The Economic Impact of CAES on Wind in TX, OK, and NM[1]

Nisha Desai (Ridge Energy Storage & Grid Services LP, Houston, Texas, USA); desai_nisha@bah.com

BACKGROUND

With an aging and limited transmission infrastructure, utilities and independent power project developers face challenges in trying to integrate wind energy into the grid. Many of the challenges occur because renewable wind and solar power are intermittent and cannot be dispatched. Wind energy resources have the potential to create or exacerbate congestion problems and voltage/grid stability issues, due to their unpredictable delivery of energy. Furthermore, wind energy may not be available at the right time to offset peak demand requirements and reduce needs for traditional generation capacity. Though cost-effective wind energy has made significant strides in penetrating into the grid, the current wind generation capacity of 6740 MW[2] remains a minute fraction of the total wind energy capacity that could be developed to meet the country's electricity needs. Integration challenges need to be addressed in order to fully realize the potential of renewable energy to contribute to the diversity of our electric power supply.

Electric energy storage has the ability to complement wind and address many of the challenges noted above. Energy storage can transform an intermittent, renewable energy resource into one that has firm capacity value and that can be dispatched in accordance with load and market prices for energy. With energy storage, renewable dispatch can also be controlled to reduce or avoid congestion, relieving pressure on transmission systems and reducing the need for traditional wires infrastructure. Furthermore, many storage technologies can also provide other services, such as reactive power, that can enhance grid stability, particularly in locations remote from load where large-scale renewable generation is often located.

In 2003, the Department of Energy, through its State Energy Program, issued a Special Projects request for proposals to study the value of adding energy storage to the grid to support renewable energy. In partnership with the Texas State Energy Conservation Office (SECO), Ridge Energy Storage & Grid Services (RES) assembled a team to propose a study of compressed air energy storage (CAES) with wind in the control area of Southwestern Public Service Company (SPS), an operating company of Xcel Energy. SPS's control area spans a region extending from the eastern plains of New Mexico to the panhandle areas of Texas and Oklahoma. Team members included representatives from Southwestern Public Service Company, RnR Engineering, the Alternative Energy Institute at West Texas A&M University, the Oklahoma Wind Power Initiative, and the state energy offices of Oklahoma and New Mexico. This report documents the team's efforts and presents the results of the study of CAES and wind.

LOCATION OF STUDY - SPS CONTROL AREA

The reason for selecting the SPS control area as the region of study was twofold: First, the region has characteristics that would make energy storage particularly beneficial in helping to integrate further wind generation into the grid. With class 4 winds in much of the area, estimates of potential wind development for the region are over 40 GW.[3] With the tremendous potential for wind resource development, total interconnection requests for Study Wind projects exceed the peak load for the incumbent utility. While SPS has been rather aggressive in contracting for over 440 MW of wind projects (approximately 10% penetration), limited transmission infrastructure and lack of purchaser's of wind energy have been impediments to further wind development.

Second, this region has geologic features that are particularly conducive to the development of the selected energy storage technology, CAES. Along with pumped hydro, CAES is a technically proven solution for bulk energy storage, and the two technologies are the only energy storage options with the capability to provide services commensurate with the requirements of several hundred megawatts of wind. CAES uses compressed air to store energy (hence the name), and thus requires access to underground formations to hold the large

[1] Funded by the Energy Storage Systems Program of the U.S. Department Of Energy (DOE/ESS) as a State Energy Grant.
[2] AWEA projects database, Jan 24, 2005
[3] Electric Power Engineers, Inc.

volumes of high pressure air. Underlying much of the region are salt formations, which have the potential to be mined out into caverns that could store air in a CAES application, similar to the salt caverns that have been used to store natural gas and other hydrocarbons for decades. With its below ground geology and its plentiful wind resources, the SPS control area is an ideal location to consider combining wind and CAES, and is therefore an ideal location to study the value of doing so.

OBJECTIVES

This project had the following main objectives with specific application to CAES and wind in the SPS control area:

- Assess the ability of CAES to positively affect dispatch of wind energy.
- Assess and quantify economic benefits of using CAES to improve grid reliability issues and congestion associated with wind energy.
- Determine the economic advantage of using CAES to firm and shape wind energy sales.
- Determine institutional barriers and opportunities for energy storage combined with renewable energy facilities.

