Under what conditions is conversion of high voltage AC transmission to DC economically attractive?

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Introduction & Motivation

HVDC transmission benefits include:

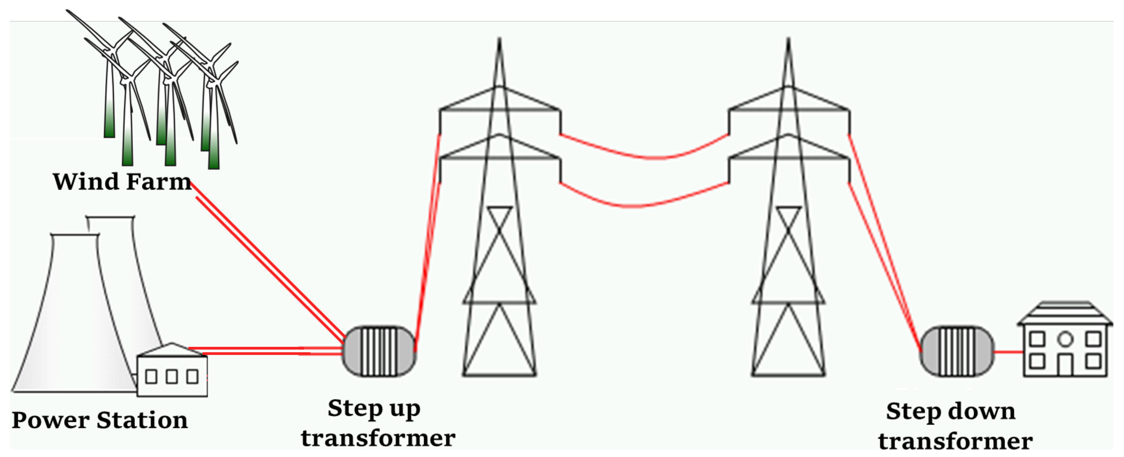
- Lower resistive losses and no reactive losses, allowing more delivered power
- Smaller required rights of way (ROW) for the same voltage, with transmission of up to 3.5X more power[1] in the same corridor and lines
- Integration of aggregate intermittent generation while minimizing voltage and frequency regulation risks, enabling decarbonization of electricity generation[2]

Drawbacks are primarily economic:

- High voltage AC/DC conversion is 160K-190K/MW.[2, 3]

Increasing transmission needs are constrained by **barriers to new construction**:

- Permitting
- Land acquisition
- Financing
- PUC project approval, rate change approval
- NIMBYism
- Health concerns



Increasing capacity in existing corridors could remove multiple barriers. When faced with a need to increase transmission in an existing corridor,

what are the benefits and costs of choosing HVDC conversion versus higher voltage HVAC? What conditions influence the choice?

Framework

Initial analysis compares options for increasing transmission in an **existing 345 kV AC double circuit corridor to allow ~5GW of power transmission**:

