Western Area Power Administration

Rocky Mountain Customer Service Region Proposed Rates

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We applaud Western Area Power Administration's (WAPA) Rocky Mountain Customer Service Region's (RMR) continued efforts to develop a transmission tariff that recognizes the costs associated with providing Regulation and Frequency Response Service (Rate Schedule L-AS3) for the Western Area Colorado Missouri Balancing Authority (WACM) and that attempts to allocate these costs to transmission customers that are responsible for their being incurred. DOE's Oak Ridge National Laboratory and National Renewable Energy Laboratory are interested in WAPA's proposed tariff because this is a pioneering effort that may influence how ancillary services are addressed for renewable generators and loads throughout the country. This is important work that WAPA is doing. It is important to do it correctly and it is worth the effort that it will take.

Unfortunately WAPA's current proposal is seriously flawed and needs to be modified. There are five fundamental flaws that pervade the proposed tariff and which lead to numerous errors:

1. WAPA's basic metric for regulation is flawed, leading to inaccurate results.
2. WAPA fails to distinguish between regulation and energy imbalance or load following. This is important because regulation is typically the most expensive ancillary service while load following and energy imbalance need not be. This error also greatly overstates the regulation needs of individual entities.
3. WAPA improperly scales non-linear regulation impacts, fails to correctly account for aggregation benefits and incorrectly allocates costs.
4. WAPA mischaracterizes the behavior of wind plant variability greatly overstating the regulation requirements attributable to wind.
5. WAPA includes a "regulation reserve charge" which is really an energy imbalance charge. This is more than simply a naming error. The charge is also inappropriate because it is penalty based rather than cost based.

In addition, the proposed tariff is silent about how the regulation charge for wind penetrations exceeding 10% of non-WAPA loads (based on capacity) will be calculated. Methods exist for calculating the regulation impact, and are robust enough to be applied to any wind penetration. A tariff that discards one method in favor of another one (which is unspecified) is not robust and cannot accurately calculate physical or cost impacts to the system because of its ad hoc nature.

These errors result in a proposed tariff that does not allocate costs based upon causation. It will not send the correct economic signals to optimize economic efficiency for all balancing authority customers.

WAPA's Basic Regulation Metric is Flawed

WAPA proposes calculating regulation consumption as follows: "Calculate the Balancing Authority hourly load variation based upon the minute-to-minute change in load magnitude." Individuals' regulation requirements are similarly calculated. Unfortunately minute-to-minute change is only very loosely related to regulation requirements. The method fails completely as a regulation metric.

Figure 1 compares the behavior of three hypothetical individuals (loads, wind generators, or balancing areas). The minute-to-minute change, integrated over the hour, is the same for all three; 60-MW-minutes. Clearly, however, the regulation burdens imposed by the three are radically different. In this very simple example the solid red entity requires 1 MW of regulation compensation. The dashed green entity requires 5 MW. The dotted blue entity requires a total of 60 MW but not of regulation. A sustained ramp is a load following requirement that can be, should be, and in most locations is supplied by moving the base load and intermediate generators. There is no regulation burden imposed by the dotted blue ramp.

