Creating a Peer Relationship for Electric Generation

By Mark B. Lively

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See footnotes at end of text.

Some large industrial concerns believe they are financially better served by owning and operating their own electric generating plants instead of buying electricity from the local national utility. These captive power plants often operate independently of the local electricity utility, effectively forming their own micro-grid. However, occasionally the micro-grid will be able to reduce its costs by buying lower cost electricity from the local utility. Conversely, occasionally the local utility may find it convenient to buy electricity from the micro-grid. Such transactions need a mutually agreeable price, a price that reflects the concurrent operating conditions. An automated dynamic pricing mechanism can achieve such a mutually agreeable price when based on the concepts used by operating engineers.

Utility operating engineers increase and decrease the output of their generators based on whether system frequency is low or high versus the standard[1]. The same concept can be used to set real time prices on a dynamic basis. When the system frequency is high, the implication is that the nominal price is too high and the settlement price should be lowered. When system frequency is too low, then the implication is that the nominal price is too low and the settlement price should be raised. This dynamic pricing concept has be described in many articles under the title of Wide Open Load Following (WOLF).[2]

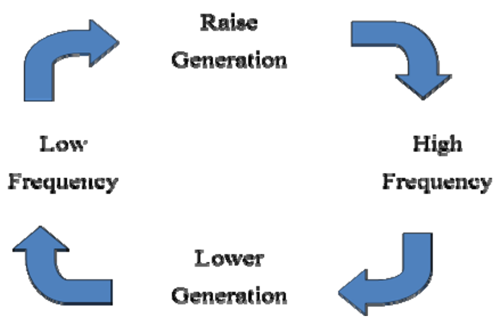

Figure 1.Control Theorgy for Operating Engineers.

Control Theory

Utility operators are always trying to balance supply and demand on a real time basis, generally by changing the output of the generators under their control, though occasionally by managing load. This utility operating protocol can be simplified into Figure 1. When system frequency is low as on the left side of Figure 1, utility operators send out control signals to increase generation. The increase in generation will lead to an increase in frequency. Conversely, when system frequency is high on the right side of Figure 1, the utility operators send out control signals to decrease generation.

Figure 2 converts the control protocol of Figure 1 into a supply and demand diagram. A shortage implies that demand exceeds supply, as is shown toward the bottom of Figure 2. Utility operators measure that shortage in terms of frequency error[3]. These calculations are performed every three or four seconds. As shown on Figure 2, demand exceeding supply means that the nominal price is below the equilibrium price. This creates pressure to increase the price toward the equilibrium price. The WOLF concept provides a formula to adjust the nominal price toward the equilibrium price, achieving some settlement price. With utilities calculating frequency error and/or ACE every three or four seconds, there could be a thousand different prices every hour.

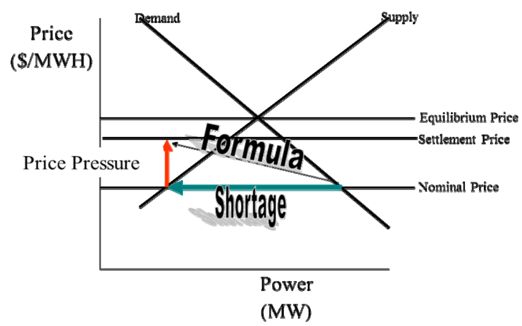

Figure 2. Wide Open Load Following Dynamic Economic Theory.

The operating protocol of Figure 1 can be converted into the WOLF pricing protocol of Figure 3 by changing physical control concepts to financial concepts. Thus, the low frequency on the left side of Figure 3 will lead the system to raise the settlement price above the nominal price, the dynamic that had been presented in Figure 2.

One option for the WOLF pricing protocol is shown in Figure 4. The solid heavy bottom line is the adjustment to move from the nominal price toward the equilibrium price. The adjustment is heavily dependent on the actual frequency at the time of the delivery. In this example the nominal price is assumed to be $30/MWH. The WOLF settlement price is the dashed lighter upper line, $30/MWH above the adjustment.