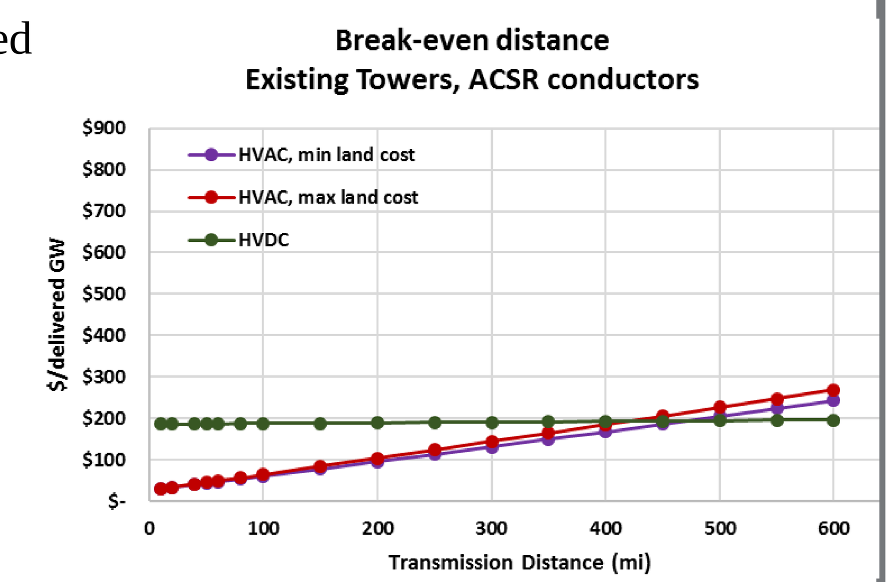
	HVAC Option: 487 kV DC Bipole	HVAC Option: 500 kV AC double circuit
Conductors[5]	Existing ACSR, with DC transmission amperages and voltages within spec	Replaced to allow for higher V and A, ACSR or ACCS HTLS
Towers	Existing but modified[a]	Modified[a] or Replaced to accommodate spacing, weight
ROW	Existing, per NESC recommendations 345 kV AC double circuits and 500 kV DC bipoles have equal ROW requirements of 200 ft	Expanded 6 acres/mi to meet 225 ft recommendation by NESC[3], BLM costs to own $85/acre to $3,500/acre
Power Losses[5]	Ohm/mi per technical product specs DC resistance[b]	Ohm/mi per technical product specs AC resistance, PF=1
Infrastructure	Converter stations ($187k/MW)[1]	345/500 kV Xfmr Stations ($13k/MVA)[3]

[a] Costs of modifying existing towers not found in the literature to date.
[b] Converter station losses not included

Preliminary Results

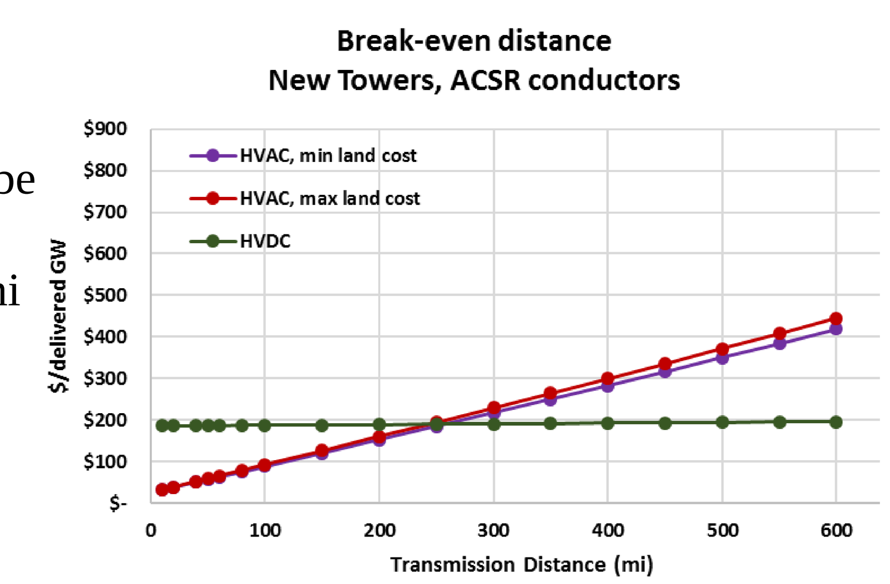
Existing Towers, ACSR conductors

Aluminum Conductors Steel Reinforced (ACSR) are the lowest cost conductor. Current ACSR specs were used to calculate DC line (795 kcmil) and AC line (1590 kcmil) losses. Even with additional land required, **AC reconductoring is more attractive at most distances that would have existing 345 kV lines.** However the conductors represent an over 200% increase in weight on the towers.



