Office of the Tasmanian Economic Regulator

Investigation Of Hydro Tasmania's Pricing Policies In The Provision Of Raise Contingency Frequency Control Ancillary Services To Meet The Tasmanian Local Requirement

A PRICING MECHANISM TO FACILITATE ENTRY INTO THE FCAS MARKET

COMMENTS OF MARK B. LIVELY
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The Regulator is concerned about the potential for Hydro Tasmania to abuse its market power in regard to FCAS.[1] Hydro Tasmania wants there to be other participants in the FCAS market.[2] Having other participants in the FCAS market would reduce Hydro Tasmania's market power. I believe that a major barrier for others to enter the FCAS market is the current requirement to participate in an auction. Auctions are expensive for the operator and very expensive for the participants. This barrier to entry can be eliminated by the introduction of a spot pricing mechanism that sets the price for FCAS without the use of a bidding system. I have described such a mechanism in various articles[3], papers[4], and regulatory filings[5] [6], calling the concept Wide Open Load Following (WOLF). A similar system is now in use in India.[7]

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[1] "the Regulator formed the opinion that Hydro Tasmania has substantial market power in respect of raise contingency FCAS", Section 2.1 (b), page 6, *AETV Discussion Paper,* 2010 May 24.

[2] "The form of regulation should encourage new entrant in markets where there is a more efficient new entrant available," page 4, item (ii), *Hydro Tasmania's Submission on OTTER's Regulation of Raise FCAS in Tasmania*, 2010 April 30.

[3] For instance, see "Tie Riding Freeloaders--The True Impediment to Transmission Access," *Public Utilities Fortnightly,* 1989 December 21 and "Microgrids And Financial Affairs - Creating A Value-Based Real-Time Price For Electricity," *Cogeneration and On-Site Power Production*, September, 2007.
http://www.cospp.com/articles/article_display.cfm?ARTICLE_ID=307889&p=122

[4] "Valuing Demand Response For Meeting Intermittencies," accepted for *IEEE Power & Energy Society General Meeting*, Minneapolis, MN, 2010 July 25-29.

[5] "Trust But Verify And Then Cash-Out, Comments Of Mark B. Lively," *National Action Plan on Demand Response,* FERC Docket No. AD09-10-000, 2009 December 4 and "Ratemaking To Facilitate Contra-Cyclical Operations: Comments Of Mark B. Lively," FERC Docket No. RM10-11-0000, *Integration of Variable Energy Resources*, 2010 March 17.

[6] Some of my writings can be accessed at no charge at http://www.LivelyUtility.com

[7] The process in India is the Unscheduled Interchange (UI) portion of the Availability Based Tariff. I discuss UI pricing results in some of my writings. UI pricing has been extensively discussed on InPowerG list server. Summaries of some of the discussions have been posted on line for easy access on the Internet. Search for "InPowerG" or "ABT UI Pricing."

INTRODUCTION

I am a consulting engineer specializing in the pricing of electricity and natural gas. I am registered as a Professional Engineer in the District of Columbia, the seat of the United States federal government. I have a Bachelors of Science degree in Electrical Engineering from the Massachusetts Institute of Technology and a Masters of Science degree in Management from the Massachusetts Institute of Technology Sloan School. I have worked on utility financial issues for almost 39 years: American Electric Power Service Corporation (1971-1976); Ernst & Ernst (1976-1979) and its successors Ernst & Whinney (1979-1989) and Ernst & Young (1989-1991); and self employed since 1991 operating as Utility Economic Engineers. In 1982, Ernst & Whinney sent me to Melbourne, Australia on behalf of the State Electricity Board of Victoria to look at the construction costs of the Loy Yang power plant.

Ernst & Whinney sent me to Johannesburg, South Africa in 1983 and 1984 to look at ESKOM's rates. While constructing an interruptible rate schedule, I found an ESKOM operating rule that limited the dispatch of expensive combustion turbines to times of severe frequency decline,[8] with the justification being financial. I used this combination of operations and finances to develop the WOLF concept, with the price of unscheduled flows of electricity based on system frequency. I have since written several articles and papers related to WOLF.

