Building the Power Grid of the Future: Resource Adequacy

NERC, Atlanta, GA

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GridLAB

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What do we have to do?

- The Brave New World includes "lots" of new DR/dispatchable demand, wind/solar, storage
- terminology
- nsmission matters – a lot!
- Alter… much new info do they provide?
- What about probabili… assessments?
- Data: how much and what kind do we…
- Questionnaire

If we aren't running LOLE-models for all days/hours of the year, how do we know when we're exposed to risk?? If we think we know the answer, why do we need a model?

2

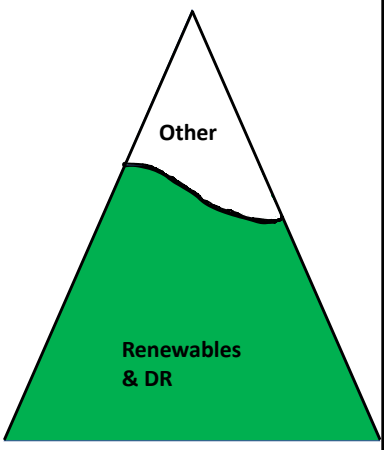
What do we have to do?

- **The Brave New World includes "lots" of new DR/dispatchable demand, wind/solar, storage**
- **Clean up terminology**
- **Recognize that transmission matters – a lot!**
- **Alternative metrics – how much new info do they provide?**
- **What about probabilistic flexibility assessments?**
- **Data: how much and what kind do we need?**
- **Questionnaire**

3

In the Brave New World we still need adequacy

- **But it may change**
- **"energy-first" planning**
  - Focus on clean energy first
  - Then "fill in" to achieve RA
- **Fill in with**
  - Storage
  - DR – or dispatchable demand
  - Quick-start thermal
  - Other
- **Will we ever *not* want to assess risks associated with meeting future demand?**



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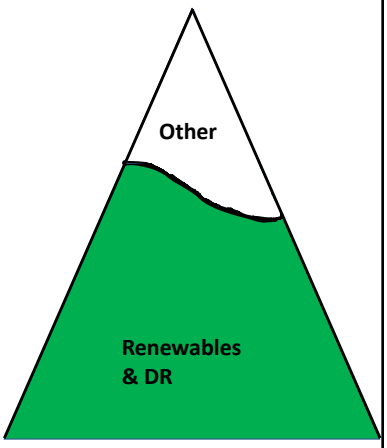
In the Brave New World we still need adequacy analysis

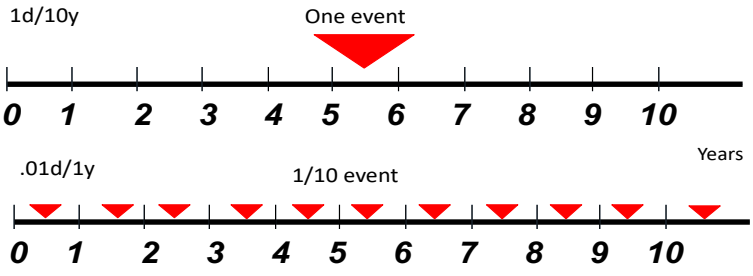
- Can dispatchable demand be used to largely eliminate times of high LOLE/EUE/risk?



5

Clean up terminology

- ELCC is typically in units of "UCAP"
- PRM is usually in units of ICAP
- What is a UCAP + ICAP?
- LOLP is not LOLE; 1d/10y is not a probability
- 1d/10y is not 0.1d/y



6

Clean up terminology

- ELCC is typically in units of "UCAP"
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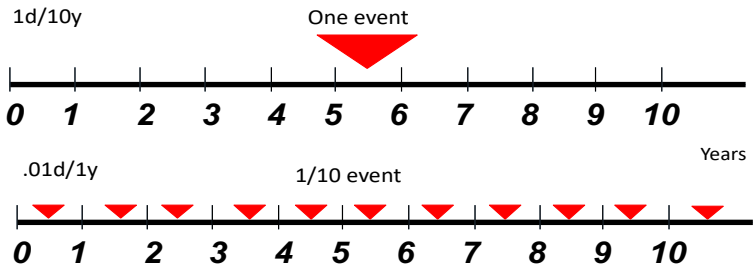

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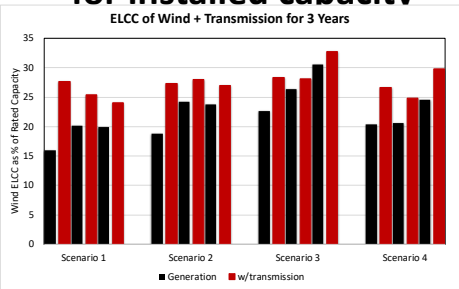
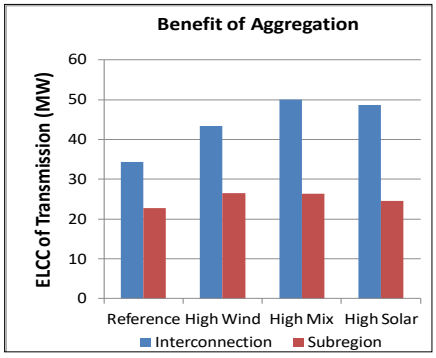
Transmission matters – a lot

- Increasing transmission links and associated operational coordination can reduce the need for installed capacity



Adapted from Eastern Wind Integration and Transmission Study https://www.nrel.gov/docs/fy11osti/47078.pdf



Ibanez and Milligan (2012), "Impact of Transmission on Resource Adequacy in Systems with Wind and Solar Power." IEEE Power and Energy Society General Meeting, Summer 2012. San Diego, and "A Reliability-Based Assessment of Transmission Impacts in Systems with Wind Energy". Available at www.nrel.gov/publications