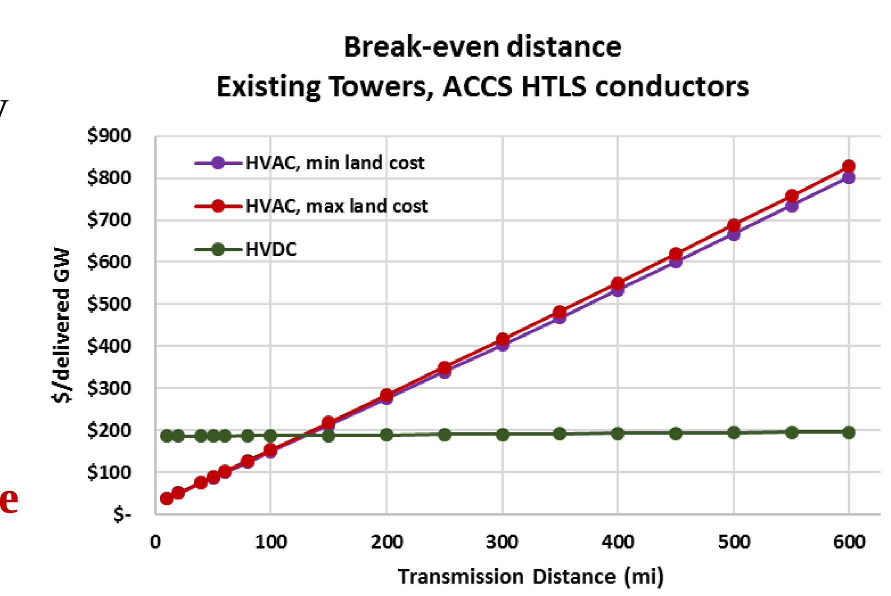
New Towers, ACSR conductors

Given the additional weight constraints, new towers may need to be constructed. The cost of towers is based on the WECC report of costs/mi of new AC transmission. **DC conversion begins to look more attractive around transmission lengths of <250 miles.**



Existing Towers, HTLS conductors

New tower construction may not be politically or socially feasible, or may take too long to construct. Another option is to use lighter weight conductors. Aluminum conductor composite core high tensile low sag lines (ACCS HTLS) are estimated 3.6X more expensive, but only 20% heavier. **DC conversion appear more economically attractive at transmission at <100 mi**



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Next Steps

Confirm assumptions and data sources in model:

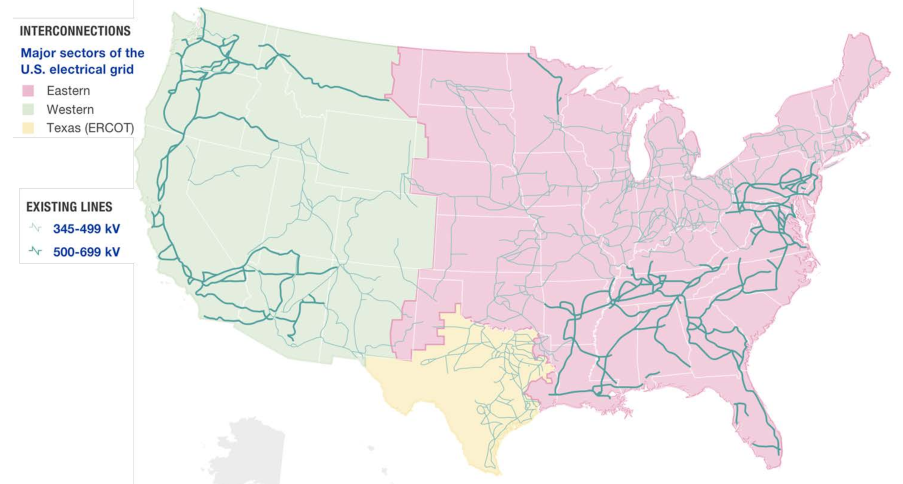
- Power losses per mile
- Conductor current and voltage reported ratings: max allowable or operational specs?
- Modifiability of towers: with insulator string lengths affecting height, and AC voltage affecting spacing, can 345 kV towers accommodate 500 kV AC?

Extend model as needed to maintain high level but incorporate relevant additional characteristics:

- Reactive power losses and non-unity power factor
- Converter station losses
- Tower modification cost estimates
- Converter station land requirements (up to 30 acres)
- Include 345 kV option with higher ampacity conductors

Identify corridors for detailed analysis:

- Where are existing constraints corridors that could benefit from a capacity upgrade? Or where is there potential for integration of significant intermittent power sources?
- What are the existing lines, age and performance?
- What are the existing tower designs and ratings?
- How would conversion change power flow and load balancing in the region?



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