I have been a frequent commentator on PowerGlobe (operated by the Institute of Electrical & Electronic Engineers (IEEE)) and on InPowerG (operated by a university in India.) On a *pro bono* basis I have made regulatory filings with the US Federal Energy Regulatory Commission and with the United Kingdom Office of Gas & Electricity Markets. Partially as a result of my comments on PowerGlobe, I have had assignments to lead an IEEE workshop at University Simon Bolivar in Caracas, Venezuela (2001); to participate in a restructuring workshop at Sultan Qaboos University in Muscat, Oman (2003); and to make a presentation at the Electricity Engineers Association in Auckland, New Zealand (2006).[9] A commentator on PowerGlobe from New South Wales told me of this OTTER proceeding, sending me the 2010 June 18 draft report "Raise Contingency FCAS – Price Control Mechanism," with the subject line "Are they crying out for WOLF?" I am filing these comments with Office of the Tasmanian Economic Regulator on my own behalf on a *pro bono* basis.

FCAS AND WOLF

Frequency Control Ancillary Services (FCAS) are used to dampen the swings in system frequency. Frequency varies from the nominal 50 Hertz when supply and demand are out of

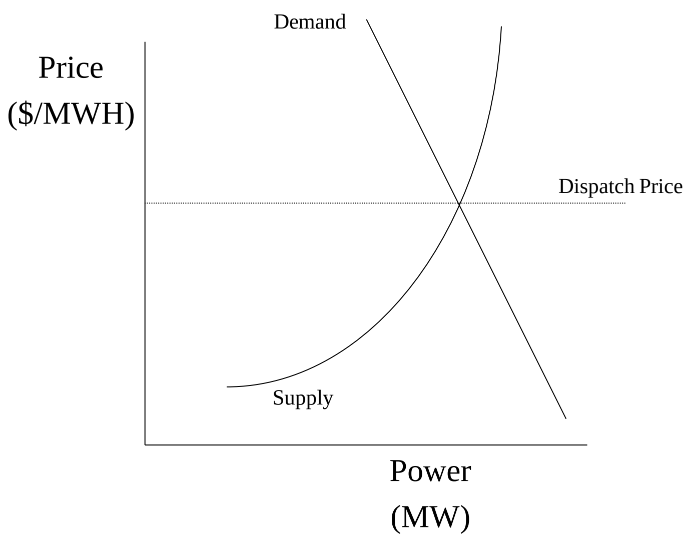
[8] Frequency had to be below 49.5 Hertz and be expected to stay there for over 2 hours before combustion turbines would be dispatched.
[9] My resume and many of my writings are available at my website http://www.LivelyUtility.com

balance. NEMMCO operates the National Energy Market (NEM) using a forwards auction for each clock half hour (i.e., thirty (30) minutes), though with some differentiation for 6 five-minute periods within each thirty (30) minute period.

- NEM is a forwards market in that the subject deliveries are for some future period of time, even though that future period might only start a few seconds after the market is closed.
- NEM is an auction because all parties submit bids for the power that they plan to provide during the future period.

The offers to supply power are summed to create a supply curve that is then matched against the anticipated demand curve every five minutes. The intersection of these two curves provides the total quantity to be dispatched and the dispatch price, as shown in Figure 1. The dispatch price is then compared to the bids of each seller to determine the quantity that each seller is to provide throughout the five-minute futures period. The dispatch price in Figure 1 is generically called the equilibrium price. NEM averages six of the dispatch prices to determine the spot price to be paid for all energy during each half hour.

NEM 5 Minute Energy Market
Figure 1



Electricity is a continuous product, both in regard to being able to be finely differentiated in respect to quantity and in regard to being delivered all the time. Since electricity is being continuously delivered, the bid based supply and demand curves of Figure 1 are only applicable to the full five (5) minute futures period, not to each instant throughout the delivery period. The theoretical supply and demand curve at **any instant** will be different from the **dispatch** supply and demand curve.

For most purposes, the difference between the bid based supply and demand curves and the theoretical supply and demand curves are irrelevant and can't be known. The differences between the two sets of curves become relevant when system frequency varies from the standard of 50 Hertz. Such a situation is illustrated in Figure 2. When actual supply and demand are not equal, the frequency will vary from 50 Hertz.