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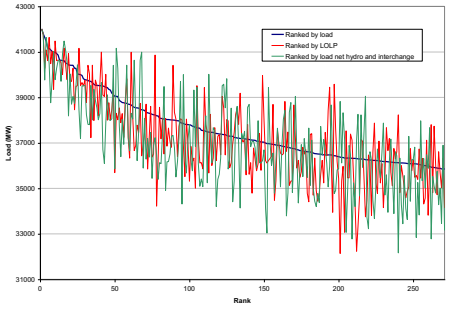
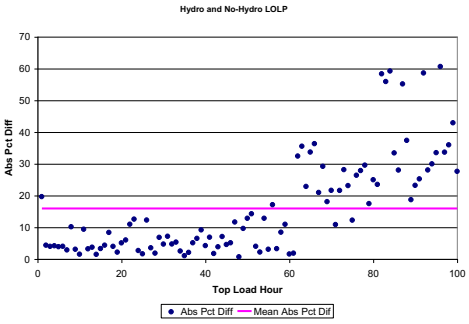
LOLP/E is function of many variables



- Demand
- Forced outage rates
- Interchange
- dispatch

- Uncoordinated maintenance scheduling may shift risk – big time



Kirby, B.; Milligan, M.; Makarov, Y.; Hawkins, D. (2003). California Renewables Portfolio Standard: Renewable Generation Integration Cost Analysis. Prepared for the California Energy Commission. California Wind Energy Collaborative, December. http://www.consultkirby.com/files/RPS_Int_Cost_Phase1_Final.pdf

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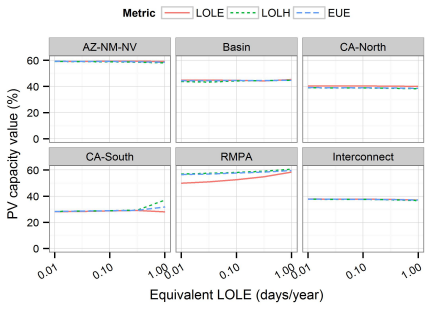
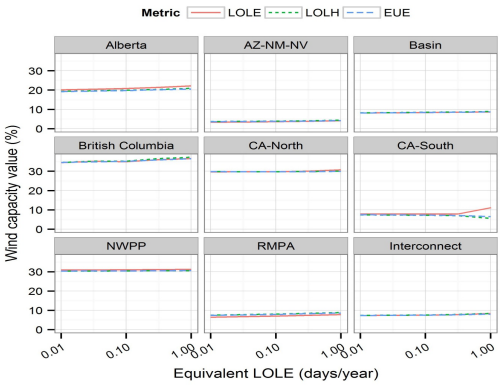
Increasing interest in different metrics



PV in the West



Wind power in the West

Timing of LOLE/EUE events may be similar, but magnitude may not be.

Milligan, Michael; Bethany Frew; Ibanez, Eduardo; Kiviluoma, Juha; Holttinen, Hannele; Söder, Lennart, Capacity Value Assessments for Wind Power: An IEA Task 25 Collaboration. Wiley Wires. 2016

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Why applying LOLE to ramping can be problematic

- Proposal: Calculate LOLE resulting from inability to ramp fast enough to keep up with changing net demand – and apply 1d/10y or similar
- This approach may have some value, but must be interpreted correctly (in context: CPS2, BAAL)
- All tools for maintaining balance, including dispatchable demand operator actions, and renewable curtailment should be considered
- Neither the (old) CPS2 nor the (new) BAAL require anything like a 1d/10y "effective ramp capability"

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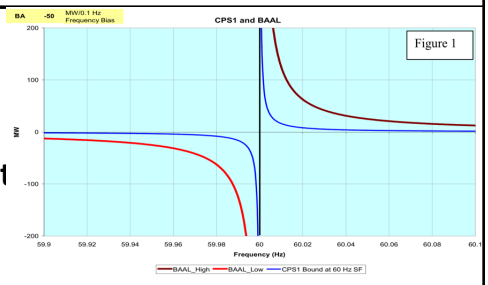
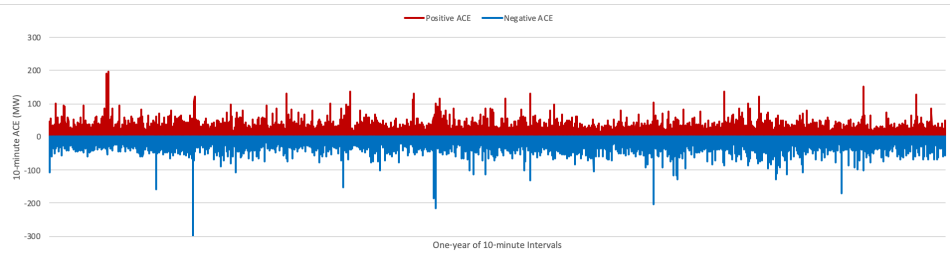
1d/10y LOLE-flex isn't compatible with how we operate

- ACE = area control error; measures unintended flows between neighbors
- Graph is from a SW utility that is aiming to a 0.2d/y ramp target, which is inconsistent with its historical operations
- BAAL or old CPS2





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How much – and what kind -- of data is enough?

