Grant County PUD Integration Study

Tom Acker, Jason Buechler
Northern Arizona University

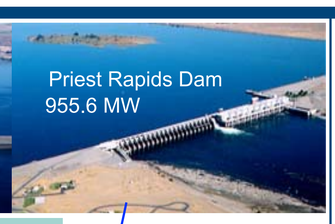
Kevin Conway, Keith Knitter
Grant County Public Utility District

NORTHERN ARIZONA UNIVERSITY

Sustainable Energy Solutions

1. Study Description

- Grant County Public Utility District, in Washington state, manages two dams on the mid-Columbia river, while also incorporating a share of nearby 63 MW Nine Canyon Wind Project.
- Current 12 MW level of wind generation is integrated with the system's 610 MW peak hydro capacity.
- Objective: Understand the impacts of current and potential future efforts at integrating wind and hydropower on system constraints
- Calculations used historical data sets that were furnished by GCPUD and 3TIER, respectively for hydro and wind data.
- Funded, in part, by a grant from the National Renewable Energy Laboratory



2. Previously Presented Results

- The wind was treated as negative load, and the Nine Canyon plant output was combined with the system request/load, considering 0 MW, 12 MW, and 63.7 MW (full output of Nine Canyon), as well as scaled to 150 MW.
- Several methods for statistically quantifying regulation and load following were considered, but all provided similar results. See Figures 1 and 2, to the right, for typical regulation and load following results. These were last presented in "Impacts of Integrating Wind Power into the Grant County PUD Balancing Area" (Acker, *et al.*, 2007).
- Impact on regulation was nearly negligible up to 63.7 MW of wind penetration, while even 150 MW showed only a small broadening trend of increasing regulation burden
- Impact on load following was more significant, showing greater hour-to-hour changes in the load.

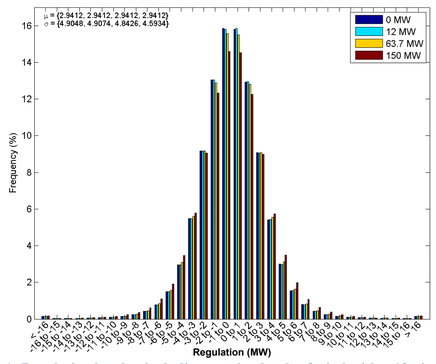


Figure 1: Regulation burden including varying levels of wind with a 10min rolling average

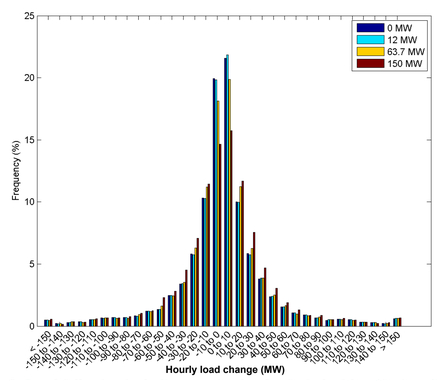


Figure 2: Load following including varying levels of wind with a 60min rolling average

3. Operating Constraints

The load following and regulation results suggest that, absent constraints, a substantial amount of wind power could be absorbed into Grant's system. This conclusion derives from the fact that Grant PUD already manages a large amount of variability, most of which is *planned* through purchases and sales.

However, the hydro resource is heavily constrained, primarily by ecological demands, water flow requirements and reliability rules, with both upper and lower capacity limits varying daily and seasonally.

Thus modest changes suggested in the load following statistics could pose potentially significant operational challenges in scheduling the resources without infringing upon system constraints.

