Pricing Ancillary Services so Customers Pay for What They Use

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SUMMARY

In competitive electricity markets, the costs for each ancillary service should be charged to those who cause the costs to be incurred with charges based on the factors that contribute to these costs. For example, the amount of generating capacity assigned to the regulation service is a function of the short-term volatility of system load. Therefore, the charges for regulation should be related to the volatility of each load, not to its average demand.

The Federal Energy Regulatory Commission (FERC) requires this as well. In its recent Notice of Proposed Rulemaking, FERC wrote (1999), "The Commission believes that, whenever it is economically feasible, it is important for the RTO [regional transmission organization] to provide accurate price signals that reflect the costs of supplying ancillary services to particular customers." Earlier, FERC (1996) wrote in its Order 888, "Because customers that take similar amounts of transmission service may require different amounts of some ancillary services, bundling these services with basic transmission service would result in some customers having to take and pay for more or less of an ancillary service than they use. For these reasons, the Commission concludes that the six required ancillary services should not be bundled with transmission service."

Fortunately customer specific measurement and allocation of ancillary service consumption can be done. This paper discusses the economic efficiency and equity benefits of assessing charges on the basis of customer-specific costs (rather than the traditional billing determinants, MWh or MW), focusing on the key real-power ancillary services of regulation and load-following.[*] We determine the extent to which individual customers and groups of customers contribute to the system's generation requirements for this services. In particular, we analyze load data to determine whether some customers account for shares of these services that differ substantially from their shares of total electricity consumption.

[*]This paper summarizes work presented more fully in: Kirby and Hirst 2000, *Customer-specific Metrics for the Regulation and Load-following Ancillary Services*, ORNL/CON-474, Oak Ridge National Laboratory, Oak Ridge, TN, January. The longer report is available at WWW.ORNL.GOV/PSR

PARSING REGULATION AND LOAD-FOLLOWING

Because electricity is a real-time product, control-area operators must adjust generation to meet load on a minute-to-minute basis. As the electricity industry becomes deintegrated, with competitive generation separated from regulated transmission and system control, defining the requirements and responsibilities to meet time-varying customer loads is increasingly important. Regulation and load following are the two key ancillary services required to perform this function.

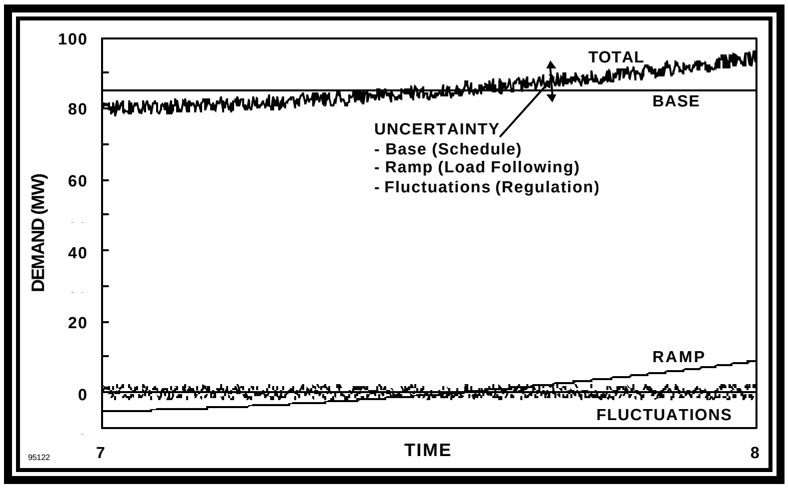

Fig. 1. Components of a hypothetical load on a weekday morning.

Loads can be decomposed into three elements (Fig. 1). The first element is the average load (base) during the scheduling period. The second element is the trend (ramp) during the hour and from hour to hour (the morning pickup in this case). The third element is the rapid fluctuations in load around the underlying trend. The system responses to the second and third components are called load following and regulation. These two services ensure that, under normal operating conditions, a control area is able to balance generation to load.