SUMMARY RESULTS

This study was able to show significant benefits from the use of CAES to integrate large quantities of wind energy onto the grid. In particular, the study was able to show that CAES can add value in the following ways:

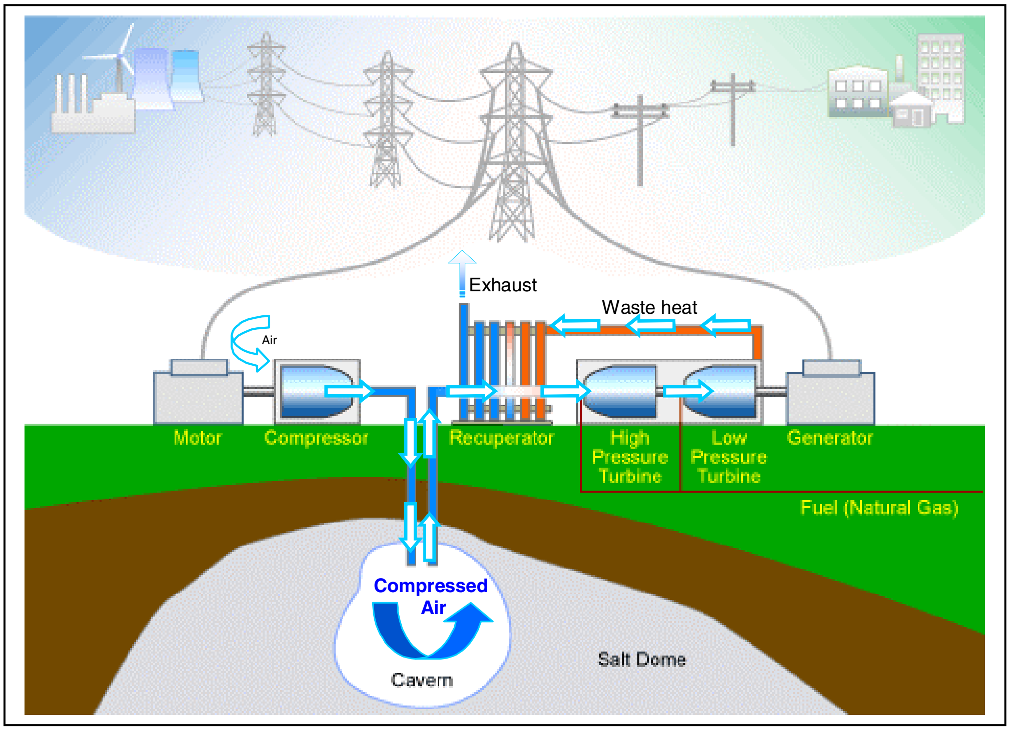
- Significantly improve the delivery profile of renewable energy to the grid.
- Ameliorate the impacts of wind energy on system ramping.
- Provide transmission benefits in excess of the cost of any transmission upgrades required by the CAES plant itself.
- Provide combined economic benefits of firming, shaped delivery, capacity value, and transmission impacts in excess of the cost of the CAES plant.

Finally, the economic feasibility of combining CAES with wind was demonstrated by evaluating the combined economic benefits of firming, shaped delivery, capacity value, and transmission impacts and comparing this against the added capital cost of the CAES plant. We estimate that SPS could realize approximately $10 Million per year in net value by using CAES to integrate an additional 500 MW of wind.

HOW CAES WORKS

A CAES plant stores electrical energy in the form of air pressure, then recovers this energy as an input for future power generation. Essentially, the CAES cycle is a variation of a standard gas turbine generation cycle. In the typical simple cycle gas fired generation cycle, the turbine is physically connected to an air compressor. Therefore, when gas is combusted in the turbine, approximately two-thirds of the turbine’s energy goes back into air compression. With a CAES plant, the compression cycle is separated from the combustion and generation cycle. Off-peak or excess electricity is used to “pre-compress” air, which is held for storage in an underground cavern, typically a salt cavern. When the CAES plant regenerates the power, the compressed air is released from the cavern and heated through a recuperator before being mixed with fuel (natural gas) and expanded through a turbine to generate electricity. Because the turbine’s output no longer needs to be used to drive an air compressor, the turbine can generate almost three times as much electricity as the same size turbine in a simple cycle configuration, using far less fuel per MWh produced. The stored compressed air takes the place of gas that would otherwise have been burned in the generation cycle and used for compression power.