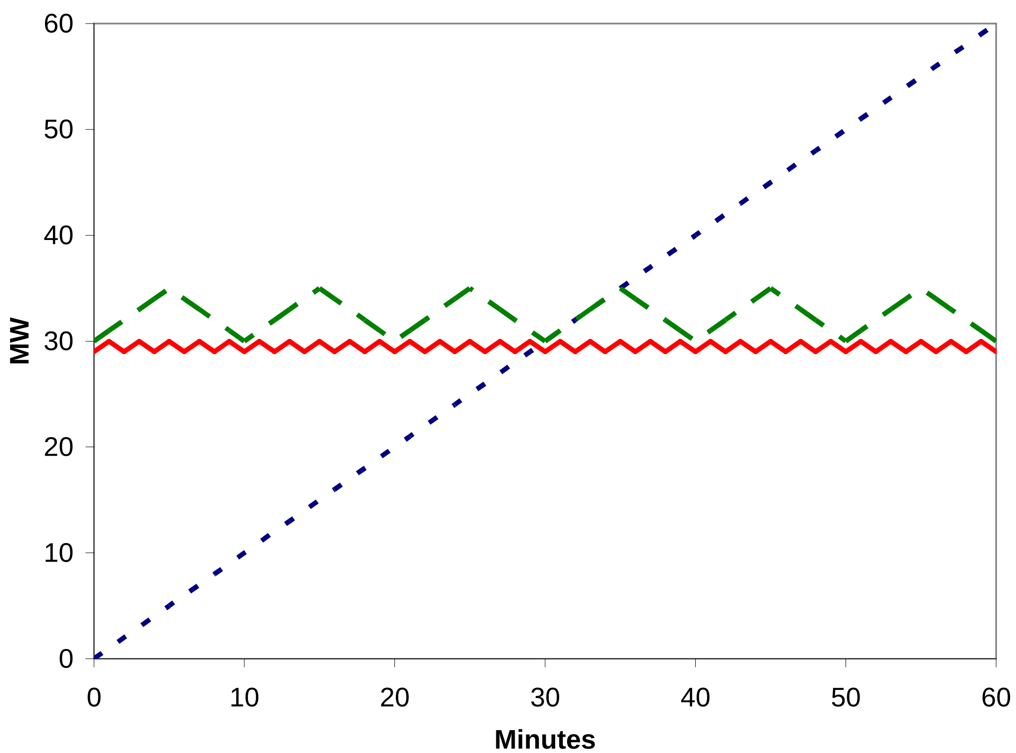

Figure 1 These three individuals impose radically different regulation requirements but have the same minute-to-minute-change metric performance.

Clearly, the minute-to-minute-change metric does not measure regulation requirements. A better metric is presented in *Customer-Specific Metrics for The Regulation and Load-Following Ancillary Services* (B. Kirby and E. Hirst, ORNL/CON-474, Oak Ridge National Laboratory, Oak Ridge TN, January, 2002). It first separates the regulation and load following requirements and then measures the regulation needs with the standard deviation. This is a better metric because the NERC and WECC performance requirements for balancing the system under normal conditions (CPS 1&2) are statistical requirements which match the standard deviation metric well. The ORNL metric finds that the green dashed entity imposes 3.9 times as much regulation burden as the solid red entity. The dotted blue ramp is load following and imposes no regulation burden.

Unfortunately the choice of a flawed metric for regulation permeates the proposed tariff and impacts essentially every aspect. Using a flawed metric such as this one distorts the economics of running the control area. Because the metric cannot distinguish between an entity that has a significant regulation impact from an entity that has no impact, the basic principle of cost-causation is violated because cost-causers don't pay for their impact, while non-cost-causers pay for somebody else's impact. This is a cross subsidy that should be avoided by a good regulation tariff.

WAPA Fails To Separate Regulation From Load Following

Basing the regulation charge on the balancing authority's and individuals' "hourly average minute-to-minute change" combines regulation and load following. Load following is the intra-hour ramping requirement while regulation should only include the residual random minute-to-minute fluctuations. Figure 2 illustrates the difference between regulation and load following.