- Weather is common driver
- Hourly wind, solar, and load data must be from same year for consistent analysis and plausible results
- Use of meso-scale weather models or actual VG production is state of the art (same as integration studies)
- Preserves underlying correlations between wind, solar, and load with temperature, other weather phenomena

Milligan, M.; Ela, E.; Lew, D.; Corbus, D.; Wan, Y; Hodge, B.; Kirby, B. (2012). Assessment of Simulated Wind Data Requirements for Wind Integration Studies. IEEE Journal on Sustainability. Vol. 3(4), October; pp. 620-626. Available at http://dx.doi.org/10.1109/TSTE.2011.2160880

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Complicated by wide-area geographic dispersion of demand, wind, solar

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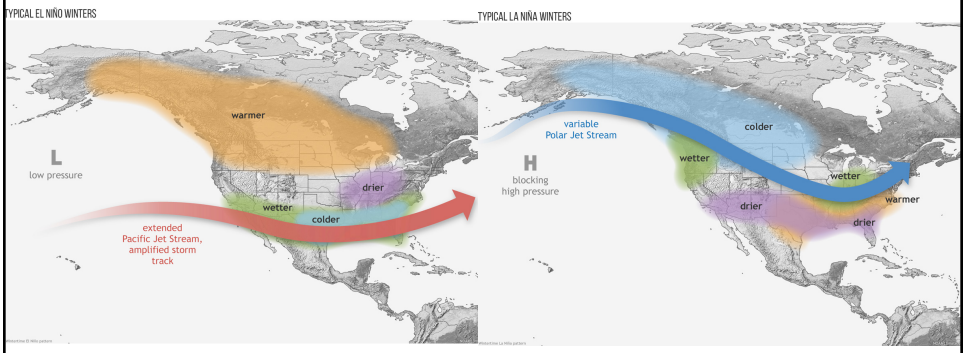
How does weather affect RE? Emergency Reserve?



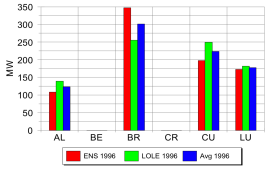


Figure 10. Optimal distribution of wind capacity using 1996 data

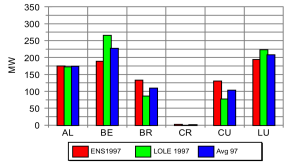


Figure 11. Optimal distribution of wind capacity using 1997 data

- **Inter-annual variability impact on RA**

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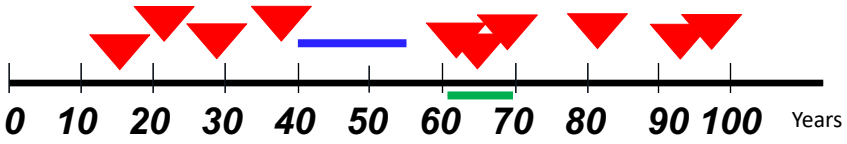
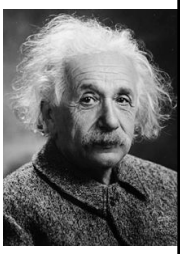
A Theory of Special Relativity for Power System Modelers

- **A modeler in year 55 with 15 years of data would conclude 0d/15y reliability**



- **A modeler in year 70 with 10 years of data would conclude 3d/10y**



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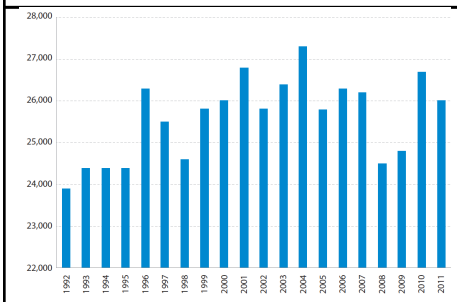
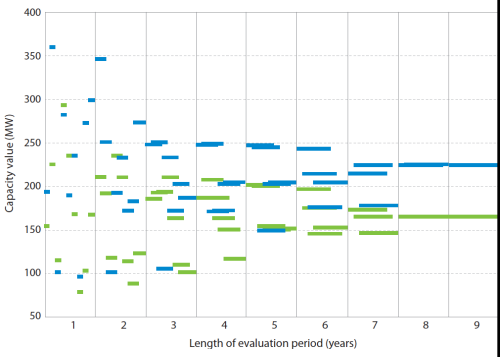
Long-term: how long is long enough



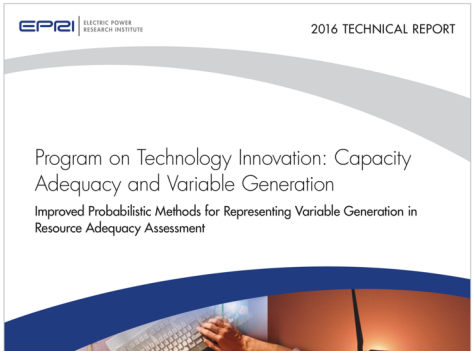
Peak demand (MW) for Sweden, 1991–2011



Multiple-year ELCC results from Finland using real data (green) and NASA/MERRA ReAnalysis-based data (blue) from 2005 to 2013 for 1,000 MW of installed wind capacity. J. Kiviluoma, VTT, Finland

Extracting weather influence on wind, demand

- **EPRI report**
  - Characterize dependence of VG and demand on temperature
  - If successful, this method may eliminate need for time-sync'd data
  - Results encouraging, but more work is needed to establish the validity of this approach
- **Kajala's Temperature-based Wind Power Model for reliability (unpublished paper, BPA)**
- ***How do we know what is good enough?***



This report is publicly available.

Aidan Tuohy, Eamonn Lannoye, Jody Dillon, Chris Dent, Amy Wilson, S. Zachary, E. Ibanez, M. Milligan: Capacity Adequacy and Variable Generation: *Improved Probabilistic Methods for Representing Variable Generation in Resource Adequacy Assessment*. Electric Power Research Institute in collaboration with National Renewable Energy Laboratory; Heriot-Watt University, Edinburgh, UK; Durham University, Durham, UK; Ecar Energy Ltd, Ireland.