Instantaneous Economics
With Frequency < 50 Hertz
Figure 2

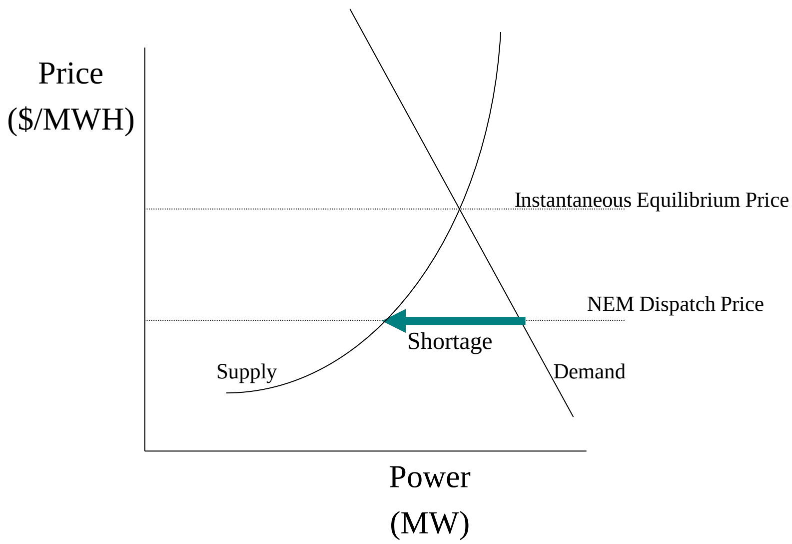
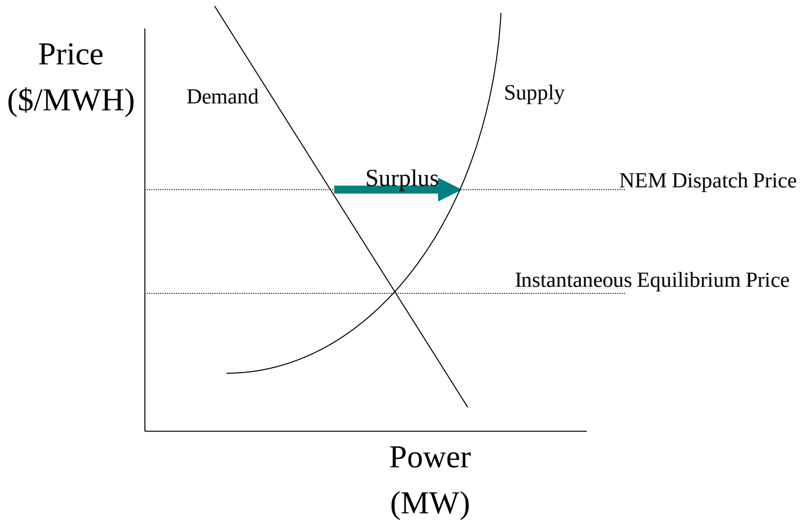


Figure 2 presents instantaneous theoretical supply and demand curves. The dispatch price refers to the price developed in Figure 1. As is indicated in the title, Figure 2 represents a situation when system frequency is less than 50 Hertz. Based on the physics of a 50 Hertz system frequency, that the system frequency is less than 50 Hertz means that generation is less than customer load (including the net effect of Basslink.) Thus, the dispatch price is at a height where the supply curve is to the left of and smaller than the demand curve and there is a shortage. Because of the normal upward slope of the supply curve and the normal downward slope of the demand curve the two curves intersect at a price level that is in excess of the NEM Energy dispatch price. Thus, when system frequency is less than 50 Hertz, the equilibrium price **for that instant** will be greater the dispatch price **for that five (5) minute period**. Figure 3 presents the same concepts as Figure 2 except for the situation where system frequency is greater than 50 Hertz, which results in a surplus and the instantaneous equilibrium price being less than the NEM Energy dispatch price.

Instantaneous Economics
With Frequency > 50 Hertz
Figure 3



The instantaneous equilibrium prices in Figures 2 and Figure 3 are the appropriate values for the FCAS price. But the actual values are not known because the shapes of the instantaneous supply and demand curves are not known. Further, the inertia of the electric system should make the instantaneous supply curve much steeper than the bid based supply curve which is for five (5) minutes. Figure 4 presents two methods for calculating a WOLF FCAS price.