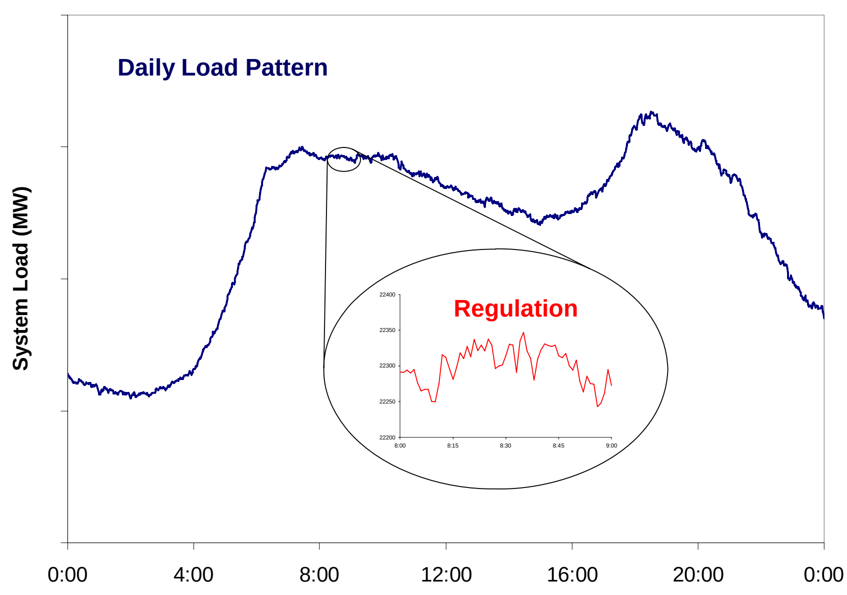

Figure 2 Regulation is the random, minute-to-minute fluctuation which is in addition to the more predictable and slower load following ramp.

Combining regulation and load following into a single service greatly increases costs because the expensive regulating units must also support the larger load following swings.

WAPA states in the Customer Brochure that:

> There are also large thermal generators within WACM that are not Federal resources and are not under the direct control of RMR …
>
> Federal generation is currently the only resource that WACM can utilize to provide Regulation Service for the Balancing Authority's needs. The other generators located within WACM are either not on Automatic Generation Control (AGC) or are operated on an Area Control Error (ACE) signal that responds only to their own sub-Balancing Authority needs.

WAPA further states that the federal hydro units are constrained in their ability to provide regulation due to water schedules and environmental constraints. The total Rocky Mountain Region generation capacity exceeds 5400 MW while the federal generation capable of supplying regulation is only 830 MW. Further, over half of those Federal generators do not have the automatic generation control required to supply regulation.

Our analysis (B. Kirby and M. Milligan, *A Method and Case Study for Estimating The Ramping Capability of a Control Area or Balancing Authority and Implications for Moderate or High Wind Penetration*, American Wind Energy Association, WindPower 2005, May 2005) of public data indicates that the thermal generation available within the RMR has 17 MW/minute upward and -20 MW/minute downward demonstrated ramping capability. Were WAPA to develop a mechanism to tap this ramping capability the cost of regulation and load following could be reduced for all customers. Further, the generators would earn additional income. It is difficult to understand why WAPA is not actively pursuing this genuine economic efficiency that could help all of its constituents. Instead, the City of Colorado Springs is considering how to provide their own regulation service for wind instead of obtaining this service from WAPA. This effectively divides a larger balancing authority into two smaller ones, which reduces the flexibility that can be used to help mitigate the impacts of variable loads and variable wind generation. The Balkanization of control areas contributes to higher costs for all customers and reduces reliability.

WAPA Inappropriately Includes A "Regulation Reservation Charge"

WAPA has included a Regulating Reserve Charge in the proposed tariff that is unrelated to the balancing authority's regulation requirements. WAPA states that "This charge will be calculated based on the hourly difference between the intermittent generator's forecast and its integrated actual generation." It is completely unrelated to the short term variability of either the individual or the aggregate load. It is inappropriate to charge regulation rates (the most expensive ancillary service) for energy imbalance (a volatile, but not necessarily high, spot energy cost). In fact, if WAPA is also charging for energy imbalance (not covered in this tariff) the inclusion of the Regulation Reservation Charge is likely double counting. Further, including the Regulation Reservation Charge as a capacity charge, which applies for over-generation imbalances as well as under-generation, will result in WAPA collecting from wind facilities for any steady, consistent over-generation while also collecting for that energy when it is supplied to the load serving entity.

WAPA Incorrectly Identifies Non-conforming Loads

In some sense this may not appear to be specifically relevant at the present time. WAPA states that they do not currently have any non-conforming loads. But WAPA recognizes that these loads may exist in the future and proposes a metric to identify them. In the Customer Brochure WAPA states:

> Non-Conforming Load is typified as a single large load or aggregation of a few large loads, such that the behavior of the aggregate in its minute-to-minute variation is dissimilar to the Balancing Authority total variation from minute-to-minute. Non-Conforming Load <u>does</u> cause a disproportionate use of the regulating resource for the Balancing Authority.

