Reducing Contingency-based Windfarm Curtailments through use of Transmission Capacity Forecasting

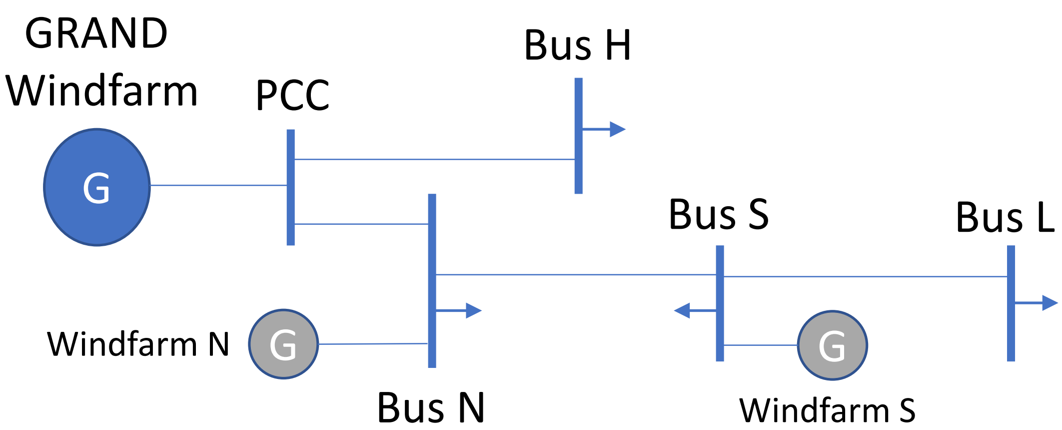
Doug Bowman
Southwest Power Pool

Jack McCall
Lindsey Manufacturing Co.

CIGRE US National Committee
2017 Grid of the Future Symposium
Cleveland, Ohio
October 23-25, 2017

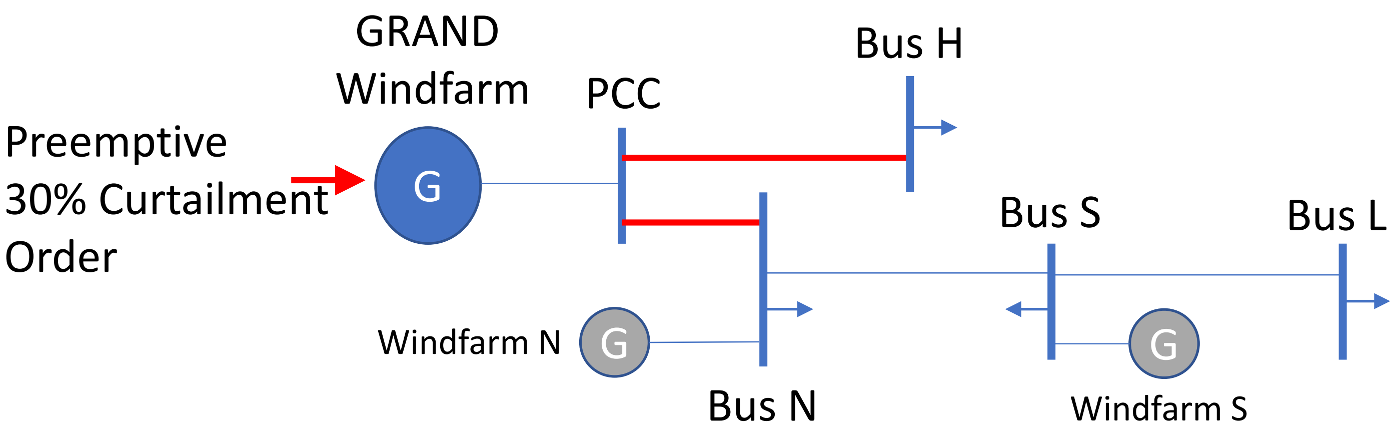
Background

- SPP is an RTO in the central US
- Within SPP is the 159.1 MW “Grand” windfarm
    - Output travels through 2 outlet transmission paths



The Need for Curtailment

- An SPP Wind Integration Study showed with normal conditions and N-1 limits, one or the other line would become overloaded.



