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Study Committee C1

Power System Development and Economics

Paper 10226_2022

UNLOCKING THE QUEUE WITH GRID ENHANICNG TECHNOLOGIES A CASE STUDY OF THE SOUTHWEST POWER POOL

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Motivation

- Transmission congestion causes out-of-merit dispatch and prevents least-cost and non-polluting resources from interconnecting to the grid. 9 GW of renewable energy resources (RE) in Kansas and Oklahoma have signed Interconnection Agreements but are stuck in the queue awaiting transmission upgrades.
- Grid-Enhancing Technologies (GETs) can reduce transmission congestion by enabling greater power flow over existing infrastructure. This study quantifies those impacts.

Method/Approach

- 24 representative historical power flow snapshots were modified to reflect transmission upgrades, generation retirements, etc. to model 2025 grid.
- Optimized the amount of RE (with 5% annual estimated curtailment as viability threshold) that could interconnect from the SPP queue with system-wide deployment of GETs.
- Calculated the production cost savings, local job creation, and other economic benefits derived from the increased transmission capacity being used by renewable energy.

Objects of investigation

- Feasible reduction in thermal unit generation was determined to accommodate additional RE.
- Wind and solar were dispatched up to their max available output in each of the 24 cases by running Security Constrained Optimal Power Flow (SCOPF)
- SCOPF was run iteratively and RE projects with high curtailment were gradually removed.
- The maximum transmission capacity impacts of GETs were calculated by applying Dynamic Line Ratings, then Topology Optimization, then Advanced Power Flow Control and then looking for further opportunities for the first two technologies.

Experimental setup & test results

- Model used SPP's grid, representative historical power flow snapshots and generation interconnection queue to evaluate the impact of Dynamic Line Ratings, Topology Optimization and Advanced Power Flow Control (in this order)

Discussion

- Results showed that GETs enabled an additional 2,670 MW or 8,776 GWh of RE over a base case of planned and projected changes.
- The annual production cost savings ($175m) were almost twice the installation cost of GETs ($90m).
- Assuming RE replace combined-cycle gas plants, the increase in RE generation would avert 3 million tons of carbon emissions annually.
- Projects enabled by GETs would contribute $15 million/year in local land lease revenue and $32 million/year in local tax revenue
- Projects would create 11,300 short term jobs and 660 long-term jobs

Conclusion

- **GETs increase transfer capacity of existing infrastructure:** Kansas and Oklahoma have twice as much capacity to integrate new RE if GETs are deployed.
- **GETs costs are miniscule:** the average capital cost for interconnecting onshore wind generators is $1,500/kW. The GETs in this study cost $34/kW, which equates to a 2% cost premium.
- **GETs create broad local benefits:** modeled deployments reduced emissions, increased tax and land-lease revenue, and created thousands of jobs.
- **GETs applications are manageable for grid operations:** the number of deployments were not a concern by SPP staff

Capacity for Additional Renewable Energy (MW) in Oklahoma and Kansas

State	Base Case			With GETs Case			Delta (GETs - Base)		
	Wind	Solar	Total	Wind	Solar	Total	Wind	Solar	Total
Kansas	1,710	0	1,710	1,910	0	1,910	200	0	200
Oklahoma	770	100	870	3,200	140	3,340	2,430	40	2,470
Total	2,480	100	2,580	5,110	140	5,250	2,630	40	2,670