What is changing: Very high RE penetrations, DR, storage

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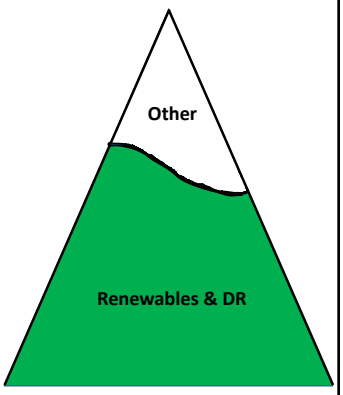
ESIG Workshop: 100% Renewable

- **What is needed for resource assessment?**
- **Consensus of the RA working group:**
  - Move to more EUE, LOLH, less on daily LOLE
  - Better multiple-year data sets for demand, wind, solar
  - Better accounting for DR
  - Better algorithms to match wind, solar, demand, hydro, chronological long-term data sets and ***ways to simulate them***



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Changes in dispatchable demand

- **Will it be possible to supply varying levels of RA at different rates? ($)**
- ***How much, and how responsive will it be?***
- **How will this affect LOLP targets and how do we calculate it?**
- **More LOLH/EUE analysis? What are the targets?**
- **More/better Monte Carlo that links underlying weather?**
- **Storage**
  - Electric vehicles (V2G?)
  - Thermal storage
  - Hot water heaters

NREL Pix Building Technologies / 23095.JPG

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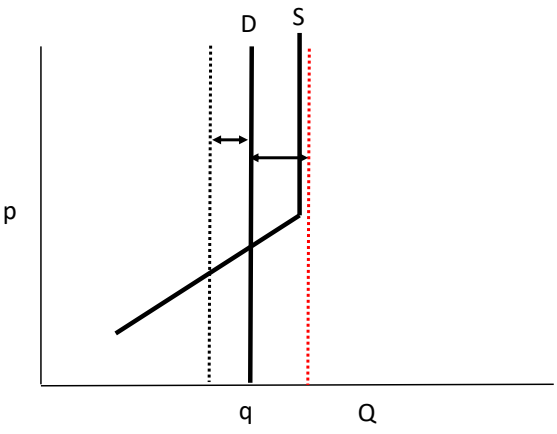
Can DR "fix" times of reliability stress?

- **Most days/hours have 0 LOLE**
- **Relatively few hours of notable risk drive capacity shortages**



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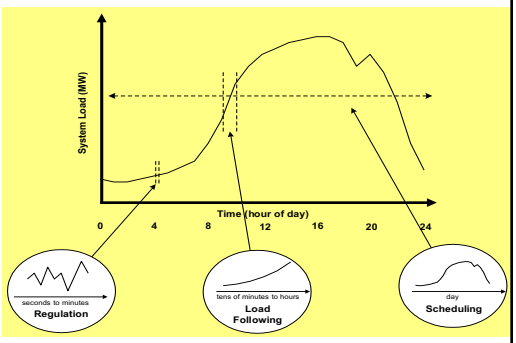
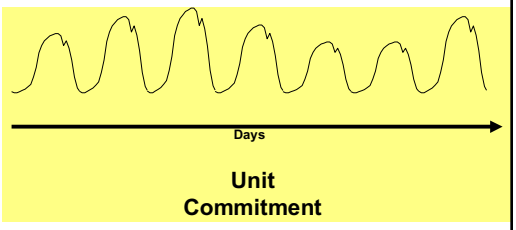
Hybrid models: LOLP based on dispatch

- To properly model DR, storage in a way that they would be used in practice → economic optimization
- Monte Carlo
- Controversy: is this really capturing reliability?
- Round-trip modeling?





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Summary: We have a lot of work to do!

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Flexibility from Demand: Enbala example (if time)

What can be done with massive aggregation of demand?

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Example of DR providing regulation

- The following example is intended to show the powerful impact of resource diversity – how can many disparate resources be combined to produce the regulation needed by the power system operator
- This type of aggregation may be possible for many other grid services, including balancing
- "Everybody doesn't have to supply everything."

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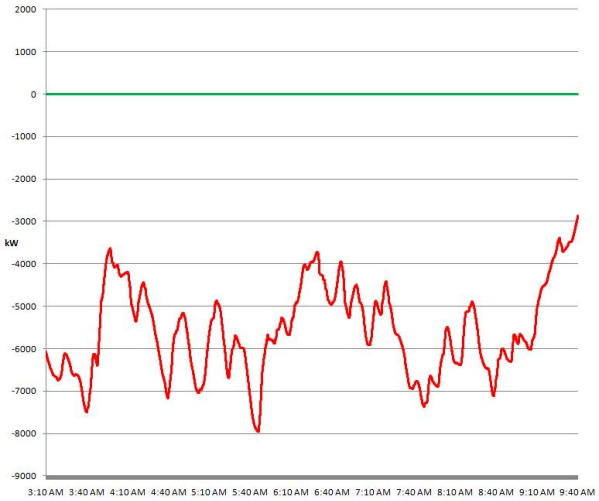
DR can also provide regulating reserves



This slide is beginning of simple animation of composite DR response

http://enbala.com/solutions.html

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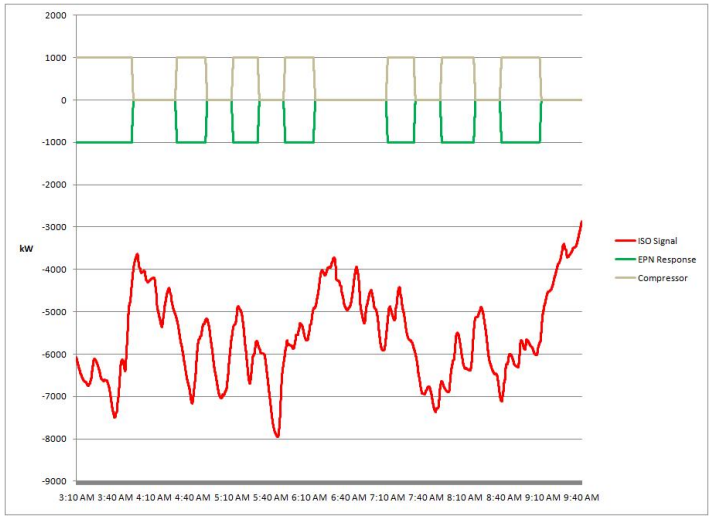
Resource Response