Earlier analysis showed that base energy, load-following and regulation can be parsed numerically. [Hirst and Kirby 1996 and 1998] Base energy is simply the integrated energy consumption for the hour. Load-following is extracted by calculating the 30-minute rolling average of the two minute load consumption readings.[*] This eliminates the short-term fluctuations. The load-following metric is simply the difference between the highest and lowest values within each hour of the 30-minute rolling average. Regulation is the residual fluctuations, the difference between the raw 2 minute load data and the 30-minute rolling average, and can be measured using the standard deviation of the 30 two minute readings for each hour.

$$\text{Load following}_t = \text{Load}_{\text{estimated-t}} = \text{Mean}\,(L_{t-7} + L_{t-6} + \ldots + L_t + L_{t+1} + \ldots. + L_{t+7})\,,$$

$$\text{Regulation}_t = \text{Load}_t - \text{Load}_{\text{estimated-t}}\ .$$

[*]The use of a rolling average to separate regulation from load following is an analytical convenience, not possible in real time. System operators instead use sophisticated analytical methods to forecast loads for the next few hours, based on current and expected weather conditions, prior loads, and other factors.

There is no hard-and-fast rule to define the temporal boundary between regulation and load following. If the time chosen for the split is too short (e.g., five minutes), too much of the fluctuations will appear as load following and not enough as regulation. If the boundary is too long (e.g., 60 minutes), too much of the fluctuations will show up as regulation and not enough as load following. But in each case, the total is unchanged and is captured by one or the other of these two services.

CUSTOMER SPECIFIC METRICS

Having established system-level metrics for regulation, we turn our attention to the development of metrics for customer-specific assignment of the total regulation amount. This customer allocation is especially important for utilities that have nonconforming loads (e.g., steel mills).

To facilitate this analysis we obtained 30-second data from a control-area operator on generation, net imports, total load, and 8 large industrial loads for a 12-day period in February 1999. These large industrial customers include, among others, steel mills, oil refineries, and air-separation facilities. For confidentiality reasons, we scaled all the data shown here.

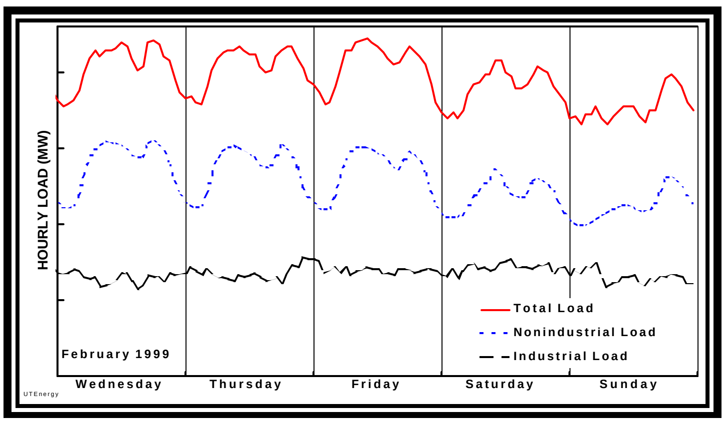

Fig. 2. Hourly system load, nonindustrial load, and industrial load for five days.

We summed the industrial loads to create a subgroup that we called *industrial load*. We called the difference between total load and industrial load *nonindustrial load*. Figure 2 shows the hourly loads for five days (Wednesday through Sunday). The total and nonindustrial loads show the expected winter patterns with morning and evening peaks, and with lower loads (by about 10%) on the weekends. The industrial load, on the other hand, is relatively constant from hour to hour. Its coefficient of variation (ratio of standard deviation to mean) is about half that of the nonindustrial load.

REGULATION

Because regulation is the short, minute-to-minute fluctuations in load, the regulation component of each customer's load is largely uncorrelated with those of other customers. If each customer's load fluctuations (F_i) is completely independent of the remainder of the system, the total regulation requirement (F_T) would equal

$$F_T = \sqrt{\sum F_i^2} \ ,$$

where *i* refers to an individual customer and *T* is the system total.

$$\text{Share}_i = (F_i/F_T)^2 ,$$

and there would be no need to analyze interactions among customer loads in calculating the total regulation burden.