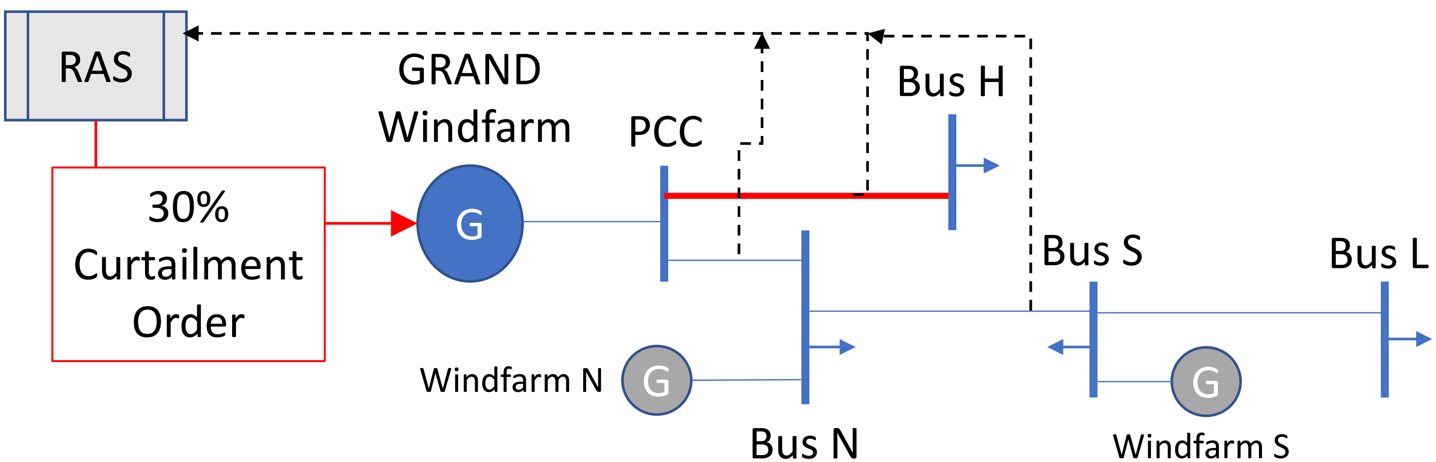
- To address these situations, up to 48.7 MW (~30%) of Grand's power production must be curtailed.

Initial Solution

- In the first three months after the curtailments were ordered, over 50,000MWh were curtailed.
  - Loss of over $1 million in revenue
  - Loss of over $1 million in production tax credits
- Grand's owner: this "hurts us, our off-taker and the market efficiency"
- Grand's owner requested SPP to implement a Remedial Action Scheme (RAS) be put in place to reduce the curtailments

Proposed Fast Reaction RAS Scheme

- Basic RAS Logic
  - Monitor the 3 at issue N-1 lines
  - For any line trip, the RAS would immediately trip CBs in Grand to curtail 49.7MW of generation capacity
  - SPP undertook detailed studies to ensure the proposed scheme would work, would have minimal likelihood of mis-operation and had no unintended consequences.



Approach Summary

- Both the Preemptive Order and the Reactive RAS did the same thing…
- Used curtailment as a means to address N-1 conditions caused by:
  - Fixed capacity line capacity ratings, during
  - Periods of high wind farm output, resulting from
  - Windy conditions

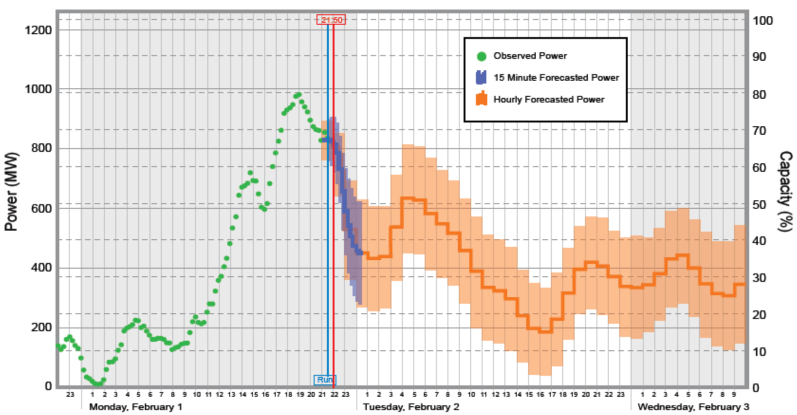
Approach Summary

- Both the Preemptive Order and the Reactive RAS did the same thing…
- Used curtailment as a means to address N-1 conditions caused by:
  - Fixed capacity line capacity ratings, during
  - Periods of high wind farm output, resulting from
  - Windy conditions