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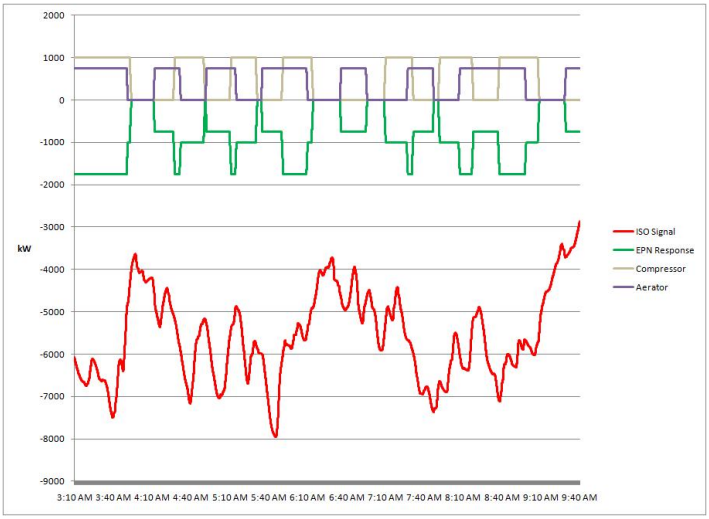
Resource Response



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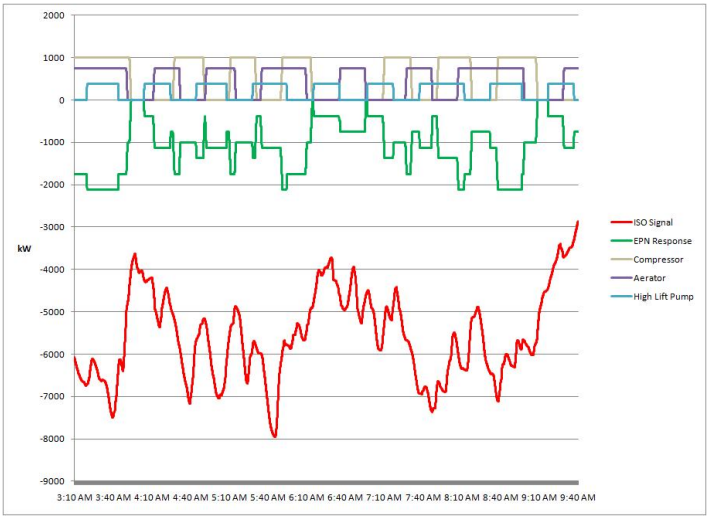

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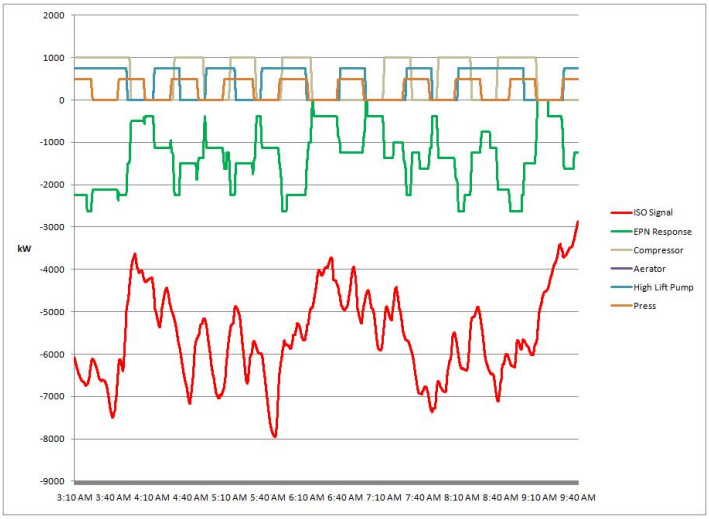

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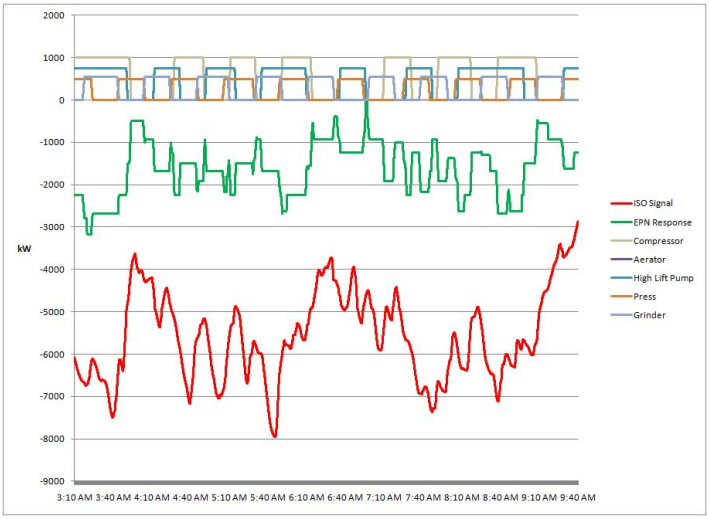