If, on the other hand, the loads are completely correlated with each other [i.e., the correlation coefficient (*r*) between each pair of loads equals 1], the total regulation requirement is the simple sum of the individual requirements:

$$F_T = 3F_i .$$

In this idealized case, the share of regulation assigned to each customer would equal

$$\text{Share}_i = F_i/F_T .$$

Figure 3 shows results from an analysis of data for 19 large industrial customers from another control area. As expected, the actual value of the total regulation requirement is slightly (9%) higher than the total calculated as if the loads were completely uncorrelated. Also as expected, the actual value is much less (63%) than that calculated as if the loads were completely correlated. In this case, the loads exhibit a slight positive correlation with each other.

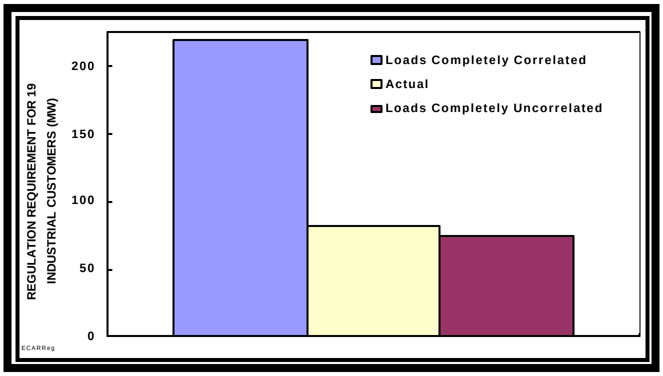

Fig. 3. Regulation requirement for 19 customers, showing the relationships among the actual value and those requirements that would occur if the loads were completely uncorrelated or were perfectly correlated.

The question is how to allocate fairly the total regulation requirement between loads. The allocation method should yield results that are independent of any subaggregations. In other words, the assignment of regulation to load *L* should not depend on whether *L* is billed for regulation independently of other loads or as part of a group of loads. In addition, the allocation method should reward (pay) loads that reduce the total regulation burden.

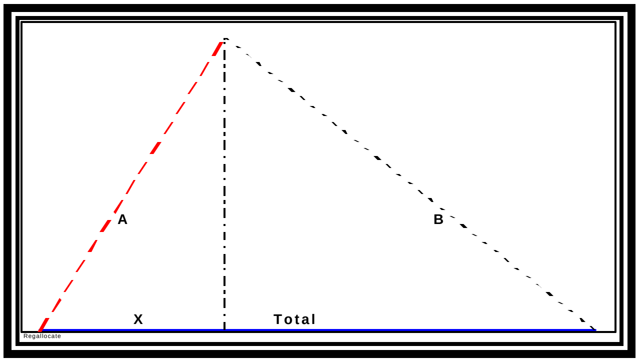

Fig. 4. Allocation of individual loads *A* and *B* to regulation *Total*. *X* is *A*'s share of the total. *B*'s share, by subtraction, is *Total* − *X*.

Figure 4 illustrates schematically the method that we developed for such allocations. This method works for the two extreme situations discussed above, when loads are either completely uncorrelated or perfectly correlated. More important, this method yields reasonable results for the intermediate cases when loads are partially correlated with each other. Consider two loads *A* and *B* and the *Total*, with the regulation requirement of each based on the standard deviation of the short-term fluctuations. We propose an approach to calculating the contribution of *A* to the *Total*, based on the projection of *A* onto the *Total* (shown as *X* in Fig. 4):

$$X = (Total^2 + A^2 - B^2)/(2 \times Total) .$$

The contribution of *B* to the *Total* is then equal to $Total - X$ or

$$Total - X = (Total^2 + B^2 - A^2)/(2 \times Total) .$$

This method can be extended to three or more loads through disaggregation of the total into various components. The only computational requirement is to calculate the standard deviation of each component and of each subtotal (total minus load *i*).

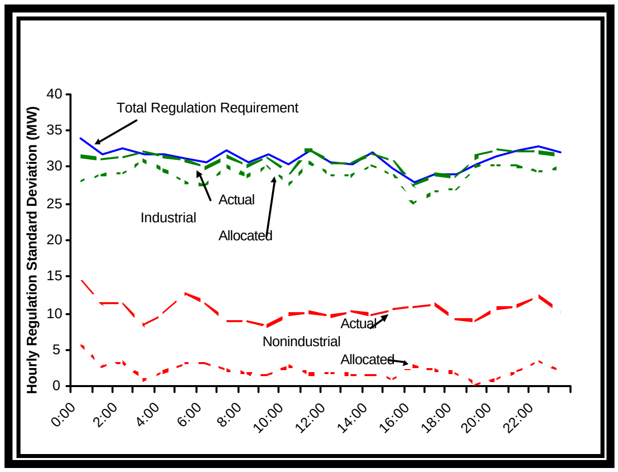

Fig. 5. Average hourly regulation requirements for industrial and nonindustrial loads.