The following figure demonstrates the operation of a CAES plant:



© Ridge Energy Storage & Grid Services

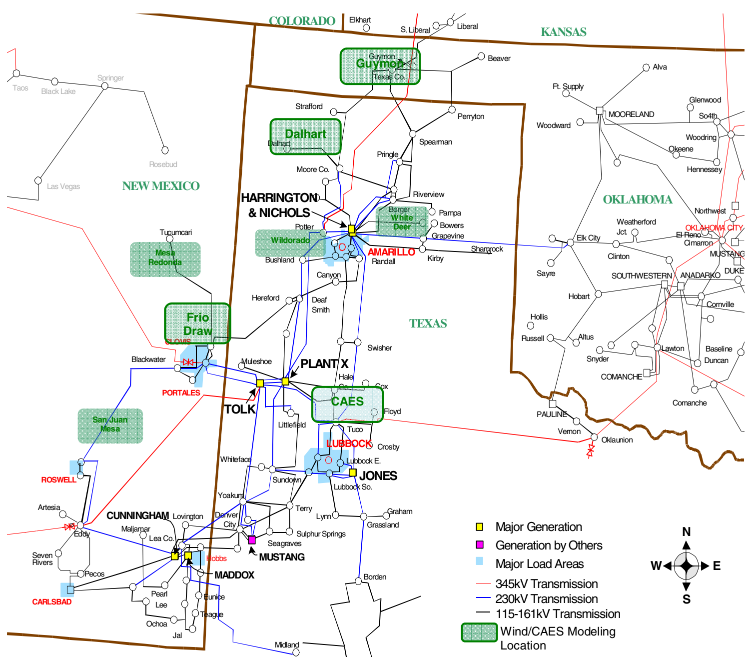
The volume of air storage required for a typical CAES plant is most economically provided by geological structures. Salt caverns, aquifers, depleted oil and gas reservoirs and rock mines have all been considered as possibilities for air storage in a CAES application. A 1990's DOE study estimated that approximately 85% of the land area of the US would be able to access suitable geology for a CAES project.

WIND MODELING

We focused on two scenarios. The first scenario, entitled the Base Wind Scenario, assumes that all four wind projects, totaling 440 MW, that have been announced by Xcel Energy in the SPS control area are online and producing energy.

The second scenario, called the Study Wind Scenario, looked at the impacts of even more wind development in the area. We selected three sites, one in Oklahoma, one in Texas, and one in New Mexico, that represented reasonable sites for Study Wind projects, enabling us to model an additional 500 MW of wind.

The following map illustrates the approximate locations of the wind farms modeled in this study with respect to the transmission grid. The CAES plant is modeled as interconnecting into the Tuco substation.



Wind Modeling - For each of the scenarios, we had to model what the wind resources looked like. Our wind modeling was focused on understanding how much wind would be produced on an hourly basis for a representative year, with all of the modeled wind farms working together. We also spent time on understanding how the wind energy profiles compared with load profiles.

CAES Dispatch Modeling - We also had to model how a CAES plant would operate in conjunction with the wind in each scenario. To start, we developed assumptions about what the plant configuration would look like and what the operating and cost parameters would be for a CAES plant. Once the operating assumptions were developed, we used these assumptions in various models to estimate what the CAES dispatch would/should look like in order to balance the wind. Our main tool for developing the CAES dispatch profiles is a wind shaping model developed by Ridge Energy. The wind shaping model estimates what CAES operations would have to look like in order to balance and shape wind to meet a particular dispatch strategy. CAES operating parameters were also fed into PROSYM, which provided an alternate estimate of how CAES would be dispatched to create value on the system.

Scenario Analysis - Once the profiles for wind and for the CAES dispatch were developed, we were able to analyze the scenarios and compare the change cases with CAES to the reference cases with wind only. Analysis focused on several areas. Descriptive analysis showed how net profiles of energy production changed, particularly with respect to load. Load flow analysis was performed to analyze the impacts of wind on the transmission system and to identify whether the addition of CAES made any significant changes to the requirements for new infrastructure to integrate wind. Finally, production cost analysis and other methods were used to quantify savings that could be achieved by wind and wind with CAES, and the difference between the two represented the economic value of adding CAES to the system. These savings were compared against the cost of adding CAES to determine the net economic impact of energy storage in conjunction with wind.