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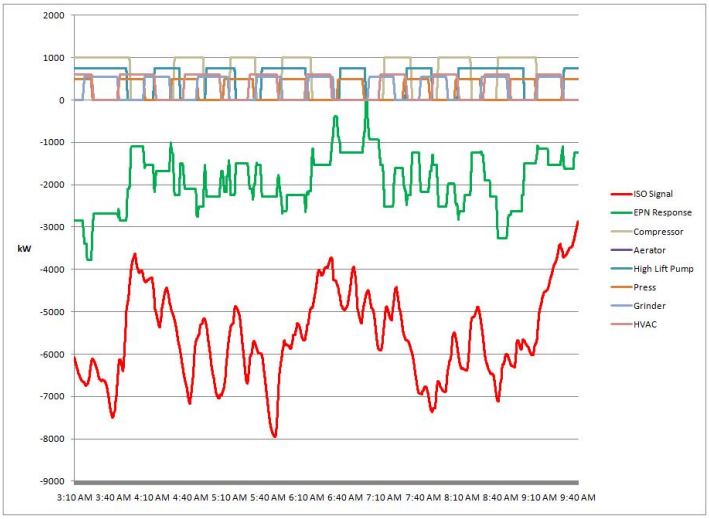

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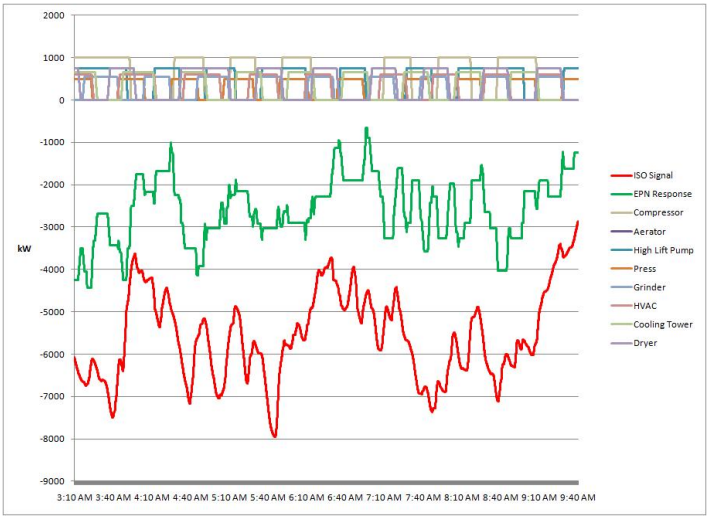

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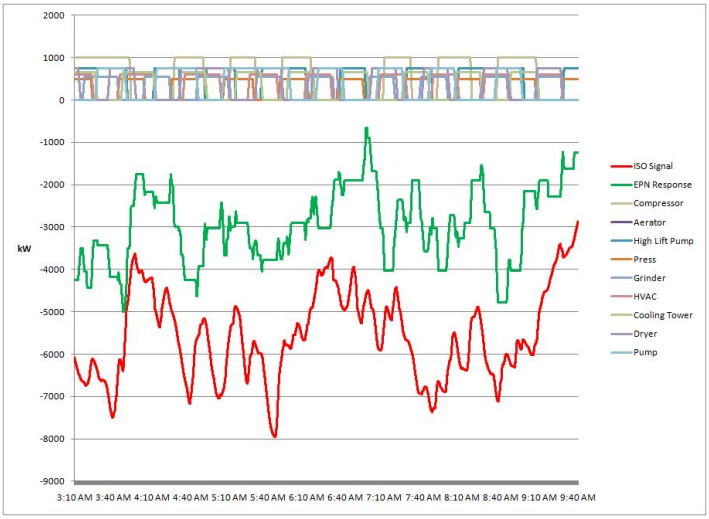

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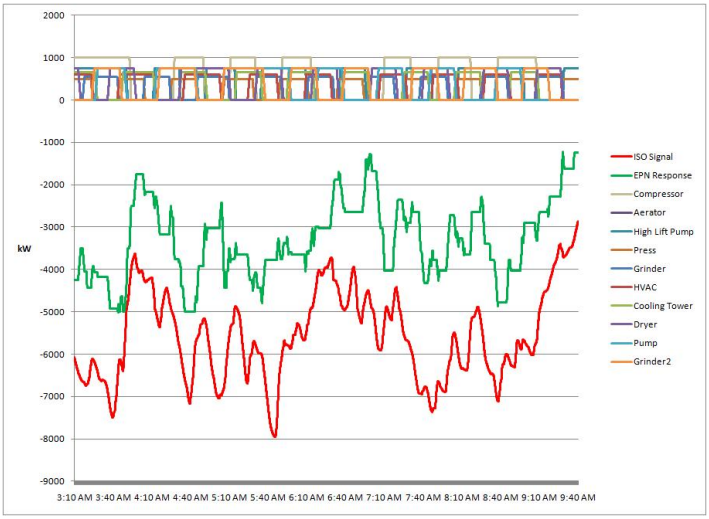

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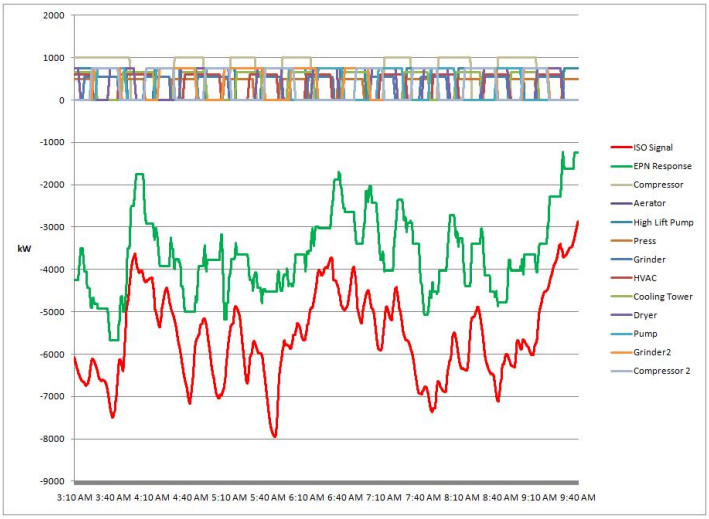
Resource Response