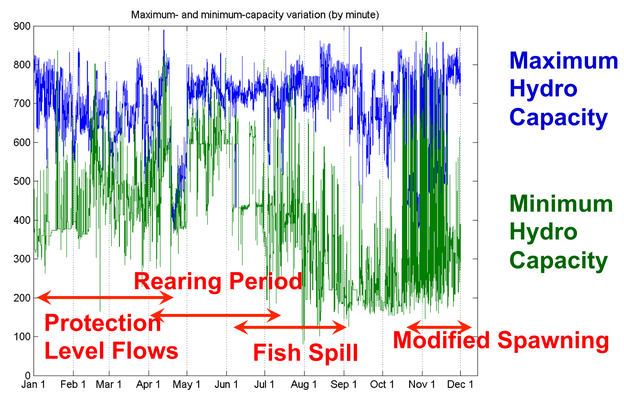


Figure 3: GCPUD hydro system capacity limits, and limiting fish operation periods

The blue and green traces in the figure above show how the maximum and minimum capacities (respectively) varied by-minute throughout 2006. The labeled red arrows indicate the periods when fish operations occur, correlating strongly with changes in capacity limits. The individual constraints are described, in detail, in the Hydrovision paper by Acker, *et al.*

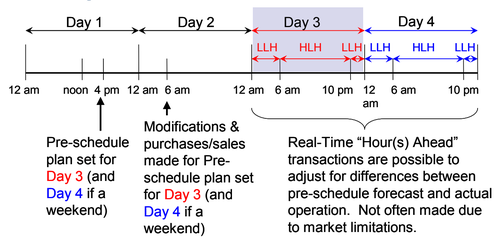
4. Planning in the Pre-Schedule

The level of wind penetration is defined as the percentage of nameplate (maximum) wind power divided by peak load. Grant PUD's 12MW share amounts to only a 2.0% penetration, but implementing 63.7MW or 150MW would mean much larger penetrations of 10.9% and 25.6%.

At significant levels of wind-penetration, it is necessary to consider wind power in day ahead and hour ahead planning so as to avoid exceeding system constraints. In this study, wind forecasts were considered in the day ahead "pre-schedule" plan (no hour ahead adjustments) with the intention of estimating the impact of wind integration on exceeding system constraints.

This study took an approach consistent with GCPUD's current pre-schedule planning method. Professional wind forecasts provided by 3TIER were "sold" in the pre-schedule, then the actual wind power output was used to modify the system generation request, less the amount of wind sold (which, for these calculations, was chosen to be 63.7 MW nameplate capacity). Sales were in averaged-flat "blocks", individually, for the heavy load and light load periods of each day. One of the most significant simplifications was regarding the timing of the planning, in regards to available forecasts. Figure 4, below, shows Grant PUD's planning timeline for both weekdays and weekends/holidays. For uniformity, this study treated all days as weekdays, as opposed to weekend days which would use a forecast 24 hours more early.

Figure 4: GCPUD Pre-schedule timeline for transactions



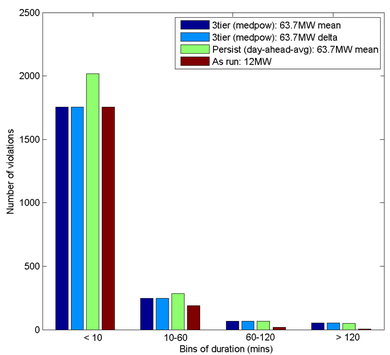
5. Exceedances: What are they?

- An "exceedance" is defined here as instance where the generation requested "exceeds" a capacity constraint.
- Two exceedance types were considered:
  1. The generation request surpasses 95% of the available capacity, thus dipping into the 5% contingency reserves and possibly surpassing a flow constraint.
  2. The generation request falls below a minimum generation requirement that is associated with a flow constraint (e.g., maintaining a minimum flow for salmon protection, etc.)
- Exceeding a system constraint can result in not complying with WECC control performance standards, or fish protection flows.
- In this study, an exceedance can occur when the actual generation is significantly different than that planned in the pre-schedule.

6. Exceedances: How many and how long?

Three wind forecast methods were considered in determining the amount of wind to sell in the pre-schedule: perfect, persistence, and the actual 3TIER forecast. The duration and maximum magnitude of the exceedances were tabulated and compared for these forecast methods and compared versus the system "as run" with 12 MW of wind. The results are shown in Figure 5. As displayed, the exceedances can be broken down into bins of duration individually relevant to system operators demonstrating that all methods were very similar, with the exception of a simple persistence approach. The number of short (under 10m) exceedances stayed about the same for all methods, but the number of longer-term exceedances did increase relative to the "as run" case. Although the increase is modest, understanding the timing and nature of these exceedances is important.