Unfortunately, WAPA does not define "large" and does provide further detail on the metrics to be used in the Customer Brochure. There is some additional detail provided in Raymond Vojdani's slides, presented at the July 27, 2005 Public Information Forum. Here WAPA states:

- The criteria will be based on the ratio of minute-to-minute changes of the load versus the hourly load.
- If this ratio exceeds 3%, the load will be deemed non-conforming.
- Regulation charges for non-conforming loads will be proportional to the magnitude of excess.

The problem with WAPA's proposal is that the regulation impacts of non-conforming loads are highly nonlinear. WAPA is correct that size matters and only large non-conforming entities can adversely impact aggregate balancing authority regulation requirements. The difficulty is that "large" is not defined. The appropriate threshold should not be a fixed 3% for an arbitrarily "large" load. A more appropriate threshold would be when the regulation impact of a load exceeds X% of the system average regulation requirement for an equivalent load of that size. Most importantly, the charges should <u>not</u> be proportional to the magnitude of the excess of the individual but should be appropriately allocated to the load based upon the impact on the aggregate regulation requirement. This relationship is highly nonlinear though it is easy to calculate. For example, the appropriately allocated regulation impact on another balancing authority of one non-conforming load is 20 times the regulation impact of another non-conforming load even though the former is only four times as volatile and its energy requirement is only five times as great.

WAPA Incorrectly Scales Variability Impacts From Wind Plants

WAPA concluded that they can support 180 MW of intermittent resource capacity. This assessment is based on linear scaling of 79 MW of wind capacity currently physically within the balancing authority. The study was well done in that three months of minute-to-minute wind plant output and balancing authority aggregate load data was used. Wind was increased incrementally until the CPS 2 limit was hit. CPS 1 was not a problem.

There are two significant flaws in the analysis, however. First, the lowest wind penetration in the entire three months that resulted in CPS2 violation was used to establish the 180 MW limit. Since CPS2 is a statistical measure it would be more appropriate to use a statistical criteria to assure that the limit is not artificially set by an outlier. Second, linear scaling of wind plant variability is simply wrong.

Slide 18 in Raymond Vojdani's July 27, 2005 Public Information Forum presentation is of wind plants that are too small to provide relevant insight and illustrates how WAPA's analysis has missed the important wind characteristics. A 10 MW wind plant is shown experiencing a 9 MW swing in 2 minutes. Concluding that large wind plants can experience similar minute-to-minute swings equal to 90% of their rating is incorrect. As with all generators, they can experience sudden trips due to electrical equipment failures. This type of event is a contingency and, as with all generators, requires contingency reserve resources. But the wind-driven output of large wind plants, while volatile in comparison with conventional generation, simply does not impose this type of regulation burden on the power system. Again, NREL's large data base is available for empirical analysis.

Table 1 demonstrates that linear scaling greatly overstates wind plant variability regardless of the time frame being studied.

Wind plant variability is shown measured in four time frames in table 1; one second, one minute, ten minutes, and one hour. Here actual step change statistics are presented for the 35 MW Texas Wind Power Project (TWPP) and the 347 MW combined four Texas wind power plants (Indian Mesa, King Mountain, Trent Mesa, and Texas Wind Power Project). These are compared with a linear scaling of the output of the TWPP project (center column) to make its name plate power capacity match that of the combined Texas wind plants. Absolute average step change, the step change standard deviation, the maximum up bound step change, and maximum down bound step change are all presented. The right hand column compares the variability of the linearly scaled 347 MW wind plant with the actual 347 MW wind plant. As indicated in the last column of the table, in every time frame and for every metric linear scaling greatly overstates the variability of the wind plant.[1]

[1] The difference in variability between linearly scaling the 35 MW TWPP wind plant to 347 MW and the actual 347 MW Combined Texas Wind Plants is actually greater than shown in Table 1. Dropouts in the time series data from the Combined Texas Wind Plants result in artificial step changes being included in the analysis and artificially high variability. No such dropouts exist in the TWPP data.

Table 1 Linear scaling overstates wind plant variability in every time frame as shown with data from Texas wind farms.