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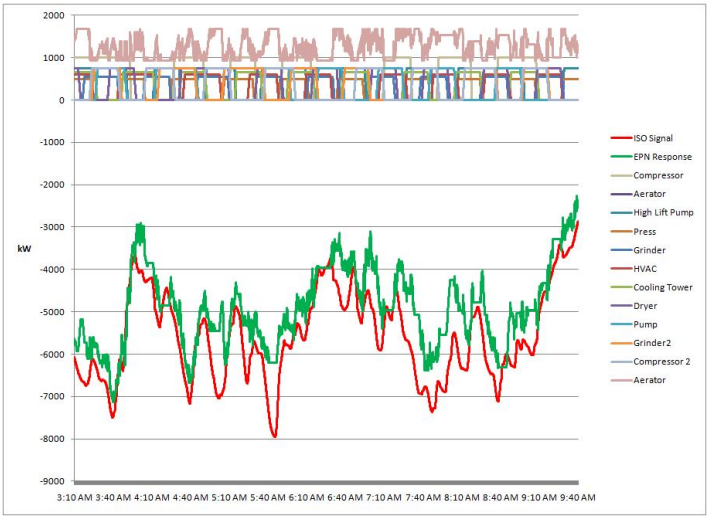

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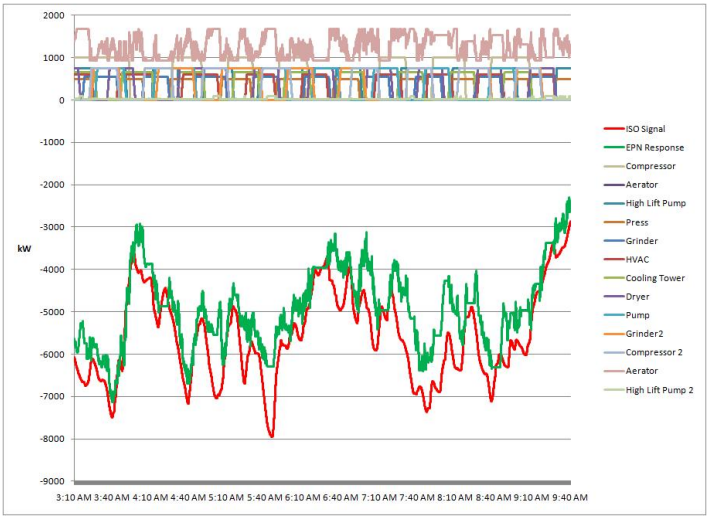

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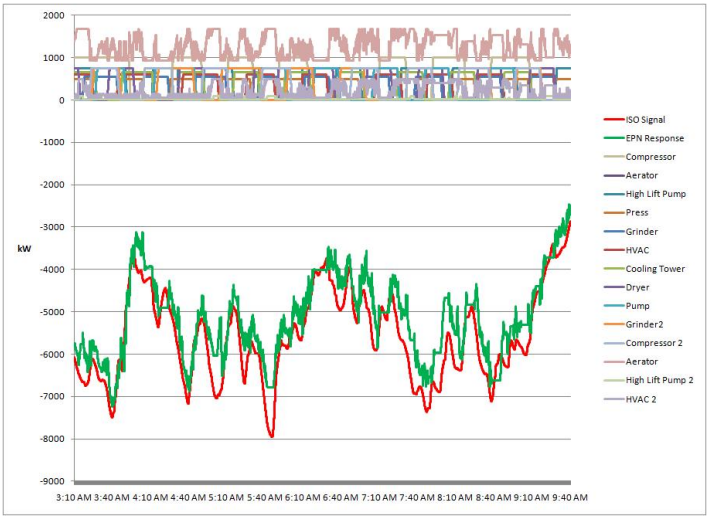

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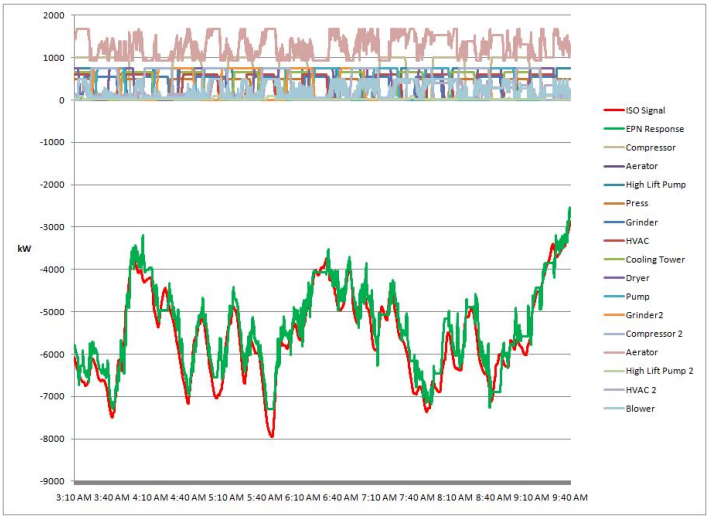