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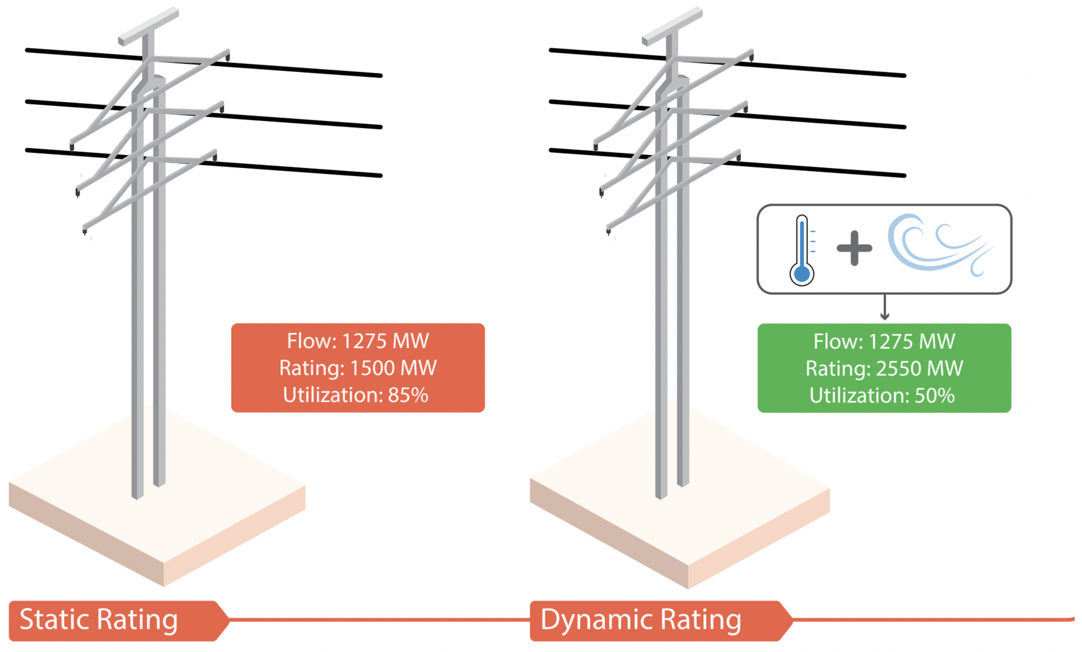
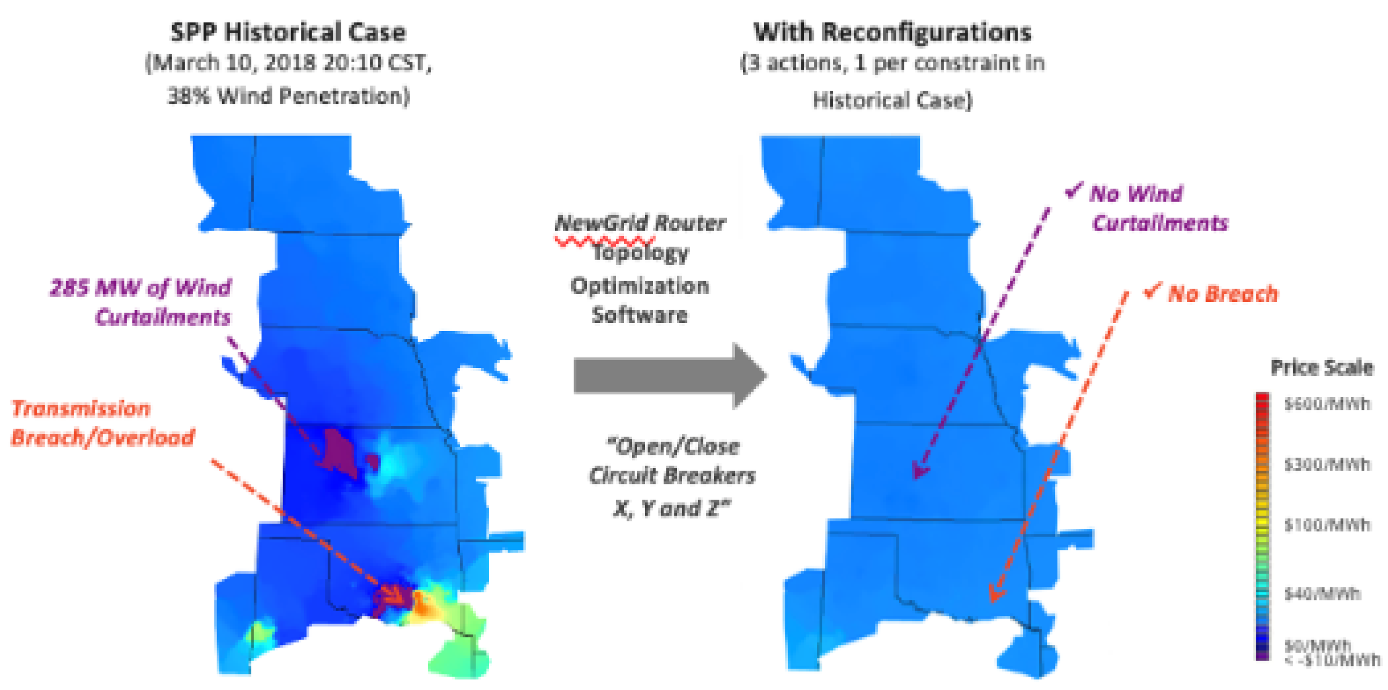
Dynamic Line Ratings

