is $7.20+$39*0.2 +$28.77*0.8 =38.02$/MWh. The hourly profits from participating in the regulation-up market are displayed in column 9 of Table 1.

Therefore, the hydro unit should fashion its bid to enter the regulation-up market when its potential profit is greater than what it will earn from the other markets. In this example, we also assume that the maximum amount of hydro that can be carried over from one day to the next is 480 MWh, which is equal to 4 hours of discharge from the unit. This means the operator can bid into the regulation-up market up to a maximum of 4 hours.

From column 9 of Table 1, we conclude that the four highest income hours for the storage hydro unit in the regulation-up market are hours 1, 10, 14, and 17. The corresponding to the high-income hours for the pumped hydro are 10, 14, 17, and 19. Unlike the hydro unit, the pumped storage unit cannot participate in the regulation-up market at hour one because it is pumping energy at hour one. The bid quantities for these units are summarized in columns 11 and 12 of Table 1.

Table 3 and 4 display the revenues of the hydro and pumped storage units in the energy-only and energy plus ancillary services markets.

Hour of the Day	Traditional Operation of Hydro Units		Competitive Bids for Ancillary and Energy Markets																
			Regulation-Up Market						Regulation-Down Market						PX Energy Market		Real-Time Market	Nex-Day Market	
	Charge/ Discarge MW	Cost/ Rev	Bid Price $/MWh	Bid Qty (MW)	Qty Accepted by PX (MW)	Revenue from Accepted Reg-Up Market ($)	Real-Time Qty Exercised by ISO (MW)	Carried Forward to Next Day (MW)	Bid Price $/MWh	Bid Qty (MW)	Qty Accepted by PX (MW)	Revenue from Accepted Reg-Down Market ($)	Real-Time Qty Exercised by ISO (MW)	Carried Forward to Next Day (MW)	Capacity Accepted by PX (MW)	Rev. from PX Energy ($)	Real-Time Energy Revenue (Payback) ($)	Rev. from Energy Carried to Next Day ($)	Total Estimated Revenue from All the Markets ($)
1	(300)	(4557)	0	0	0	0	0		0	0	0	0	0		0	(4557)	0	0	(4557)
2	(300)	(4578)	0	0	0	0	0		0	0	0	0	0		0	(4578)	0	0	(4578)
3	(300)	(4635)	0	0	0	0	0		0	0	0	0	0		0	(4635)	0	0	(4635)
4	(300)	(4674)	0	0	0	0	0		0	0	0	0	0		0	(4674)	0	0	(4674)
5	(300)	(5631)	0	0	0	0	0		0	0	0	0	0		0	(5631)	0	0	(5631)
6	(300)	(5559)	0	0	0	0	0		0	0	0	0	0		0	(5559)	0	0	(5559)
7	0	0	7	0	0	0	0		0	0	0	0	0		0	0	0	0	0
8	0	0	6	0	0	0	0		0	0	0	0	0		0	0	0	0	0
9	0	0	1	0	0	0	0	24	0	0	0	0	0	72	0	0	0	2784	2784
10	0	0	0	120	120	780	24		0	0	0	0	0		0	0	830	0	1610
11	120	3452	2	0	0	0	0	120	0	0	0	0	0		0	0	0	3480	3480
12	120	3463	1	0	0	0	0		0	0	0	0	0		120	3463	0	0	3463
13	120	3900	1	0	0	0	0		4	120	120	960	24		120	3900	(661)	0	4199
14	120	3906	0	120	120	492	24		4	0	0	0	0		0	0	1440	0	1932
15	120	4218	0	0	0	0	0		7	120	0	0	0		120	4218	0	0	4218
16	120	4200	5	0	0	0	0		7	120	120	960	24		120	4200	(560)	0	4600
17	120	3584	0	120	120	876	24		1	0	0	0	0		0	0	893	0	1769
18	120	3596	0	0	0	0	0		1	120	120	1480	24		120	3596	(1080)	0	3996
19	120	3576	4	120	120	648	24		1	0	0	0	0		0	0	583	0	1231
20	120	3572	6	0	0	0	0		1	120	0	0	0		120	3572	0	0	3572
21	0	0	5	0	0	0	0	120	0	0	0	0	0		0	0	0	3480	3480
22	0	0	4	0	0	0	0	120	0	0	0	0	0		0	0	0	3480	3480
23	0	0	6	0	0	0	0		0	0	0	0	0		0	0	0	0	0
24	0	0	5	0	0	0	0		0	0	0	0	0		0	0	0	0	0
Total Income		**7835**			**480**	**2796**	**96**				**360**	**3400**	**72**			**(6684)**	**1445**	**13224**	**14181**
Avg $/MW		**65**				**23**						**28**				**(56)**	**12**	**110**	**118**

Table 4. Pumped Hydro Bids and Revenues

For the storage hydro unit, the optimal strategy is to bid 120 MW into the regulation-up market for the 4 hours shown in Table 1 and to bid 120 MW into the PX energy forward market and the regulation-down market for the remaining 6 hours (13, 15, 16, 18, 19, and 20). The total daily income would be $44,496 or $371/MW-day. The estimated annual income is $85,470/MW-yr.

If the operator wants to equalize the income from PX energy or the regulation –up market then the regulation bid should equal PX price minus the expected income from the real-time market. This will guarantee that the operator will receive at

least correct value for the product. In the peak hours the unit's value is the PX price, and in the off-peak hours, the value of the hydro unit is equal to the marginal value or the water value of the unit. Analysis similar to that used in the above example can be used for each market.