	TWPP Wind Plant	TWPP X 10 (linear scaling)	Combined Texas Wind Plants	*Variability Over-Statement*
	(kW)	(kW)	(kW)	
Rated Power	35,000	347,000	347,000	100%☑
1-Second Step				
Avg	26	256	190	135%
Stdev	45	453	282	161%
Max(+)	669	6,690	3,798	176%
Max(–)	(15,658)	(156,580)	(124,817)	125%
1-Minute Step				
Avg	256	2,556	1,320	194%
Stdev	469	4,686	2,056	228%
Max(+)	8,285	82,850	61,662	134%
Max(–)	(16,359)	(163,590)	(124,948)	131%
10-Minute Step				
Avg	725	7,248	5,084	143%
Stdev	1,275	12,750	7,905	161%
Max(+)	16,435	164,350	104,763	157%
Max(–)	(22,582)	(225,820)	(136,843)	165%
1-Hour Step				
Avg	2,097	20,967	15,475	135%
Stdev	3,335	33,348	22,283	150%
Max(+)	27,418	274,180	102,654	267%
Max(–)	(24,944)	(249,440)	(143,532)	174%

Table 2 provides the same analysis with output from the Lake Benton II wind project. Variability of the 14 turbine Foxtrot substation is scaled to match the 138 turbine Lake Benton Wind Project and the full output from the ~250 MW Buffalo Ridge substation.

The difference between the actual and linearly scaled results is even more dramatic with the Wisconsin data than the Texas data. Especially in the faster time frames (1 second and 1 minute) linear scaling dramatically overestimates the variability of wind plants, leading to an inaccurate assessment of regulation requirements that are imposed by wind.

Table 2 Wisconsin wind plant data confirms that linear scaling overstates wind plant variability.

	14 Turbines (actual)	14 Turbines X 9.8 (linear scaling to 138 turbines)	138 Turbines (actual)	*Variability Over-Statement*	14 Turbines X 22.8 (linear scaling to 250 turbines)	250+ Turbines (actual)	*Variability Over-Statement*
	(kW)	(kW)	(kW)		(kW)	(kW)	
Rated kW	10,500	103,500	103,500	100%☑	240,000	240,000	100%☑
1-Second							
Avg	41	413	148	279%	932	189	493%
Stdev	56	552	203	272%	1,274	257	496%
Max(+)	798	7,866	4,740	166%	18,240	16,234	112%
Max(–)	-9,326	-91,927	-79,080	116%	-213,165	-138,944	153%
1-Minute							
Avg	131	1,286	494	260%	2,981	730	408%
Stdev	225	2,218	849	261%	5,144	1,486	346%
Max(+)	6,808	67,107	39,511	170%	156,611	37,388	419%
Max(–)	-8,575	-84,525	-79,274	107%	-196,000	-167,492	117%
10-Minute							
Avg	329	3,240	2,243	144%	7,513	3,713	202%
Stdev	548	5,400	3,810	142%	12,521	6,418	195%
Max(+)	9,784	96,442	71,787	134%	223,634	86,575	258%
Max(–)	-10,151	-100,059	-92,412	108%	-232,022	-167,883	138%
1-Hour							
Avg	736	7,255	6,582	110%	16,824	12,755	132%
Stdev	1,124	11,077	10,032	110%	25,685	19,213	134%
Max(+)	9,047	89,177	81,625	109%	206,788	121,654	170%
Max(–)	-8,208	-80,907	-73,908	109%	-187,611	-148,057	127%

The implication of this data for the proposed WAPA regulation tariff is profound. It is clear that WAPA's estimate of the quantity of wind that could be accommodated by the control area/balancing authority is too low, perhaps significantly. It is not possible to estimate the capacity of wind that could be integrated into the control area without data that we do not posses, and further analysis. We renew our previous offer to help WAPA develop an appropriate regulation tariff and to help analyze the impact of wind.