- Line ratings calculated based on measured or forecasted ambient conditions, often finding capacity 40% higher than static line ratings.



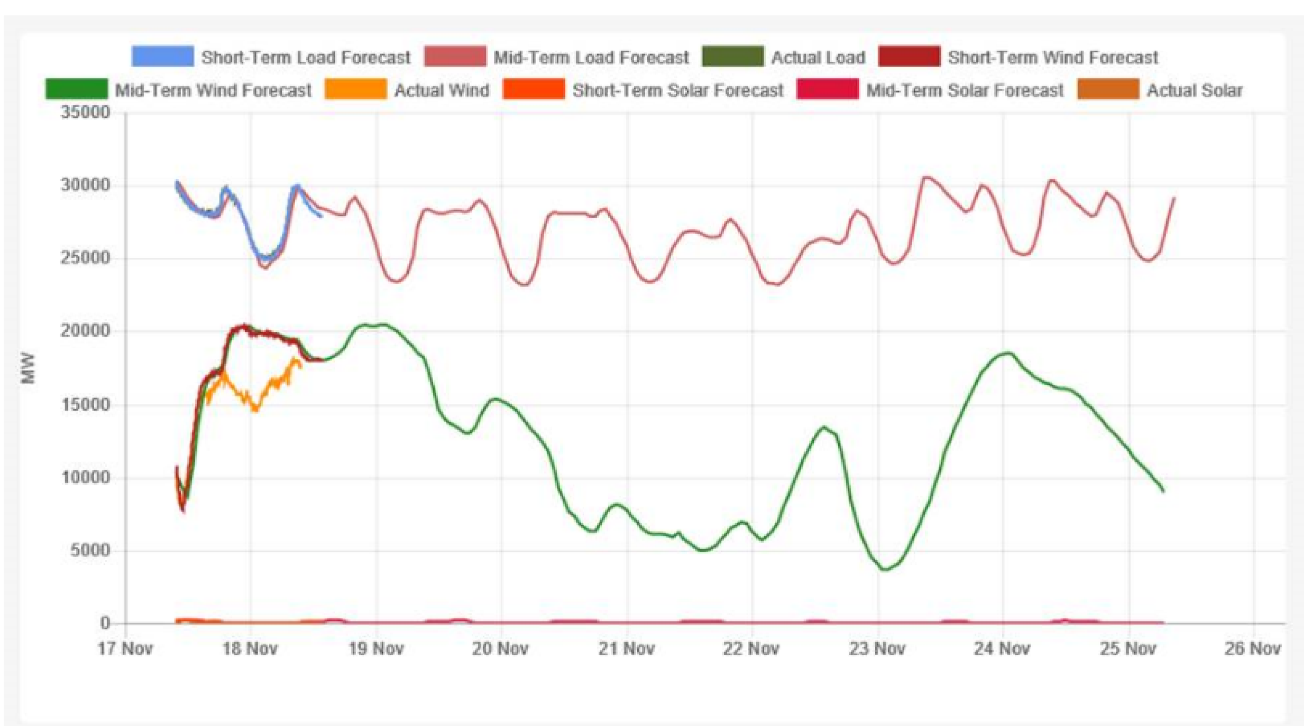
Topology Optimization

- Software **calculates** optimal power flow achieved by grid reconfigurations: switching circuit breakers open or close.