WOLF FCAS Price
Figure 4

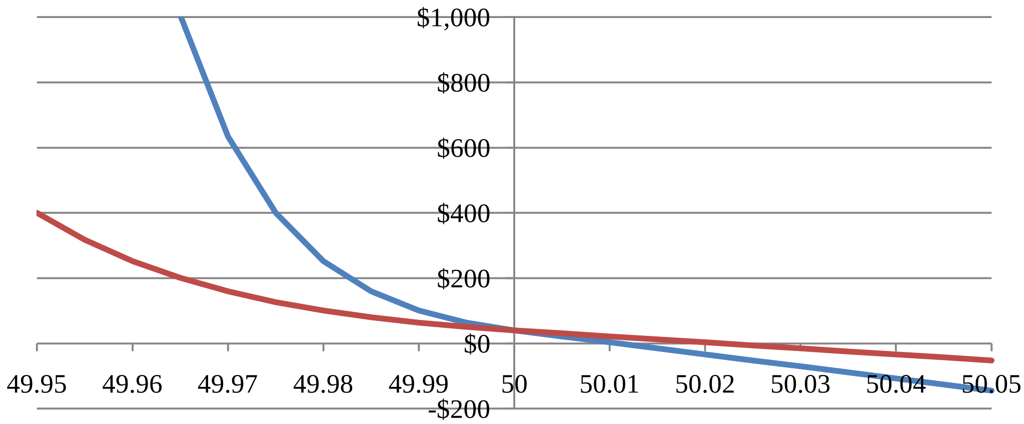


Figure 4 is centered on 50 Hertz and the dispatch price of Figure 1. For illustrative purposes the dispatch price is shown as $40/MWH. To the left, the WOLF FCAS curves increase exponentially as the system frequency moves below 50 Hertz. For illustrative purposes, this portion of the curve is shown as changing by a factor of 10 for either (1) each 50 milliHertz or (2) each 25 milliHertz decline in frequency. Thus the price at 49.950 Hertz[10] is either (1) $400/MWH[11] or (2) $4,000/MWH[12]. To the right, the WOLF FCAS price decreases linearly as the system frequency moves above 50 Hertz. The linear factor has been set so that the slope of the curve at 50 Hertz is a continuous variable. The WOLF FCAS prices in this example go negative at about (1) 50.022 Hertz and (2) 50.011 Hertz.[13]

The sensitivity of the WOLF FCAS prices in Figure 4 depends on the choices between scaling constants of (1) 50 milliHertz or (2) 25 milliHertz. The choice of a scaling constant relates to decisions about how tightly the system is to control system frequency. Smaller scaling factors will produce more extreme prices. The more extreme prices will tend to reduce the system frequency variations experienced by the system. For instance, the simple introduction of a dynamic, frequency based pricing system in India significantly reduced India's system frequency variance.

The WOLF FCAS price in Figure 4 would be applicable to all deviations from the power level specified as the quantity that a supplier was to supply according to the NEM energy auction for the five (5) minute period. The price would be determined every six (6) seconds based on the average frequency for that six (6) second period. The concurrency of the pricing and the delivery makes the WOLF pricing mechanism as close to a spot market as is possible for electricity.

WOLF FCAS GENERATION EXAMPLE

The WOLF FCAS would apply only to the difference between a generator's actual production and the dispatch specified in the NEM five (5) minute energy auction, as is demonstrated in Figure 5. The assumption is that during the NEM energy auction the generator has a dispatch signal for 60 MW. During the various FCAS six (6) second periods, the generator produces (X) 57 MW; (Y) 60 MW; or (Z) 66 MW. During the various FCAS six (6) second