The method proposed here can accommodate a mix of individually metered loads and subaggregations, such as several large industrial loads that are metered separately and aggregations of thousands of residential and commercial customers. The subaggregations of the nonmetered residential and commercial loads will have the correct share of regulation assigned to them; any cost shifting will occur within the subaggregations and not between the subaggregations and the individually metered loads. This desirable property greatly reduces the need to meter any but the most nonconforming loads.

LOAD-FOLLOWING

We calculate each customer's share of load following (or that of each group of customers) as the ratio of the customer's *coincident* load-following amount to the total load-following amount:

$$\text{Share}_i = (\text{Load}_{i,\,Tmax} - \text{Load}_{i,\,Tmin})/(\text{Load}_{Tmax} - \text{Load}_{Tmin}) ,$$

where *i* refers to a customer or group of customers, T_{max} is the time within the hour that the system reaches its maximum load, and T_{min} is the time within the hour that the system reaches its minimum load. Note that T_{max} and T_{min} refer to the times of the maximum and minimum *system* loads, not those for the individual components.

RESULTS

REGULATION

During the 12 days studied, the hourly regulation standard deviation for the system as a whole ranged between 16 and 50 MW, with a mean of 31 MW. The nonindustrial and industrial standard deviations averaged 10 and 31 MW. The regulation requirement did not vary dramatically throughout the average day, as shown in Fig. 5.

The allocation method assigned the industrial customers 93% of the regulation total, almost triple their 34% share of system load. We applied the same method to allocate the industrial load among its components (Table 1). Interestingly, two of the loads are negatively correlated with the others, yielding small negative regulation requirements.

LOAD-FOLLOWING

Figure 6 shows load-following requirements for one of the 12 days studied in this project. The dramatic hour-to-hour variations are quite different from the pattern we had expected to see.

We had anticipated an early-morning peak, an early-evening peak, and a late-evening drop-off. The hourly averages across all the days show just such a pattern (top of Fig. 7). Averaged across all 12 days, load-following requirements peak at 4 and 5 a.m. and again at 5 p.m. Requirements then drop sharply at 9 and 10 p.m. We had not anticipated the large, random, load-following requirements of the nonindustrial customers.

The bottom part of Figure 7 helps explain the high share of load-following assigned to the industrials. It shows the absolute value of system load following and the coincident contributions from the two components. It shows clearly the importance of the

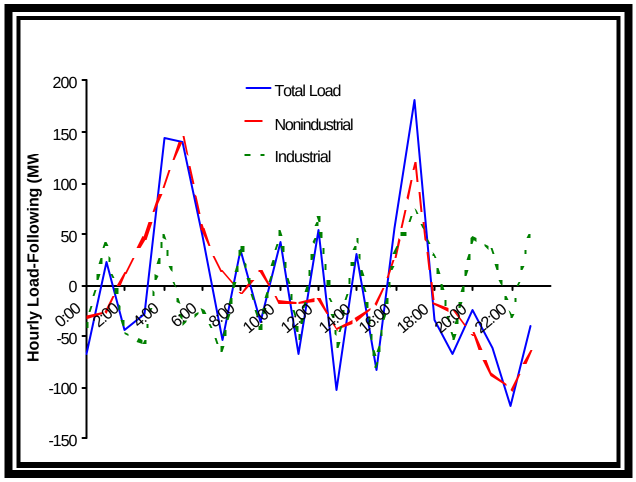

Fig. 6. Load-Following requirement for 1 day.