Transmission congestion is already hampering RE production and economics

- SPP Operations data below show wind curtailment in the light orange line - transmission shadow prices indicate that this was due to transmission congestion.
- Transmission congestion costs in the United States exceed $6-8 billion per year and are increasing.



Advanced Power Flow Control

- Flexible Alternative Current Transmission Systems devices change circuit impedance to control power flow.

Why GETs belong on the grid

- Dynamic Line Ratings, Topology Optimization and Advanced Power Flow Control create operational improvements that enhance the utilization of grid assets.
- GETs can be deployed much faster than traditional grid upgrades to achieve significant increases in transmission capacity within months.
- GETs will not add significant complexity to operations, and their deployment will increase situational awareness and enable the grid to be used as a dynamic asset, rather than a fixed one.

GETs utilized in this study

- Technologies included in this study are commercially available and deployed around the world. US utilities have piloted the technologies, but regulatory reforms will enable their full integration in electricity system, and further changes may be needed to incentivize their use.
- **Hardware Solutions**: DLR on 56 lines and Advanced Power Flow Control on 8 locations.

Hardware Solutions by Voltage Level	345	230	161	138	115	69	Total
DLR*	10	3	11	22	3	7	56
Advanced Power Flow Control	3	0	4	1	0	0	8

- **Software Solutions**: 204 unique Topology Optimization reconfigurations, average 13 per snapshot.

Software Solutions by Voltage Level	345	230	161	138	115	69	Total
Lines	20	10	31	75	4	30	170
Substations	4	0	1	1	0	0	6
Transformers (high voltage terminal)	10	1	4	13	0	0	28

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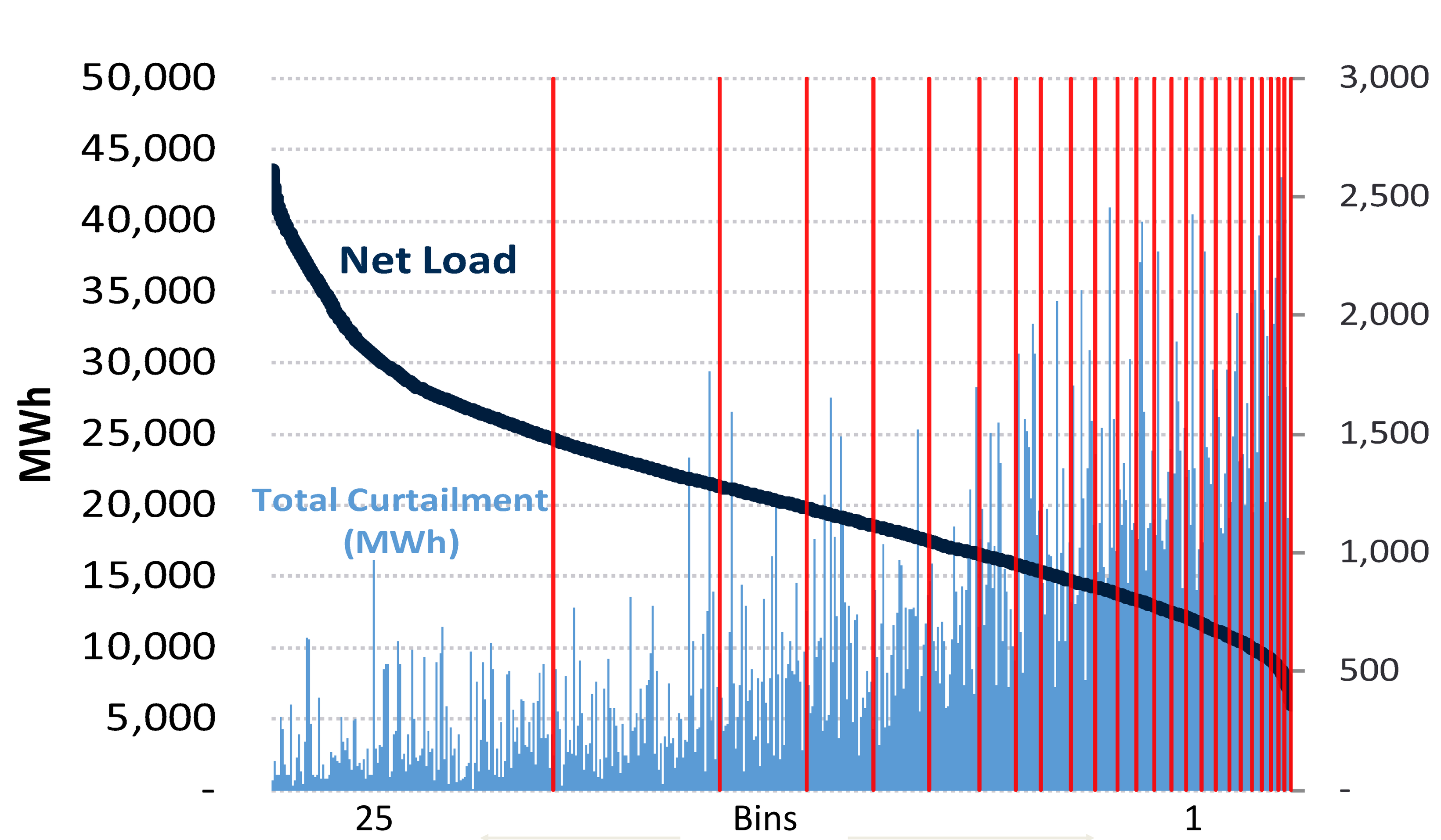
Study snapshot selection and modifications