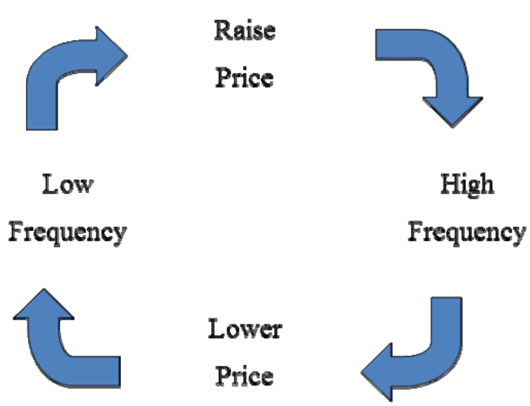

Figure 3. WOLF Pricing Control Theory.

Sometimes the nominal price is set poorly, or needs to be changed as circumstances change. In terms of Figure 2, demand consistently to the right of supply occurs when the nominal price is too low. This means

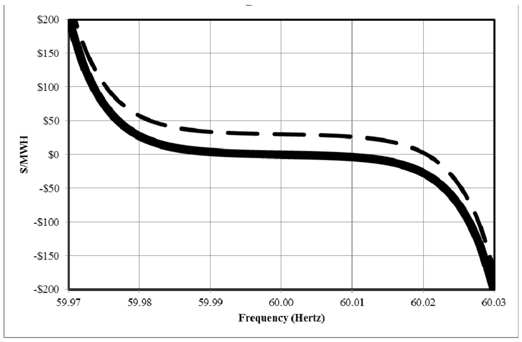

Figure 4. Pricing Curve.

there is a consistent upward price pressure. The consistent imbalance between supply and demand shows up as frequency consistently to the left on Figure 4.

A consistent low frequency will accumulate a negative time error, where synchronous[4] clocks are behind the GPS signal. Some systems have protocols to run their systems with a target frequency higher than standard to alleviate this time error. Figure 5 provides a WOLF protocol for dealing with this same issue. When clocks are slow, the nominal price is increased.

Wolf Eliminates Buyers Remorse

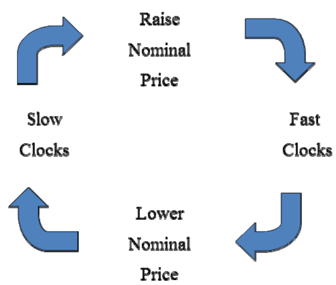

Figure 5. WOLF Pricing Control Theory for Persistent Error.

Buyer's remorse is a reference to the regret most people experience when making major purchases. The buyer might hear of a better deal in the form of a lower price from another company, or even that the seller had given a better deal to another buyer. The converse of seller's remorse is also true, in that a seller may hear of another deal in which the transaction price was higher for what might otherwise have been the same physical terms. The longer the deal, the more likely that buyer's remorse will occur. Buyer's remorse is especially endemic in contracts where one of the entities is part of the government which is subject to a change of the officials in charge.

WOLF pricing greatly reduces the potential for buyer's remorse. Changing the price a few times a minute means that the decision process is operational, how much electricity should the party generate. The actual transaction will be pure physics, the difference between generation and load will be delivered across the interchange between the utility and the industrial plant. Thus, under the concept that load is invariant, the utility (or the industrial plant) has to look at the operating decision as to how much generation to produce. Having prices change a few times a minute results in each transaction being for less energy and thus for less money. These small transactions greatly reduces the anxiety associated with the interconnection between the utility and the industrial facility.

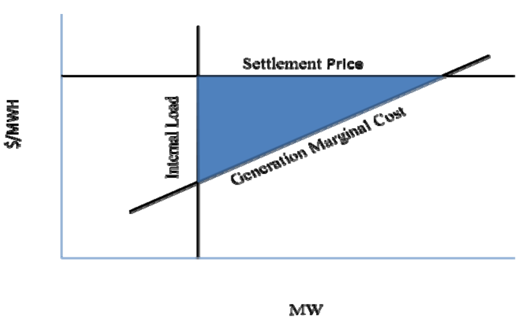

Figure 6. Profit Associated with Setting Generation Marginal Cost at WOLF.

Utility operators have long minimized their operating costs through the concept of equalized lambda, or equalized marginal cost. The marginal cost of producing an additional unit of electricity will vary across the operating range of a generator. The marginal cost will also change with the input cost of fuel. Utility operators ramp up some units and ramp down other units until each unit has the same marginal cost. WOLF pricing for the electricity at the interconnection provides one mechanism for identifying marginal cost or system lambda.