The collection and analysis of the wind data, predicted output of the modeled distributed wind plants, and the discovered changes in daily and hourly production, do nothing to diminish the potential for wind power on the existing utility grid. All the factors do point out that the successful inclusion of a properly sized and placed CAES plant would enhance the value of the wind power. The wind pattern, coupled with the broad change in daily wind shear values, also points to the added value of a CAES plant when the opportunity to shift the greater than expected night time energy to periods during the daytime when the utility needs that energy. The overall value for this type operation of the CAES in cooperation with the dispersed wind plants would do much to mitigate the intermittency that is the common complaint against wind alone, and the CAES plant could improve reliability for the local area.

The Panhandles of Texas and Oklahoma, coupled with the far Eastern New Mexico region, have a known proven resource for wind energy. The land area, natural gas resources and the underground formations that lend themselves to reduced CAES costs are in place. This combination of the two different power production methods (wind and natural gas) will prove to be a way to extend existing natural gas supplies, while utilizing all the energy that comes from the wind plants at the delivery times that best assist the utility.

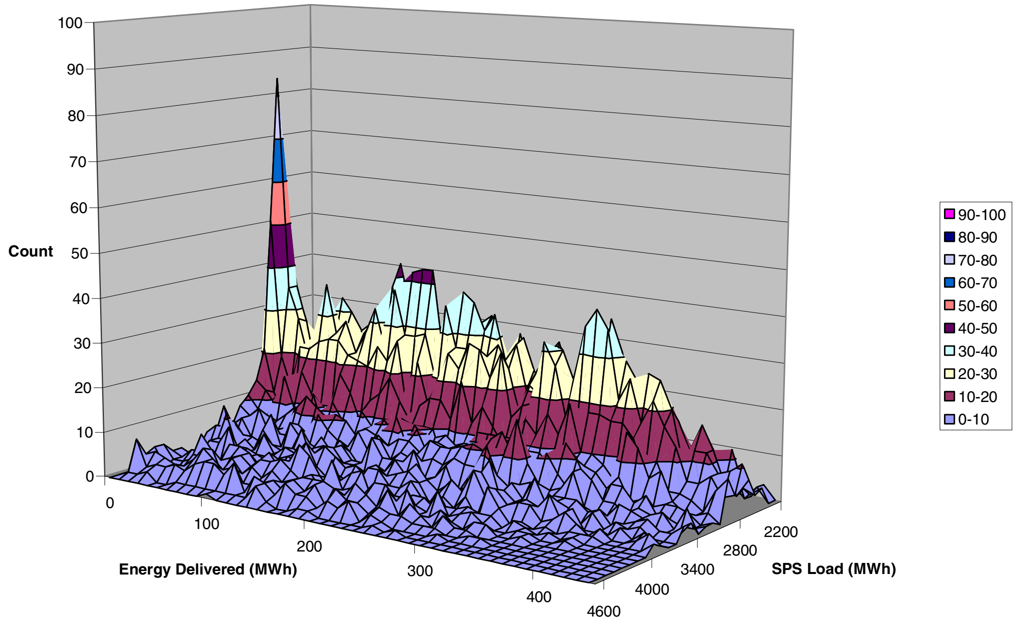
DISPATCH IMPACTS

In the scenarios we examined, modeling of CAES operations with wind showed that CAES has the potential to improve the dispatch profile of the wind energy. In particular, it showed that CAES can (1) improve the shape in which energy is delivered onto the grid, (2) positively impact ramping requirements associated with wind, and (3) allow stored energy to be made available to serve peak demand, whether or not the wind is blowing.

On average, in the scenarios we studied, wind energy delivery profiles do not correspond closely to load profiles. The first graph below plots 440 MW of nameplate wind versus load.

The graph provides insight by showing the number of hours per year when wind energy and load are within certain ranges. For example, the spike shows that there were 84 hours in the year when wind production was less than 10 MWh, while load was between 2700 and 2800 MW.