- Hours sorted by decreasing net load, 25 bins selected to contain 1/25th of annual curtailment, then representative hour from 24 bins, and modified with expected retirements and upgrades.



- Conditions in year 2025 were modeled based on announced thermal generation additions and retirements, 73 planned transmission projects and upgrades from the SPP 2019 Integrated Transmission Planning Assessment Report, and load projections.

Maximizing renewables

- Model dispatched wind and solar up to maximum available output with SCOPF. Fossil units under 100 MW were shut down, and over 100 MW assumed min-gen of 30% max-capacity.
- Dispatch of existing wind and solar was prioritized over new wind and solar. Projects curtailed greater than 5% (annual estimate) were deemed nonviable.
- No redispatch of nuclear plants in SPP.
- Import and exports out of the region studied were held steady.
- GETs were deployed in sequence – Dynamic Line Ratings, Topology Optimization, then Advanced Power Flow Control, then revisiting the first two technologies for further deployments. The relative or optimal impacts of each individual technology were not studied, only the combined technologies were assessed.

Assessing Benefits

- GETs technology vendors provided installation and operating cost estimated values.
- Production cost and carbon reduction benefits were calculated using SPP market data.
- Economic impacts of renewable energy deployment were approximated from 21 public studies.
- Local benefits, which cover 3% of national load, were extrapolated to national benefits based on a linear factor of 30.
  - Over $5 billion in production cost savings (paying back initial investment in 6 mo.)
  - 90 million tons/year of carbon reductions
  - $1.5 billion in local tax and land lease revenue
  - Nearly 20,000 long term jobs
- The benefits of increased RE deployment, broken down below, are based on assumed capacity factors of 37.5% for wind and 18% for solar. Production cost savings are based on $20/MWh of avoided cost, and carbon reductions are based on averting 350g per kWh.

Annual GETs Benefits for Decarbonization		
Additional Generation	New Wind	8,640 GWh
	New Solar	60 GWh
	Total	8,700 GWh
Reduction in Curtailment from Existing Wind		76 GWh
Total Increase in Renewable Generation		8,776 GWh
Annual Production Costs Savings		$175 million
Annual Carbon Reduction		3 million tons