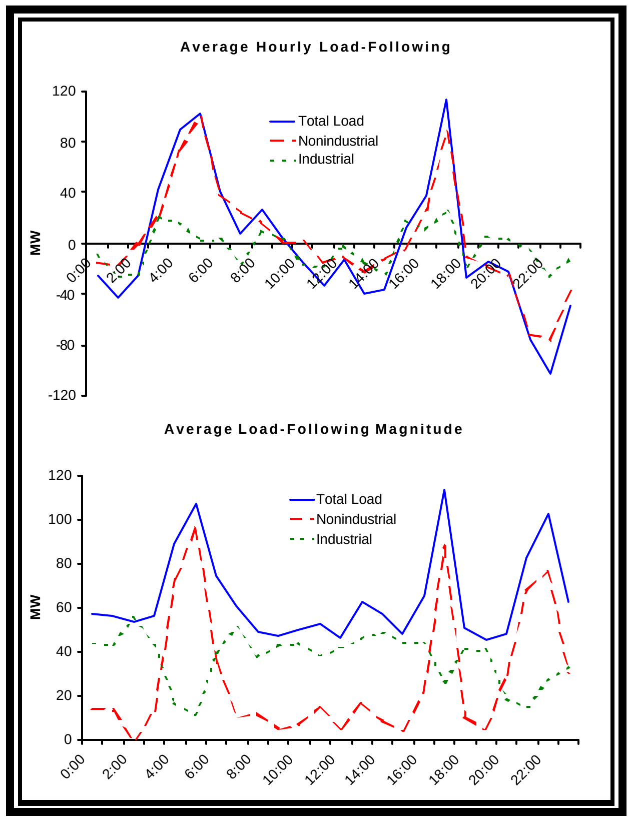

Fig. 7. Morning and evening nonindustrial load-following requirements are predictable, mid-day and mid-night industrial requirements are not.

industrial load during the hours of mild load-following changes. Unlike the nonindustrial load, the industrial load's load-following pattern is not predictable from day to day.

Because the *cost* of load following is likely to vary from hour to hour and be more expensive during peak-demand periods, the industrial share of load-following costs is likely to be lower than 56%. Correspondingly, the nonindustrial shares of load following and energy are 42% and 66%. Given this substantial difference between shares of load and load following, customer-specific assignment of load following is probably warranted.

We also examined the individual industrial loads and their relationship to the total industrial load. Here, too, the shares of load-following requirement vary considerably, both in absolute terms and relative to the energy shares (Table 1). For example, one customer accounted for 22% of the industrial energy use but 40% of the industrial load-following requirement. On the other hand, another accounted for 33% of the energy share but none of the load-following requirement.

Table 1. Characteristics of total load and its components for 12 days in February 1999

	Energy		Regulation		Load following	
	(MW)	Share (%)	(MW)	Share (%)	(MW)	Share (%)
Total load	1954	—	31.2	—	63.9	—
Nonindustrial load	1284	65.7	2.2	7.2	27.0	42.3
Industrial load	670	34.3	29.0	92.8	36.9	57.7
1	264	13.5	16.4	52.6	20.9	32.7
2	33	1.7	2.8	9.0	4.2	6.6
3	77	3.9	6.4	20.5	5.9	9.2
4	10	0.5	0.5	1.7	0.4	0.6
5	10	0.5	2.9	9.2	5.4	8.5
6	275	14.1	-0.1	-0.2	0.0	0.0

CONCLUSIONS

Current U.S. utility practice (i.e., the tariffs filed with FERC as required by Order 888) typically charges customers for ancillary services on the basis of average load (i.e., energy). Application of the allocation methods developed here shows that charging customers for these ancillary services on the basis of average loads can be inequitable. For one control area, a few large industrial customers account for 34% of system load, compared with 93% of the regulation and 58% of the load-following requirements. The subsidies inherent in today's ancillary-service pricing methods cannot, and should not, be sustained. Indeed, industrial customers with near-time-invariant loads, such as aluminum smelters and paper mills, will justifiably claim they require none of these services and, therefore, should not have to pay for them.

The results presented here are consistent with anecdotal evidence from other control areas. The regulation requirements for one utility are 50% higher when a single metal-fabrication customer operates than when that customer is offline. Another utility has two steel mills that account for 3% of total load, but over 50% of regulation and load-following requirements. A steel mill in a third utility's service area accounts for 1% of load and 22% of regulation requirements; a paper mill in the same service area accounts for 5% of load but only 1% of regulation.

Fair pricing, and sustainable electricity markets, require that prices more closely reflect consumption.

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