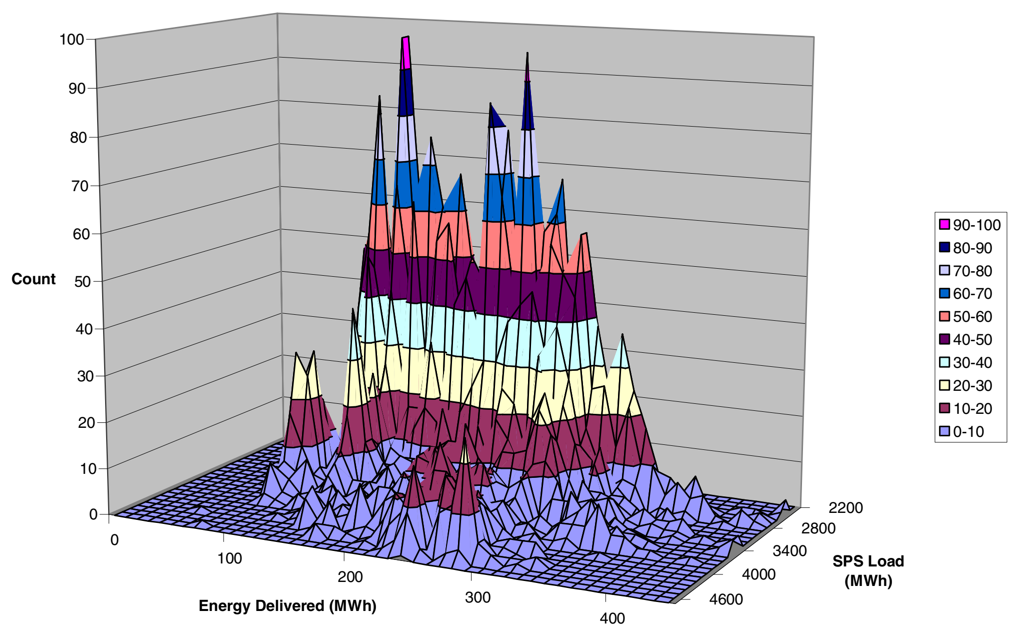
440 MW Wind vs Load



Essentially, there is a negative correlation between the amount of wind produced and the amount of load. It is interesting to see that when the wind is producing at a high percentage of nameplate capacity, that load is very likely to be low.

The next graph plots the frequency of wind/CAES deliveries versus load.

440 MW Wind Plus CAES vs Load



There are several differences in the 3-D charts that depict the key impacts of wind hybridization with CAES. First, note that there are close to zero hours when less than 70 MW of energy is being delivered to the grid from the combination of wind and CAES. Effectively, CAES has baseloaded over 70 MW of the 440 MW of wind on the grid and turned it into a round-the-clock product. Next, note the dramatic reduction in the number of instances when energy deliveries are at a high percentage of nameplate wind while load is low. In fact, there are significantly fewer times when energy deliveries are above about 350 MW. Third, note the increased volumes of energy that are delivered during the peak demand hours compared to wind on its own. Finally, note that the frequency of energy deliveries within a certain range of hourly volumes has dramatically increased, implying greater predictability in long term planning for energy supplies due to the hybridization of wind with CAES.

ECONOMIC ANALYSIS

Our economic analysis shows that there is value to be generated from using energy storage in conjunction with wind resources in the Panhandles of Texas and Oklahoma and the eastern plains of New Mexico. Value can be created by a 500 MW CAES plant by providing firming services, shaping services, long term capacity benefits, and improved transmission flows in two scenarios: first, where the CAES plant is being used to manage 440 MW of wind that SPS has agreed to contract for; and second, where the CAES plant is being used to facilitate the integration of an additional 500 MW of Study Wind. In the first scenario, however, the annual benefits provided by the CAES plant only justify the investment cost in a CAES facility if SPS can leverage its low cost of capital by actually owning the plant. However, in a scenario where the CAES plant is coupled with 500 MW of Study Wind, the benefits provided by CAES can allow for third party ownership of the plant under an IPP financing structure. By treating the CAES plant and Study Wind as a single project, it is also possible to compare the per MWh costs of the net delivered energy to the costs from conventional thermal generation and show that a combined wind/CAES project would be a highly competitive alternative to consider when adding new physical generating resources to the grid.

($000)	**Base Wind Scenario**	**Study Wind Scenario**
Net Shaping Value	($283)	$10,918
Firming Value	$3,222	$3,552
Capacity Value	$20,507	$20,507
Additional Imports	$5,778	$4,282
New Transformer	($490)	($490)
Total Annual Value	$28,734	$38,769
Annual CAES Capacity Cost (SPS ownership structure)	($28,472)	($28,472)
Net CAES Value /year	$262	$10,297

FINAL WORD

The study concluded that under a range of scenarios, the combined cost of 270 MW of CAES with 500 MW of new wind would be competitive with conventional generation resources that might be considered as an addition to the grid – as long as the federal PTC for wind remains in place. This conclusion should highlight the opportunity for using CAES as a cost-effective way of encouraging further wind development in the SPS service territory, and also elsewhere in Texas, Oklahoma, and New Mexico. We hope that this study encourages utilities and developers to engage in dialogue about combining CAES with further wind development in the region.