Wind Power Variability in the Regulation Time Frame

Wind power variability in the regulation time frame can be studied outside the context of the integrated system, although such an analysis cannot in itself determine wind's regulation impact on the power system. Wind power variability across a single wind plant, and especially among multiple wind plants, is largely uncorrelated for physical reasons associated with the geographic size relative to the wind speed. In the regulation time frame, entities movements tend to be uncorrelated. This does not need to be assumed, it can be easily measured. (B. Kirby and E. Hirst, *Customer-Specific Metrics for The Regulation and Load-Following Ancillary Services*, ORNL/CON-474, Oak Ridge National Laboratory, Oak Ridge TN, January, 2000.) Figure 3 presents three actual wind plants that are moving largely independently. This represents a more realistic example. The aggregation of these three plants has more fluctuation than any single plant alone. There is still significant aggregation benefit, however. Plant A spans a range of 22.6 MW, plant B spans a range of 13.5 MW, and plant C spans a range of 39.4 MW. Combining these ranges would yield an expected range of 75.4 MW but the aggregation's range is only 53.3 MW.

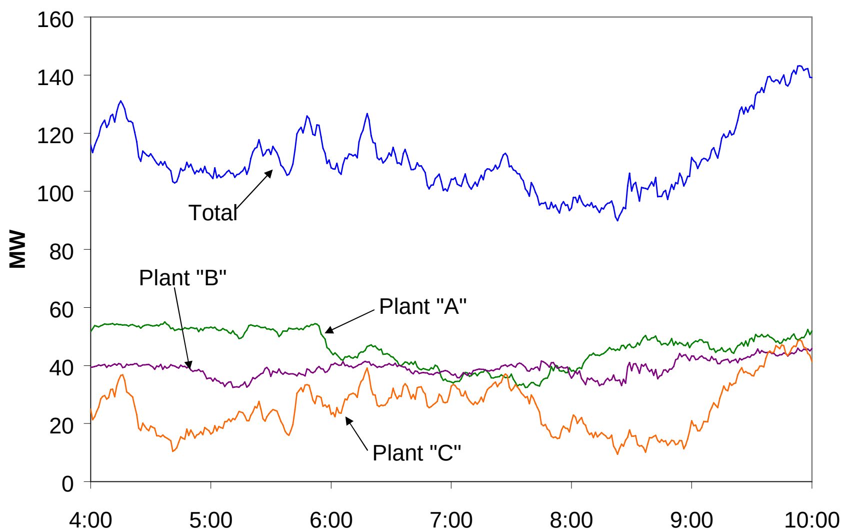

Figure 3 Aggregating 3 plants greatly reduces the fluctuation burden presented to the power system.

We have presented several ways of examining wind plant fluctuations. Linear scaling does not work in any of these cases. NREL has collected years of second-to-second data from wind plants of various sizes throughout the country. That data is available to WAPA for analysis and impact studies. There is no need to incorrectly scale wind plant data.

Conclusions

While we applaud WAPA for attempting to address regulation and frequency response as a service that should be paid for based upon the impact individuals have on the balancing authority we are disappointed that the proposed tariff continues to be seriously flawed:

- WAPA's basic metric for regulation is flawed, leading to inaccurate results.
- WAPA fails to distinguish between regulation and energy imbalance or load following. This is important because regulation is typically the most expensive ancillary service while load following and energy imbalance need not be. This error also greatly overstates the regulation needs of individuals.

- Lack of WAPA access to the extensive intra- and inter-hour ramping capability of the region's thermal generation increases regulation costs for all customers and deprives the thermal generators of additional income.
- WAPA improperly scales non-linear regulation impacts, fails to correctly account for aggregation benefits and incorrectly allocates costs.
- WAPA mischaracterizes the behavior of wind plant variability greatly overstating the regulation requirements attributable to wind.
- WAPA includes a "regulation reserve charge" which is really an energy imbalance charge. This is more than simply a naming error. The charge is also inappropriate.
- WAPA's metric does not work above the 10% penetration rate (as defined by WAPA). For wind capacity in excess of this limit, there is no indication of what metric will be used to calculate the impact of wind on the system regulation requirements

We continue to offer the support of two DOE national laboratories to help WAPA develop a technically sound Regulation and Frequency Response Service tariff that can be used as a model for the rest of the industry.