Information

• Poster Title:
  – “Integrating Remote Wind Resources: The Role of Energy Storage”

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Background Information

- 29 U.S. states have renewable portfolio standards (RPS) that require some amount of low-carbon generation. Wind power is likely to play a large role in meeting these goals. For example, Illinois set a 25% RPS target for 2025 of which 60-75% of this target must be met using wind resources. Previous work [1] showed that in meeting this target, building local wind resource in Illinois is less expensive than building wind in and transmission to remote locations with higher capacity factors (CF).
- However, building local resources may be not possible due to public disapproval, to maxed out wind potential, or to the onset of even stricter targets requiring more wind resources than are available locally. In this case, massive transmission investment would likely be needed to access these remote resources.
- Past research suggests that energy storage technology could replace some transmission capacity [2], however at what costs? And how do they compare with transmission costs?

Research Objectives

1) Instead of making cost assumptions for transmission and storage, this research finds the costs at which building remote versus local wind is most economic in terms of minimizing total levelized cost of electricity (LCOE). This decision is made from a system planner’s perspective.
2) In making this decision, it adds the option to build energy storage capacity as well as transmission and finds the optimal level of both for different costs. The focus is on remote resources in North Dakota versus local resources in Illinois but the results and tools developed are generalizable to other locations.
3) It also considers the problem from an individual agent’s perspective in which an investor would build the cost of a remote wind farm and all or most of the storage and transmission costs. In this case, the optimal investment decision is based on maximizing yearly return on investment (ROI) from selling electricity. Work by [2, 3, 4] suggest that in addition to transmission savings, an individual investor could also gain value from storage capacity through price arbitrage. It is assumed that the investor will enter a fixed price purchasing power agreement (PPA) with a load serving entity (LSE) and that this contract will be based on historical location marginal prices (LMP). For this, 2010 hourly LMP data from the Illinois Hub are used. 2006 simulated data from the Eastern Wind Interconnection Study (EWITS) are used for hourly wind output.
4) To the author’s knowledge, this is the first attempt at analyzing this decision from both an investor’s and system planner’s perspective.

Using Storage for Integrating Remote Wind

- Building storage at a remote wind farm can add value in two ways: 1) price arbitrage and 2) transmission savings.
- The first adds value by allowing the operator to store power when transmission is constrained and then deliver it once the value of electricity is higher and transmission is unconstrained. See the graph below.
- This ability could help the investor negotiate a higher rate for a bundled PPA since they could deliver renewable power to LSE’s seeking RECs at times when power is most valuable to the LSE. It is therefore assumed that the investor receives the annual revenue from matching hourly wind output to highest hourly prices (LMP).
- Second, storage could allow the investor to replace some transmission capacity. Referring to the figure above, so long as the storage was large enough, the 70% transmission constraint might be able to send the same amount of power as a 100% transmission line. This might be optimal depending on the price of storage and transmission.

Modeling Steps and Objective Function

Investor Perspective:
1) Parameterize transmission (TC) and storage (SC) capacity
2) Optimize the wind farm’s operation to maximize net revenue assuming certain hourly prices and wind output
\[
\text{Max} \quad \sum p_{t} q_{t}, V_{t} \quad \text{subject to} \quad q_{t} = \text{delivered power,} \quad W_{t} = \text{power produced,} \quad S_{t} = \text{power stored,} \quad SC = \text{storage const. as a % of wind nameplate capacity,} \quad TC = \text{transmission const. as a % of wind nameplate capacity,} \quad 0 < \frac{q_{t}}{W_{t}} < 1, \quad \frac{S_{t}}{W_{t}} < TC
\]
3) Restart at 1) by changing TC and SC
4) Calculate ROI for the year for each scenario and find the maximum

System Planner’s Perspective:
1) Set TC, fix power required per year (Q), let SC = inf (unconstrained)
2) Optimize the wind farm’s operation to minimize total curtailed power assuming certain wind output
\[
\text{Min} \quad \sum q_{t}, V_{t} \quad \text{subject to} \quad q_{t} = \text{delivered power,} \quad S_{t} = \text{power stored}, \quad SC = \text{storage const. as a % of wind nameplate capacity,} \quad TC = \text{transmission const. as a % of wind nameplate capacity,} \quad 0 < \frac{q_{t}}{W_{t}} < 1, \quad \frac{S_{t}}{W_{t}} < TC
\]
3) Restart at 1) by changing TC
4) Calculate LCOE for each scenario and find the minimum

Assumptions

- A 200 MW wind farm is to be built either in location A or B in the figure above. A and B have average capacity factors of 48% and 33% respectively.
- For A, the goal is to solve for the optimal capacity of transmission, (1,000 km from load) and storage capacity to 1) minimize LCOE for the system planner’s perspective and 2) maximize profits for the investor’s perspective.
- For B, no transmission or storage is adds.

Discussion and Policy Implications

- Based on this case study, assuming that transmission costs are $600/kM-km or lower, from a system planner’s perspective does not replace transmission unless costs are $20/kWh or lower.
- From an individual investor’s perspective, the same result holds. This decision is made from both an investor’s and system planner’s perspective.

Results ($600/MW-km TRNS cost Base Value)

- From the system planner’s perspective, building local wind is optimal for costs above $700/MW-km. At lower TRNS cost, remote wind is optimal but without storage. Storage replaces TRNS when its cost is $20/kWh or less (right). When TRNS costs approach $1,200/MW-km, storage is optimal up to $400/kWh at this TRNS cost. Local wind is best.
- The most optimistic estimates of storage cost are $25/kWh for CAES and $50/kWh for batteries.

References


[ Supplemental Material: "Integrating Remote Wind Resources: The Role of Energy Storage" ]

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