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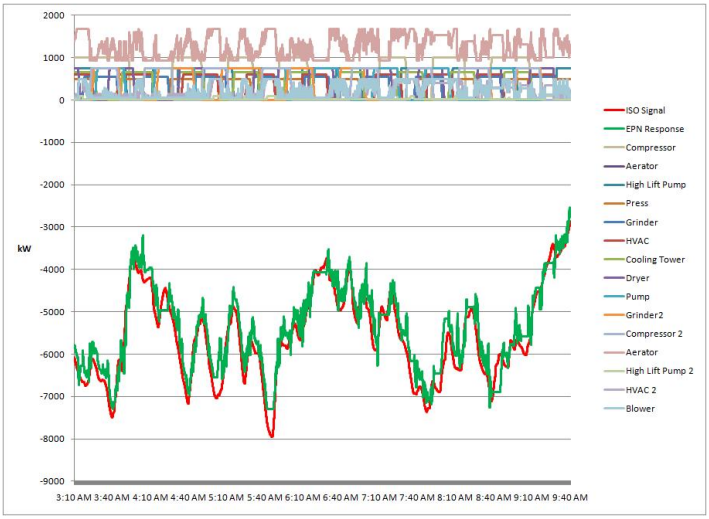

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Regulation – Resource Response

The aggregate response of each resource in the network is compiled to form the regulation response

http://enbala.com/solutions.html

Composition of resources

- **The Enbala regulation example is compelling**
- **How can this be translated to other grid services, and to longer time frames?**

Appendix:

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Renewables are Flexible

	Inverter-Based			Synchronous				Demand Response
	Wind	Solar PV	Storage/ Battery	Hydro	Natural Gas	Coal	Nuclear	Demand Response
Disturbance ride-through								
Reactive and Voltage Support	●	◔	◔	●	◑	◑	◑	◑
Slow and arrest frequency decline (arresting period)	●	●	●	●	●	●	●	◕
Stabilize frequency (rebound period)	◔	◔	◔	◔	◑	◑	◕	◑
Restore frequency (recovery period)	◔	◔	◔	◔	●	◔	◕	○	◑
Frequency Regulation (AGC)	◑	◑	◑	●	●	●	◕	○	●
Dispatchability/ Flexibility	◔	◔	◔	●	●	◔	◔	○	◑

● Excellent ◔ Very Good ◑ Good ◕ Limited ○ Incapable

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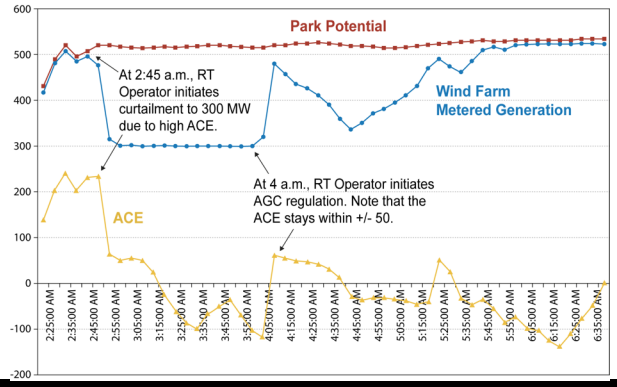
Renewables are flexible

- **Wind can provide synthetic inertial control and primary and secondary frequency response**
- **Wind can follow economic dispatch signals, and can be incorporated into economic dispatch or market operations**
- **This example shows how Public Service Company of Colorado improved its Area Control Error (ACE) using controllable wind energy during a period of very high wind and low demand**
- **Next slide enlarges the graph**

Source: Public Service Company of Colorado



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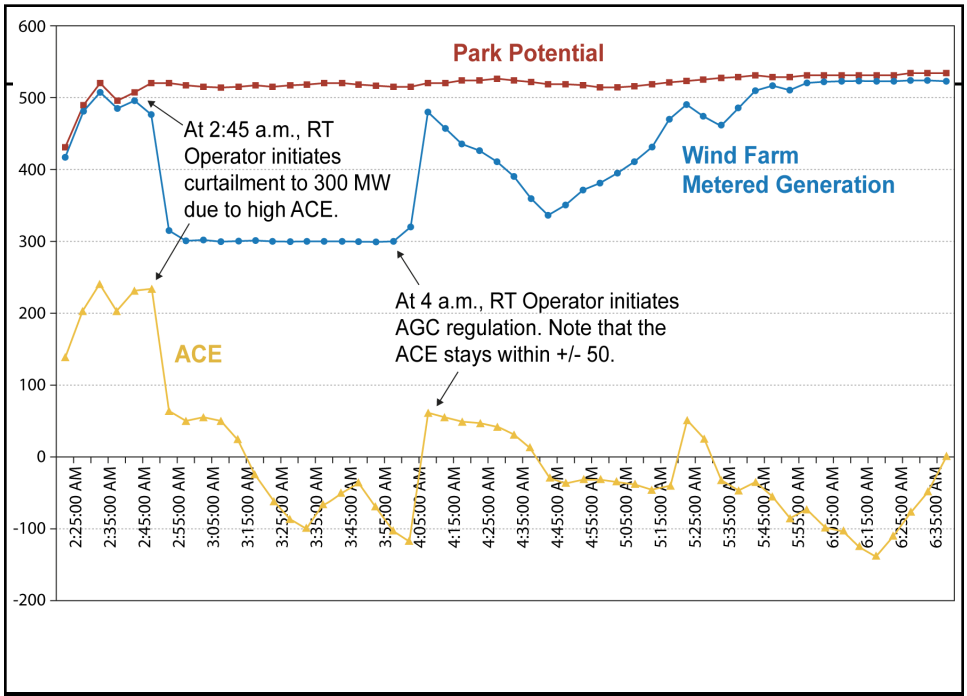

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Summary: Flexibility

- **Flexibility is increasingly important**
- **BUT – LOLP-based flexibility assessments may not be useful**
  - What target?
  - How does this type of analysis true up with actual NERC Balancing Standards?
- **Wind/solar can provide significant flexibility, faster response than thermal units**
  - Whether to dispatch wind/solar is an economic question, not a reliability question (usually)