- *Is there another way that takes into account the fact that windy conditions also cool the transmission line conductors?*

FORECASTING

- Accurate models for load forecasting are essential to the operation of a utility
  - Next day loads can usually be predicted to within 1-3%



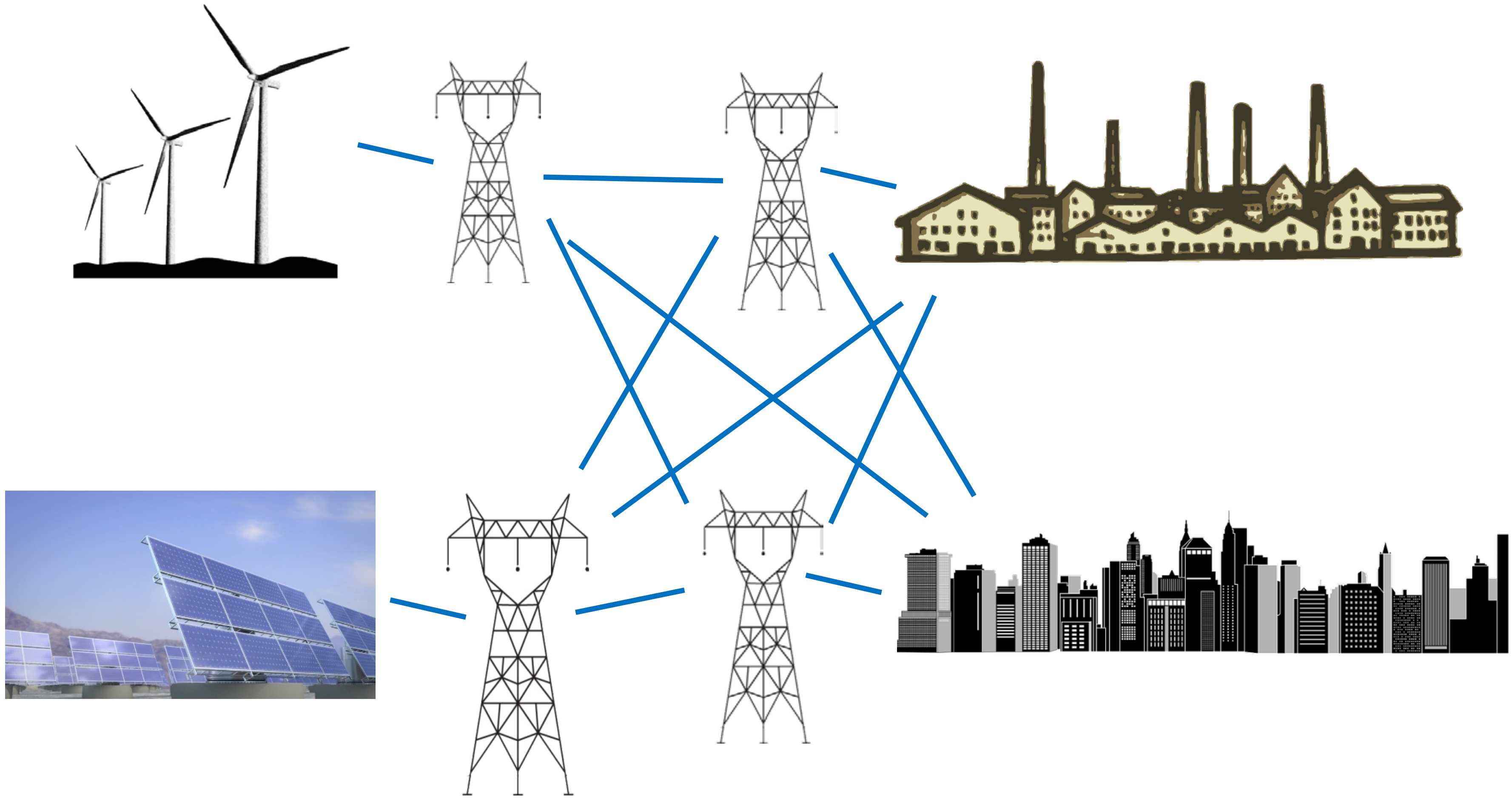
- Statistic-based numerical weather prediction (NWP) models utilize weather data to forecast wind energy day out output