Setting the operating level of each generator to achieve a marginal cost equal to the WOLF price will produce a level of generation that may be in surplus to the organization's load, or there could be a deficit. If there is a surplus, then the operator is making a slight profit on the delivery. The profit margin is the result of marginal cost being greater than incremental cost. This concept is demonstrated in Figure 6. The sloping line is the marginal production cost for one of the participants. The vertical line is the participants internal demand for electricity, which can be considered to be fixed. The horizontal line is the settlement price. The area within the triangle is the profit associated with increasing generation until the marginal cost of generation is equal to the settlement price.

Figure 6 is presented for the entity that is making the sale. Figure 6a presents a similar profit diagram for the entity that is buying power at the concurrent WOLF price.

Reliability issues will lead utility operators to operate at a level other than the WOLF price. Operators who are delivering electricity will tend to operate at a marginal cost level below the WOLF price, reducing the power being delivered off its system. This power reduction partially protects the utility from having to cope with a sudden loss of load should the interconnection fail. Conversely, operators who are receiving electricity will tend to operate at a marginal cost level above the WOLF price, again reducing the flow on the interconnection and reducing the power received from off system. In the import case, the protection is against having to cope with the sudden loss of supply should the interconnection fail.

Operating at a level different from the WOLF price can also provide the utility with a financial reward, whether the entity is long or short. The additional financial benefit is from the incremental revenue associated with the infra-marginal delivery or receipt. For the entity making the sale, a slight reduction in the amount of the sale will reduce the profit associated with the reduced volume, but will increase the profit associated with the remainder of the sale. This is illustrated in Figure 7.

Figure 7 shows the seller producing at slightly less than the a level that is the estimated WOLF settlement price. The slight reduction means that the seller forgoes a slight amount of profit at the far right end of the triangle. But the lower production level will result in a lower frequency and a higher WOLF price. The higher WOLF price produces the additional profit shown by the rectangle. Note that this gamesmanship is also available to the purchaser, which can increase generation beyond that which would be indicated by its internal marginal cost. This concept is shown in Figure 7a.

The buyer in Figure 7a produces more electricity than is indicated by equating generation marginal cost to the WOLF price. The buyer thus forgoes some of the profit associated with buying electricity at less than the buyer's marginal cost. The increased generation increases frequency and suppresses the WOLF price below the generation marginal cost. The profit on the infra-marginal purchase can be significantly more than the forgone profit on the reduced purchase.

The combined efforts of the buyer to reduce the WOLF price and of the seller to increase the WOLF price will be a dynamic dance, sometimes with the buyer benefiting, sometimes with the seller benefiting. The WOLF pricing mechanism produces a fair price independent of which party is trying to maximize its profitability.

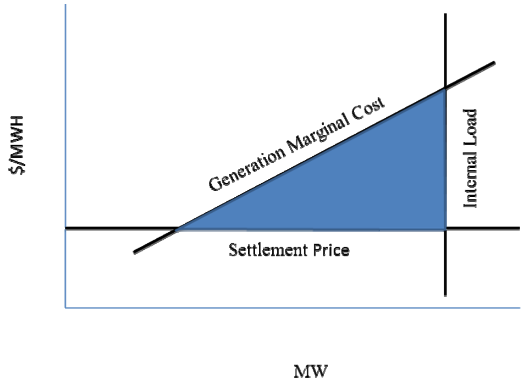

Figure 6a. Profit Associated with Setting Generation Marginal Cost at WOLF.

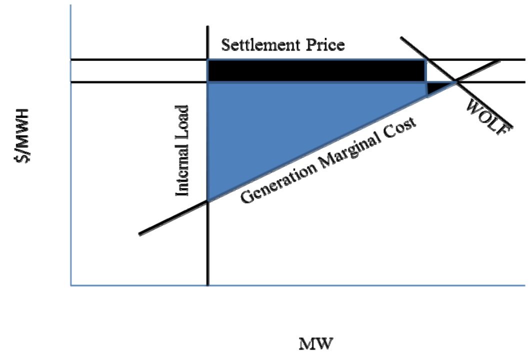

Figure 7. Profit Associated with Setting Generation Marginal Cost Below WOLF.

Wolf Creates Reliability Payments

The references above to the marginal costs of the buyer and of the seller suggests that the buyer has additional capacity that it could use but chose not to use since the WOLF price is lower than the buyer's marginal cost. Such transactions have historically been called economy energy, where the buyer had capacity it could operate but that the cost of operation was greater than the transaction price.