Note that in Table 3, the regulation-up bid equals the PX price or water value minus the real-time energy price, while the regulation-down bid equals the PX price minus water value. In this example, the regulation-up market accepts all 4 hours of regulation-up bids and the hydro unit receives an income of $3,012 from the regulation-up market. Three hours (13, 16, and 18) of regulation-down bids are accepted by the PX, and the unit gets an income of $3,400 from the regulation-down market. The net income from the real-time market for the day is $1,798.

The unused energy from the regulation-up and regulation-down market is carried forward to the next day and scheduled for the PX energy market, for a profit of $13,224. The carry-over energy is scheduled for the next day PX market at 120MW for the hours 11, 12, and 21 and at 96MW for hour 22. We assume that the carry-over energy is sold to the PX at $29/MWh next day.

In Table 4, we summarize the performance of the pumped storage unit. The operations of the pumped storage unit and the hourly revenues are very similar to those of the storage unit shown in Table 3. The main difference is that the pumped storage unit is normally used for charging between hours 1 through hour 6. As a result, the unused energy is scheduled for sale in hour 9 of the next day at $29. The total daily income of the pumped storage unit is $7,835 ($65/MW) and $14,181 ($118/MW) respectively for operating in the conventional mode or in multiple-product markets. Table 5 summarizes the operating income of these alternatives on a daily and annual basis. The annual results are obtained by accumulating the daily operating income over 365 days.

	Traditional Operation of Hydro Units		Competitive Bids for Ancillary and Energy Markets	
	Storage Hydro	Pumped Hydro	Storage Hydro	Pumped Hydro
One Day Income ($/MW-Day)	312	65	371	118
Annual Income ($/MW-Yr.)	72,072	15,015	85,470	29,741

Implications for a Bidding Strategy

Looking at the price trend in Figure 1, one will see that the generator's highest expected profits in the early and late hours of the day lie in the regulation-up, regulation-down and the real-time markets. Ancillary service reserves the unit, but cannot guarantee energy production in terms of capacity or duration of operation; this market carries some uncertainty. If the hydro units in the example were dispatched for regulation energy during earlier hours of the day, the capacity actually dispatched would vary according to the regulation service required and the fluctuation in the need for it.

Table 5. Comparison of Income from Traditional Operation VS. Proactive bidding

During peak hours, the higher PX energy prices promise the most profit in that market.

How should a bidding strategy balance the various profit opportunities in multiple product markets simultaneously? The operator of a hydro unit needs a bidding strategy that will result in a uniform expected level of profit, whichever market accepts it. The rationale behind this condition is the optimization of income, assuming indifference to the origin of profit. Given the expectations summarized in Tables 3 and 4, the operator develops bids that position the generator as a price-taker in the most profitable market during each hour.

In all hours, the operator will compare the PX energy prices, regulation-up plus the expected profit from the real-time market, the PX plus regulation-down minus expected payment to ISO for non-delivery of energy. The operator then determines the market that maximizes profit and makes sure that the generator receives the same profit from all other markets. For example, if regulation market provides the maximum profit, he will make sure bids are low enough to have a high likelihood of acceptance in that market. Thus, he stands to make no less from regulation than the expected profits from other markets. In the early hours of a day, when the PX prices are low and the loads are growing, the regulation-up market is the market of choice. In the late hours of the day, the loads go down and the regulation-down market becomes attractive. During the peak hours, the energy market gives the highest return. Note that the evaluation of both the regulation-up and down markets requires implicit estimation of the value of the energy that will be carried over to the next day. This quantity is not known ahead of time and varies every day.

Finally, the bidding quantity and prices are based on the equilibrium prices of energy and ancillary services; however, these equilibrium prices themselves may change due to recalculation of the bids. Therefore, the equilibrium prices must be determined[4] and the process repeated until the market prices stabilize.

Incorporating Volatility and Hydro Conditions Into Forecasts

When forecasts of income are made over a period of time, it is necessary to study electricity price volatility explicitly and the impacts of hydro conditions on the expected revenues. It is also essential to quantify other risks associated with the operation of the hydro and storage units, such as load variations.

To capture these variations, a structural market model is needed, in order to perform a systematic evaluation of volatility. The evaluation is based on Monte Carlo sampling of the probability distribution of the fundamental drivers such as weather, hydro conditions and other factors that contribute to the volatility of energy and ancillary service prices.

Because a structural model can simulate a large numbers of possible scenarios, it provides the

- distribution and volatility of income, which can be used for pricing options for trading purposes,
- percent of time the projected income exceeds a desired value, and
- risk premiums at various strike prices.

[4] Forecasting Energy and Ancillary Service Prices and Asset Evaluation. 1999, LCG, Los Altos, California.

Volatility and hydro conditions significantly influence the present value of the lifetime income of a hydro unit, including both energy and ancillary service revenues. Likewise, the structural model must take into account all relevant hydro system capabilities, constraints, and network effects.

Conclusion: The new pricing and consequent bidding opportunities in ancillary services mean that hydropower plants' revenues are not necessarily dictated by the avoided costs of non-hydropower generating plants. Despite the progress that lays ahead in the emergence of liquid ancillary services markets, hydropower generators' ability to provide various products requires increased attention to multiple markets. As operators gain insight concerning the prices prevalent in a particular energy or ancillary service market, their minimum requirements for returns from the other markets will inevitably cause dynamic price changes. For both bidding strategies and long-term valuation of generating assets, a structural model with the ability to capture price volatility and dynamic interactions for all products is needed. By optimizing bids with the model, operators can progress beyond inefficient, outmoded practices and optimize their generating plants' earnings potential.

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