SPP Southwest Power Pool

LINDSEY

We FORECAST these because they vary

We FORECAST these because they vary

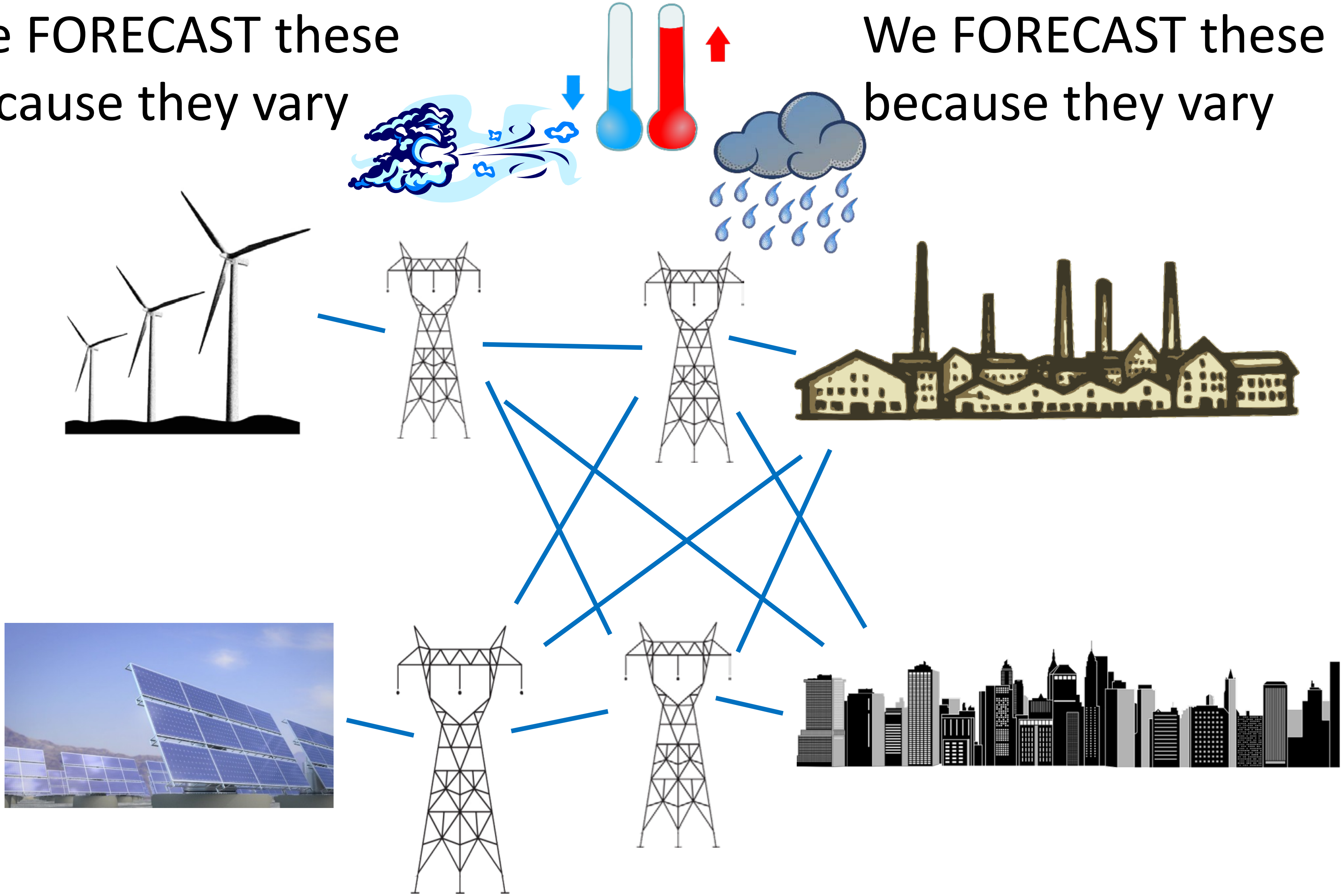


SPP Southwest Power Pool

LINDSEY

We FORECAST these because they vary

We FORECAST these because they vary

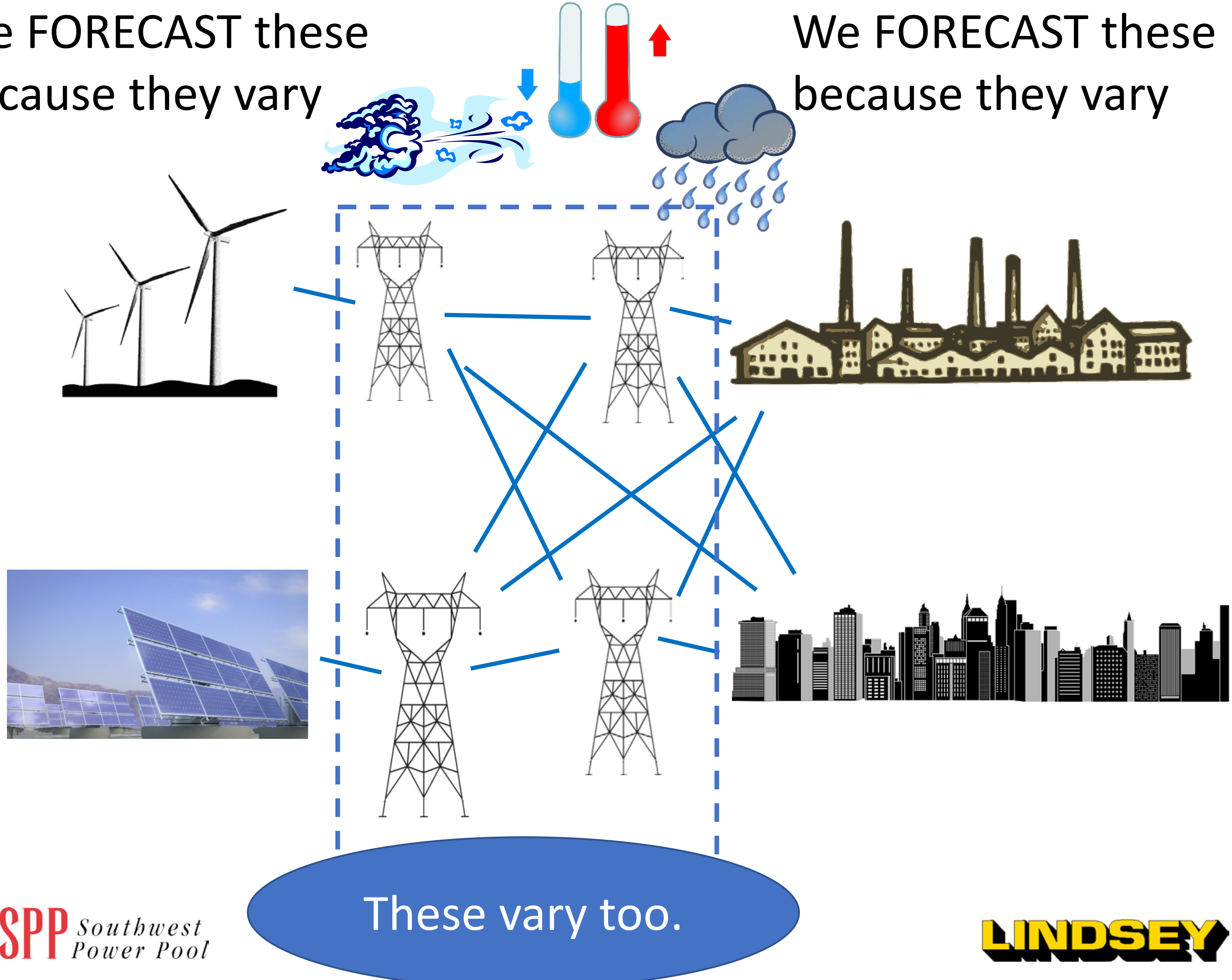


SPP Southwest Power Pool

LINDSEY

We FORECAST these because they vary

We FORECAST these because they vary



SPP Southwest Power Pool

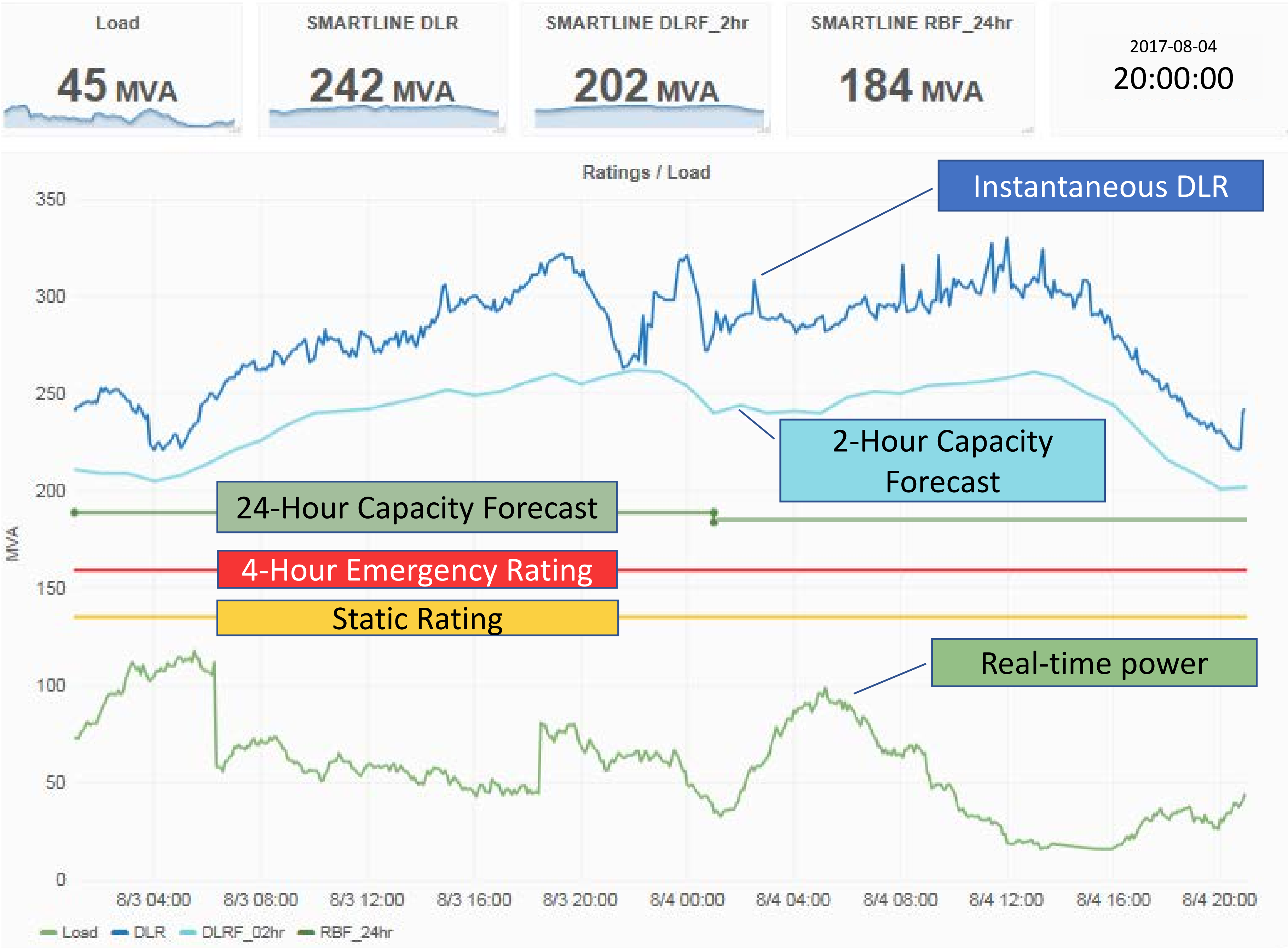
LINDSEY

Dynamic Line Rating

- Line ratings are based on environmental factors including wind speed and direction