In some situations, the buyer will not have additional generation and the transaction can be considered to be a capacity transaction. Under a traditional capacity transaction, the seller commits to deliver electricity out of its reserves and is paid for fuel and other operating costs plus a portion of the cost of owning and operating the reserves. WOLF prices depend on system frequency and receive no input from either party as to their reserve position. The WOLF price is simply from a formula with frequency as the input in Figure 3. Reserves matter only in regard to how much their owners decide to deploy them.

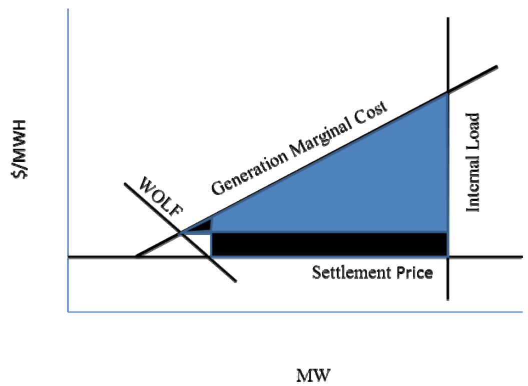

Figure 7a. Profit Associated with Setting Generation Marginal Cost Above WOLF.

Figure 7 showed how a seller could increase its profitability by a partial withholding of generation. The increased profitability can be considered to be a contribution to the fixed costs of the seller, a form of reliability payment.

Many utilities have implemented a concept called Demand Side Management. As mentioned above, utility operators usually dispatch their generators to achieve a balance between supply and demand. Sometimes utility operators have the ability to dispatch load, either on a contractual basis with some customers or using rotating blackouts to reduce load in wide areas. In essence, the WOLF pricing mechanism then is driven by the utility's demand curve instead of by its supply curve. The utility can either pay the high WOLF price or curtail load. Without the interconnection and the ability to buy electricity at the high WOLF price, the utility would have had to curtail some load in order to prevent a cascading blackout.

California has increasingly been warning about a shortage of ramping capacity. The concern is not that the utilities in California do not have enough capacity to meet the California peak but that the generators cannot move rapidly enough to meet swings in load. The example used by California is a spring afternoon with air conditioning ramping up as solar PV is ramping down. The dynamic WOLF pricing system handles this situation by continuing to use system frequency to set the price. Sometimes the dispatchable generators will ramp up too quickly and suppress the WOLF price. Sometimes the dispatchable generators will ramp up too slowly and the WOLF price will be very high.

WOLF pricing of unscheduled flows of electricity also provides the parties incentives to sign term contracts, specifying power delivery profiles and fixed prices, even though such term contracts can lead to buyer's remorse. WOLF pricing would be applicable to the difference between metered energy and the specified delivery profiles. In many respects, such term contracts can be considered to be hedges against future real time deliveries.

Conclusions

Some industrial facilities operate their own micro-grid, often in frustration from trying to negotiate what they consider to be economically fair contracts with the local national utility. Groups of utilities long ago realized the economic and reliability benefits associated with more generators connected together synchronously. A real time price for very short intervals of time changes the concept of buyer's remorse from a strategic issue to an operational issue. Each system operator attempts to optimize his generating level by matching the marginal cost of his generators against the WOLF transaction price. The very short intervals over which the WOLF price is applicable makes most such operating decisions have a very small individual effect. Further, a history of WOLF transaction prices may make some term contracts politically acceptable.

Footnotes

[1] The standard frequency in the U.S. is 60 Hertz or 60 cycles per second. The standard in Europe is 50 Hertz. Most of the rest of the world is split between these two frequencies.

[2] For instance, see Lively, Mark (1989) "Tie Riding Freeloaders--The True Impediment to Transmission Access," Public Utilities Fortnightly, 1989 December 21; Lively, Mark (1997), "Competition Versus the Good Old Boys' Club," Forum, IEEE Computer Applications In Power, January 1997; Lively, Mark (2005), "Creating an Automatic Market for Unscheduled Electricity Flows," The National Regulatory Research Institute, Volume 3, December 2005.

[3] Or in terms of Area Control Error (ACE) when the utility is part of a larger system

[4] Clocks plugged into an electrical outlet.