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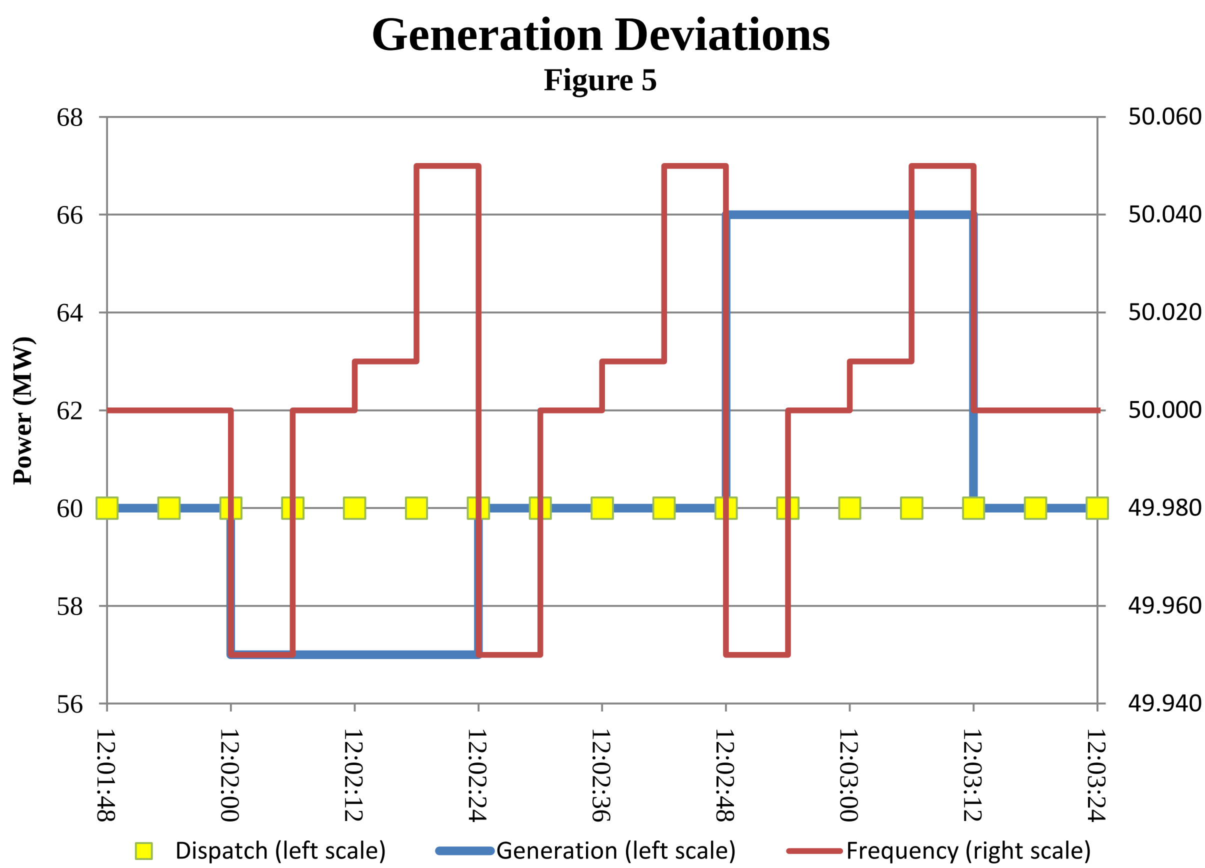
[10] 50 milliHertz below the standard 50 Hertz

[11] 10 times the illustrative dispatch price of $40/MWH because the decline in frequency is equal to the 50 milliHertz scaling constant

[12] 10 times 10 times the illustrative dispatch price of $40/MWH, with the two multiplications due to the decline in frequency being equal to twice the 25 milliHertz scaling constant

[13] The negative price phenomenon associated with electricity is caused by (1) tax and other incentives that lower the short run marginal cost for some electricity below zero; (2) byproduct benefits associated with cogenerating steam; and (3) inertia tying the ability to generate in one period to the amount of generation in another period. See "Renewable Electric Power—Too Much of a Good Thing: Looking At ERCOT," *Dialogue*, United States Association for Energy Economics, 2009 August.

periods, the system frequency is (A) 49.950 Hertz; (B) 50.000 Hertz; (C) 50.010 Hertz; or (D) 50.050 Hertz. This physical information is summarized in Table 1. The production levels are compared to the 60 MW dispatch amount to determine the surplus (deficit) power level. The surplus power level is converted into energy based on the six (6) second FCAS period.



The financial impacts of the WOLF FCAS generation example are shown in Table 2. The first column identifies the FCAS interval. The second column copies the energy developed in Table 1 by FCAS period. The next pair of columns develops the WOLF FCAS payment for each FCAS period under the assumption that prices change by a factor of 10 for each 50 milliHertz decline in system frequency. The last pair of columns develops the WOLF FCAS payment for each FCAS period under the assumption that prices change by a factor of 10 for each 25 milliHertz decline in system frequency. The prices and payments in the last pair of columns are more extreme as WOLF FCAS attempts to keep frequency tighter.