- Static ratings use very conservative values for these environmental conditions
- Many utilities recognize this by using seasonally adjusted ratings.
  - The lines in question have separate Summer and Winter ratings.
- DLR techniques have revealed that based on real-time weather, significant additional line capacity exists most of the time
- BUT....this is *real-time*

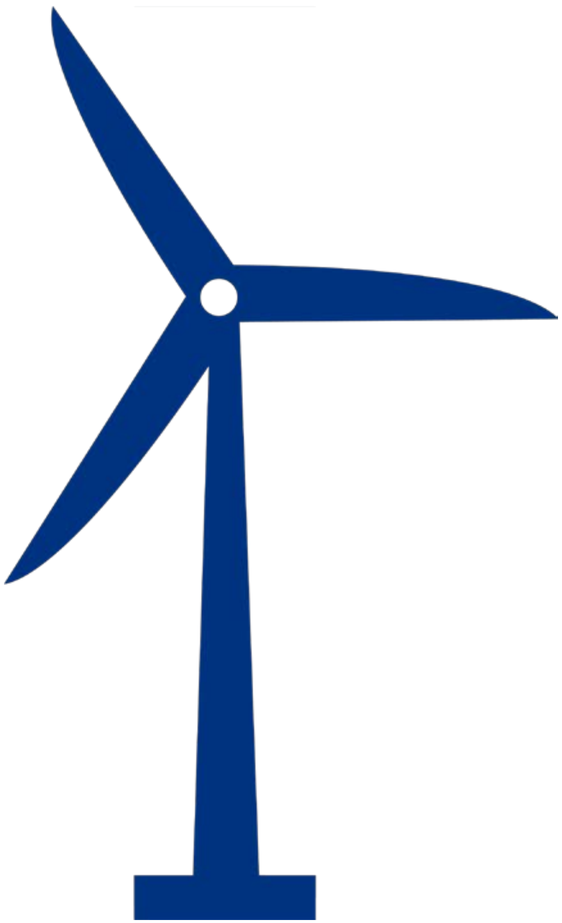
Transmission Capacity Forecasting

- Some next generation DLR systems also include transmission capacity forecasting (TCF) capability
