Transmission Interface Limits for High-Spatial Resolution Capacity Expansion Modeling

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Motivation

- Capacity expansion models are typically modeled zonally to reduce computational burden. Accordingly, they rely on accurate approximation of interface transfer limits (ITLs) between zones.
- This project adapts an optimization-based method that incorporates network constraints (e.g., topology, line rating, voltage/stability limits). to develop county-level ITLs for use in the Regional Energy Deployment System (ReEDS).
- We test this method for a range of subnetwork sizes to evaluate how sensitive the ITL results are to size of the subnetwork.

Methods

- We adapt an optimization based ITL estimation method from Brown 2023 (http://arxiv.org/abs/2308.03612).
- We apply the method to U.S. transmission system data from North American Renewable Integration Study (NARIS), which after data cleaning includes ~56,000 buses and ~94,000 transmission lines.
- The subnetwork for estimating an ITL is selected by collecting all features within a certain number of "hops" (zones crossed) from the interface; we compare results for 2-, 4-, 6-, 8-, and 10-hops to understand how subnetwork affects the ITL estimates (Figure 1).

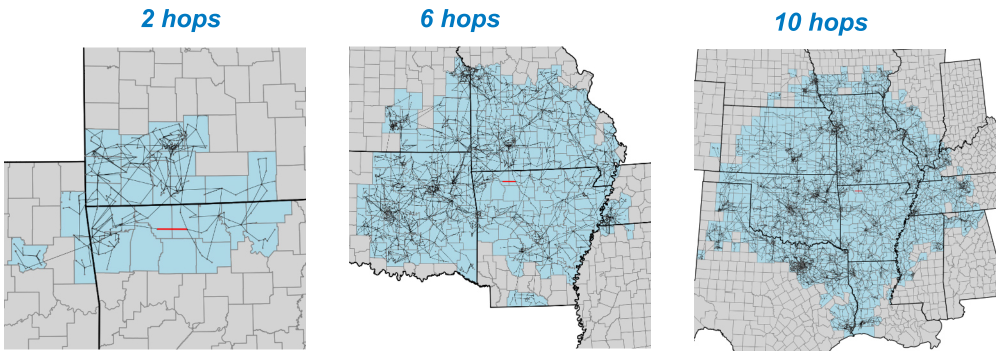

Figure 1. Example of network subsets containing all zones (in blue) with buses and lines that are 2, 6, and 10 hops away from the optimized interface (in red).

Summary of Transfer Limits by Hop

- Total transfer capacity saturates after six hops, with additional hops changing the total estimate by less than 0.1% (Figure 2).
- Many interfaces are more constrained in one direction because of network constraints, resulting in a gap in transfer capacity between the two directions.
- More hops provides better accuracy but at higher computation cost.
  - The 2-hop method performs relatively poorly (Table I).
  - Computation time increases exponentially with the number of hops (Table II).
  - 6-hops seems to be relatively good compromise, although the choice of hops for a given analysis might depend on the preference for accuracy vs. computational burden.
- Figure 3 depicts a visualization of the county-level ITLs for the U.S.

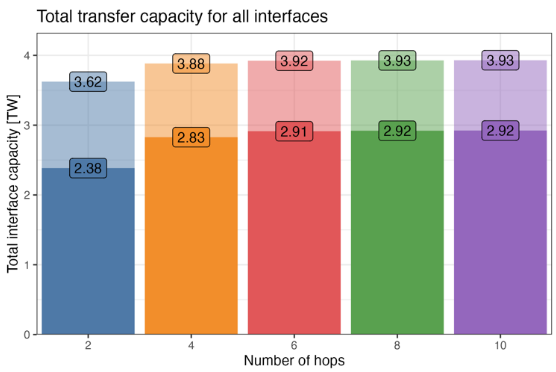

Figure 2. Total U.S. county-level transfer capacity in terawatts (TW) by number of hops. Upper bars indicate the totals when taking the higher value of the forward and reverse directions for each interface, and lower bars indicate the totals when using the lower value.

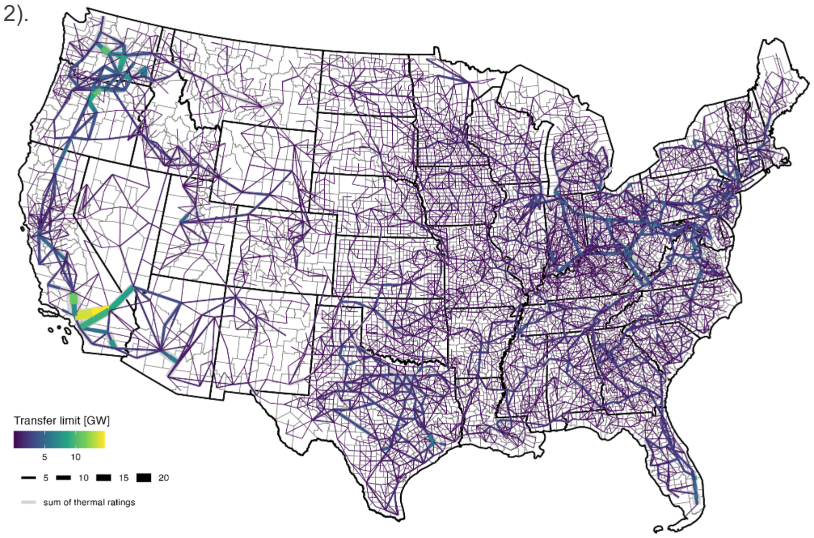

Figure 3. Map of county-level ITLs. Transfer limits are bidirectional, with the width and color of the bar starting in the midpoint of a county indicating its export capability to other counties. The gray lines indicate the sum of rated capacity for the interface. Results shown for the six-hops approach.

Hops	MAE (MW)	MBE (MW)	MAPE (%)	RMSE (MW)	P50 (%)
2	90.2	-60.3	72.6	272	15.8
4	20.7	-10.5	14.9	73.3	3.40
6	5.96	-1.10	7.95	19.8	1.16
8	1.89	-0.365	4.89	7.53	0.40

Table I. Summary of performance metrics relative to results using 10 hops.

Hops	Interface solve time (seconds)			Total time (hours)
	Mean	*P90*	*Max*	--
2	29	48	106	114
4	61	113	318	238
6	195	390	1024	766
8	521	1062	3603	2045
10	1205	2633	7049	4731

Table II. ITL computation time by hop.

Conclusions

- We apply an ITL estimation method to develop county-level interface values for use in the ReEDS capacity expansion model.
- There is a tradeoff between computation time and accuracy when deciding the size of the subnetwork used for each ITL; this modeling suggests 6 hops provides a good balance between the two.
- Using this method, only a small handful of interfaces have transfer limits that equal the sum of rated capacity, indicating the value in using this method to derive more accurate values for modeling.
- The county-level ITLs are publicly available as part of the ReEDS model and will be used to inform county-level modeling for a range of power system planning studies.

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