WOLF FCAS Generation Example
Physical Data
Table 1

	FCAS Interval		System	Generation		
ID	Begin	End	Frequency	Production (MW)	Surplus (MW)	Energy (MWH)
XA	12:02:00	12:02:06	49.950	57	-3	-0.0050
XB	12:02:06	12:02:12	50.000	57	-3	-0.0050
XC	12:02:12	12:02:18	50.010	57	-3	-0.0050
XD	12:02:18	12:02:24	50.050	57	-3	-0.0050
YA	12:02:24	12:02:30	49.950	60	0	0.0000
YB	12:02:30	12:02:36	50.000	60	0	0.0000
YC	12:02:36	12:02:42	50.010	60	0	0.0000
YD	12:02:42	12:02:48	50.050	60	0	0.0000
ZA	12:02:48	12:02:54	49.950	66	6	0.0100
ZB	12:02:54	12:03:00	50.000	66	6	0.0100
ZC	12:03:00	12:03:06	50.010	66	6	0.0100
ZD	12:03:06	12:03:12	50.050	66	6	0.0100

WOLF FCAS Generation Example
Financial Data
Table 2

	Energy	50 MilliHertz		25 MilliHertz	
ID	(MWH)	Price	Payment	Price	Payment
XA	-0.0050	$400.00	$ (2.00)	$4,000.00	$ (20.00)
XB	-0.0050	$40.00	$ (0.20)	$40.00	$ (0.20)
XC	-0.0050	$21.58	$ (0.11)	$3.16	$ (0.02)
XD	-0.0050	-$52.10	$ 0.26	-$144.21	$ 0.72
YA	0.0000	$400.00	$ -	$4,000.00	$ -
YB	0.0000	$40.00	$ -	$40.00	$ -
YC	0.0000	$21.58	$ -	$3.16	$ -
YD	0.0000	-$52.10	$ -	-$144.21	$ -
ZA	0.0100	$400.00	$ 4.00	$4,000.00	$ 40.00
ZB	0.0100	$40.00	$ 0.40	$40.00	$ 0.40
ZC	0.0100	$21.58	$ 0.22	$3.16	$ 0.03
ZD	0.0100	-$52.10	$ (0.52)	-$144.21	$ (1.44)

The WOLF FCAS price diagram in Figure 4 is based on the common approximation that the difference between supply and demand is directly proportional to the frequency error. This approximation is used in many control schemes, such as the Area Control Error (ACE) concept used for utilities that are interconnected synchronously with large systems. Other aspects of frequency error can be included in the WOLF FCAS pricing formulation, including the rate at which the frequency error is changing over time and the time accumulation of the frequency error as indicated in the cumulative time error. Such enhancements are likely to be less important than geographic differentiation and the pricing of reactive power.

WOLF FCAS DEMAND SIDE MANAGEMENT EXAMPLE

The WOLF FCAS price can also be used for Demand Side Management, such as the control of water heaters or major industrial loads. This is illustrated in Figure 6 where a load is partially interrupted for 23 seconds, nominally while the WOLF FCAS price is high enough to induce the retail consumer to shut off in order to supply FCAS. In 1983 I proposed that ESKOM in South Africa implement a frequency based control of its water heaters.