Figure 5: Breakdown of exceedances by method and duration



7. Exceedances: Changes from system "as run"

Table 1, below, compares (both by magnitude and duration) the set of maximum-constraint exceedances generated as the system was actually run in 2006, and the set of exceedances that would have occurred with a 63.7 MW pre-schedule plan.

There were about 2100 individual exceedances, as run, in 2006 with 12 MW wind; however only a handful of those exceedances changed with the 63.7 MW plan, and many of those differences actually represented reduction in magnitude or duration.

Table 1: Breakdown of exceedances by duration and magnitude

Duration of Exceedance (minutes)

Mean value of exceedance (% of available capacity)

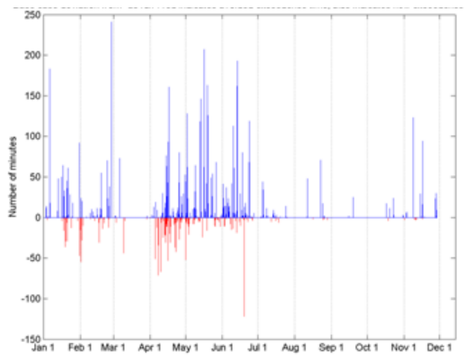
		1	6	11	16	21	26	31	36	41	46	51	56	61	66	71	76	81	86	91	96	101	106	111	116	121	126	131	136	141	146
			6	11	16	21	26	31	36	41	46	51	56	61	66	71	76	81	86	91	96	101	106	111	116	121	126	131	136	141	146	
0.95	0.96	-59	-11	13	8	2	4	0	4	0	2	-3	3	1	-1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
0.96	0.97	-14	-4	-5	8	9	6	6	-1	5	2	2	1	-1	2	2	5	0	2	0	1	0	1	0	3	-1	0	0	0	0	5
0.97	0.98	-7	4	1	0	1	2	-2	1	0	0	1	-1	2	3	0	-1	0	-1	0	0	4	0	0	0	0	1	0	-1	0	6
0.98	0.99	-1	0	0	0	-2	-1	-1	1	-1	0	4	1	1	1	-1	1	2	0	0	0	0	0	1	0	0	0	0	1	0	2
0.99	1	0	2	1	0	1	-1	0	0	-1	0	0	0	0	0	-1	0	1	-1	0	0	0	0	0	0	1	1	0	0	0	4
1	1.01	-1	1	0	-1	0	0	0	0	1	0	-1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1.01	1.02	0	-2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.02	1.03	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.03	1.04	-1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.04	1.05	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.05	1.06	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.06	1.07	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.07	1.08	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.08	1.09	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.09	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	1.11	-1	0	0	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.11	1.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.12	1.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.13	1.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.14	1.15	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.15	1.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.16	1.17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.17	1.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.18	1.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.19	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.2		1	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

8. Exceedances: When do they occur and what cause?

The timing of the tabulated exceedances correlates expectably well with the timing of system constraints throughout the year, as does the timing of the *changes* in exceedance durations after implementing a pre-schedule plan.

Figure 6, below, shows how these changes occur throughout the year, and to what degree, for 63.7 MW of wind. (Blue indicates amount of increased time, red indicates amount of decreased time.) This indicates that there may be times of the year when a more conservative planning method should be utilized to mitigate impacts when constraints are most limiting.

Figure 6: Changes in exceedance durations throughout the year



9. Conclusions

- This study has shown that while additional regulation and load following burdens may not be physically unmanageable, they do add variability to the system that can result in additional capacity exceedances.
- Including wind forecasts into a pre-schedule planning algorithm can *both* create new and negate existing exceedances that would have occurred without wind. The actual number of exceedances was only barely increased.
- Missed wind forecasts often responsible for increasing or decreasing the duration of exceedances
- Greatest number of exceedances occur during spring runoff when flow is

10. References

Acker, T., Knitter, K., Conway, K., and J. Buechler, Impacts of Integrating Wind Power into the Grant County PUD Balancing Area. 2007.

Acker, T., Knitter, K., Conway, K., and J. Buechler, Wind and Hydropower Integration in the Grant County Public Utility District, Washington, Proceedings of the Hydrovision 2006 Conference, July 2006.

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