Perfect Power Delivery Except for 23 Seconds

Figure 6

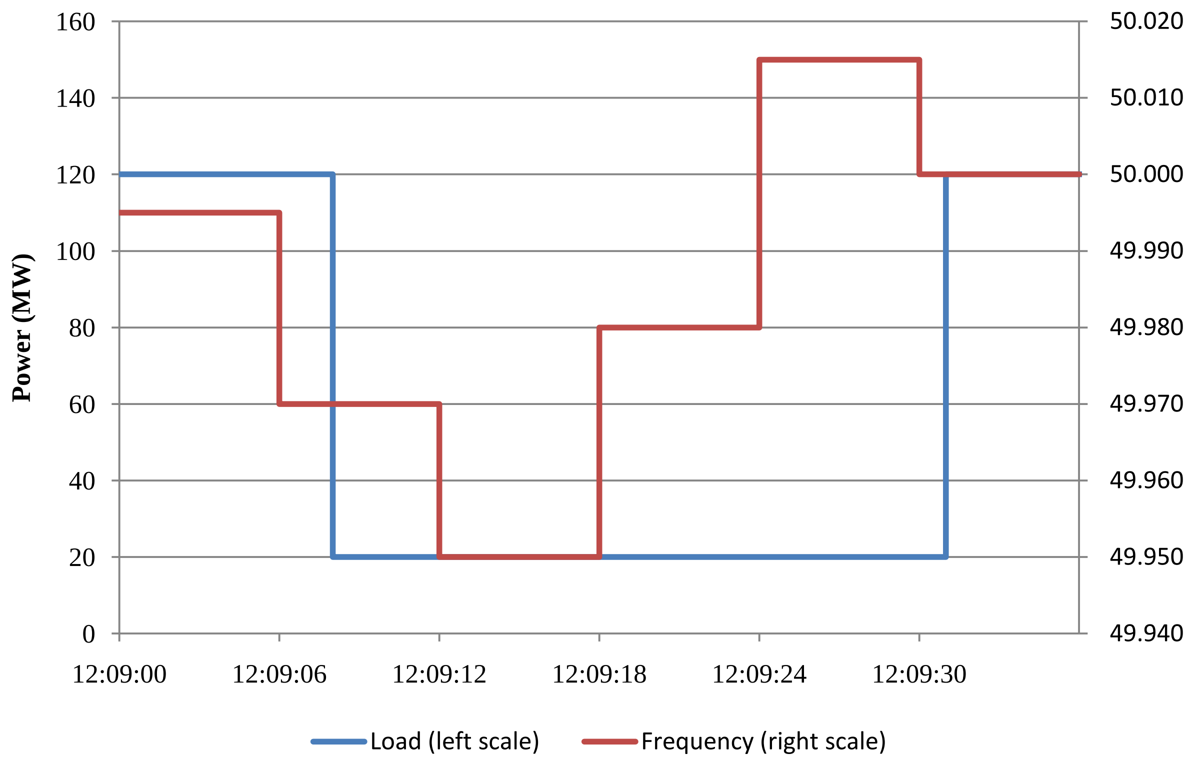


Figure 6 could be how a group of such water heaters would respond to frequency controllers. The load drops from 120 MW to 20 MW two seconds after the frequency drops to 49.970 Hertz. The load goes back to 120 MW seven seconds after the frequency goes above

49.980 Hertz. The frequency plot in Figure 6 is obviously average frequency for the FCAS period, not the way actual frequency would occur.

The WOLF pricing mechanism for FCAS eliminated the need for the retail consumer to participate in any bidding program. Again, I believe the need to participate formally in bidding programs is a major impediment to entry into any FCAS program. The customer in Figure 6 would buy its 120 MW needed supply in the NEM energy market. During the interruption period, the retail consumer would sell back the load interruption at the WOLF FCAS price.

The financial implications of this series of transactions are shown in Table 3 for the case of a WOLF FCAS price that has a 10 fold increase in prices for each 50 milliHertz decline in frequency. Even more extreme financial implications are shown in Table 4 for the case of a WOLF FCAS price that has a 10 fold increase in prices for each 25 milliHertz decline in frequency.

Financial Effect of Demand Side Management Used with WOLF FCAS Pricing
Assuming a 10 Fold Price Change With Each 50 MilliHertz Decline in Frequency
Table 3

	FCAS Interval			WOLF FCAS			
ID	Begin	End	Frequency	Price	MW	MWH	Payment
1st	12:09:00	12:09:06	49.995	$50.36	120.00	-	$ -
2nd	12:09:06	12:09:12	49.970	$159.24	53.33	0.11	$ 17.69
3rd	12:09:12	12:09:18	49.950	$400.00	20.00	0.17	$ 66.67
4th	12:09:18	12:09:24	49.980	$100.48	20.00	0.17	$ 16.75
5th	12:09:24	12:09:30	50.015	$12.37	20.00	0.17	$ 2.06
6th	12:09:30	12:09:36	50.000	$40.00	103.33	0.03	$ 1.11

Both tables are predicated on the six FCAS intervals beginning at 12:09, with each FCAS interval lasting 6 seconds. During the first interval the frequency is slightly low at 49.995 Hertz. The frequency drops to an average of 49.950 Hertz during the 3rd interval. The frequency goes above nominal during the 5th interval, perhaps as some FCAS participants over-react to the incentives.

The WOLF FCAS price is from Figure 4. The price soars as frequency drops. But, during the 5th interval, when the frequency is above nominal, the price turns negative in Table 4, providing an even greater incentive for Lower FCAS, where generators are encouraged to lower generation when frequency is above nominal.

The customer has a load of 120 MW. During the 1st period, the customer does not react to the high price and returns no energy under the FCAS program. The 100 MW of the load is interrupted for 2/3 of the 2nd period. During the 2nd period the customer thus is forgoing consumption of 0.11 MWH. This action by the customer earns the customer $17.69 during that 2nd FCAS period in Table 3, $70.44 in Table 4. The customer earns an even greater amount during the 3rd FCAS period when the frequency drops to its lowest average level in the example.

Financial Effect of Demand Side Management Used with WOLF FCAS Pricing
Assuming a 10 Fold Price Change With Each 25 MilliHertz Decline in Frequency
Table 4

	FCAS Interval			WOLF			
ID	Begin	End	Frequency	FCAS Price	MW	MWH	Payment
1st	12:09:00	12:09:06	49.995	$63.40	120.00	-	$ -
2nd	12:09:06	12:09:12	49.970	$633.96	53.33	0.11	$ 70.44
3rd	12:09:12	12:09:18	49.950	$4,000.00	20.00	0.17	$ 666.67
4th	12:09:18	12:09:24	49.980	$252.38	20.00	0.17	$ 42.06
5th	12:09:24	12:09:30	50.015	-$15.26	20.00	0.17	$ (2.54)
6th	12:09:30	12:09:36	50.000	$40.00	103.33	0.03	$ 1.11

During the 5th period the frequency is high and the price is negative in Table 4. The customer is slow to react to frequency returning to normal. Therefore, the customer's delivery of 0.17 MWH faces a low pricing in Table 3 and a negative price in Table 4. During the 6th FCAS period, the customer resumes consumption and receives a payment for only the 0.03 MWH that it didn't consume early in the 6th period. The price in the 6th FCAS period is the dispatch price for NEM energy, assumed to be $40/MWH.

WOLF FCAS ADVANTAGES

WOLF's use of the pricing curve in Figure 4 creates a negative feedback control system that will tend toward the short run marginal cost of the participants. For instance, assume a short run marginal cost of $100/MWH for some FCAS suppliers and assume an anticipated WOLF FCAS price of $300/MWH. These suppliers can increase net income by increasing production, earning the difference between the $300/MWH FCAS price versus the $100/MWH short run marginal cost. However, the increased production of the FCAS supplier to earn a net income will increase system frequency. The increase in system frequency is a movement to the right on Figure 4, which lowers the WOLF FCAS price. WOLF pricing of FCAS will thus tend to stabilize system frequency by providing financial incentives for all parties to supply Raise FCAS when frequency is low and to provide Lower FCAS when frequency is high. This negative feedback phenomenon also occurred when India implemented ABT pricing of UI, as I have discussed in various papers, articles, and regulatory filings.

WOLF FCAS differs from the NEMMCO auction in that the settlement period is aligned with the dispatch period. WOLF determines the WOLF FCAS price every six (6) seconds and has a settlement period that is similarly six (6) seconds long. In contrast, NEMMCO has a dispatch period of five (5) minutes but a settlement period that is thirty (30) minutes long. In the load control example developed in Figure 6, the customer was penalized in the 5th FCAS period for staying curtailed even though frequency had a reached level higher than the nominal 50 Hertz. Under the NEMMCO pricing of the NEM energy market, the surplus during one part of a settlement period appears to be used to offset a shortage another part of the settlement period. WOLF assumes metering that will allow a much finer granularity of the dispatch and settlement periods, and assumes that they are well aligned.[14]

An important part of the WOLF FCAS concept is that the price only applies to the difference between actual deliveries and scheduled deliveries, and that the price applies whether the difference is positive or negative. Applying the WOLF FCAS price to only the difference between actual and scheduled deliveries avoids some of the crippling effects that occurred in the Enron debacle in California in 2000/2001. The price manipulations attributed to Enron was multiplied because the manipulated price became the market price for all electricity being delivered at that period of time, not just the Enron energy. WOLF FCAS prices would be applicable only to the incremental WOLF FCAS deliveries.

CONCLUSION

The FCAS concept should be changed from being a forwards auction to being a simple pricing mechanism for unscheduled deliveries of electricity. Such a change would allow more parties to participate in the FCAS market, reducing the market power of Hydro Tasmania, a concept that Hydro Tasmania nominally supports.[15] Such a change would also provide a financial mechanism for retailers to evaluate Demand Side Management, justifying a greater deployment of Demand Side Management.

Respectfully submitted,

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2010 July 9

[14] "Electricity Is Too Chunky: The Midwest power prices were neither too high nor too low. They were too imprecise," *Public Utilities Fortnightly,* 1998 September 1.
[15] See footnote 2.