- TCF uses:
  - Learned conductor behavior
  - Learned weather forecast to actual weather conditions
  - Advanced statistical engine to correlate the above
- The result are 2- to 48-hour transmission capacity forecasts with 98% confidence factors



Load
45 MVA
SMARTLINE DLR
242 MVA
SMARTLINE DLRF_2hr
202 MVA
SMARTLINE RBF_24hr
184 MVA
2017-08-04
20:00:00
Ratings / Load
Instantaneous DLR
2-Hour Capacity Forecast
24-Hour Capacity Forecast
4-Hour Emergency Rating
Static Rating
Real-time power
MVA
350
300
250
200
150
100
50
0
8/3 04:00
8/3 08:00
8/3 12:00
8/3 16:00
8/3 20:00
8/4 00:00
8/4 04:00
8/4 08:00
8/4 12:00
8/4 16:00
8/4 20:00
Load
DLR
DLRF_02hr
RBF_24hr

Is It Windy Enough for TCF to Work



- The worst case line needs 147.4% of Static to avoid any curtailment.
- 3.0 m/sec (6.7mph) ground wind speed delivers 150% of line static rating
- Ave Annual Wind Speed is 6.8 m/sec
- Lowest Monthly Ave Wind is 3.3m/sec
- Analysis shows 9.6 m/sec ground wind speed is needed to produce max wind farm output
- All lines are perpendicular to prevailing wind pattern, maximizing cooling effect

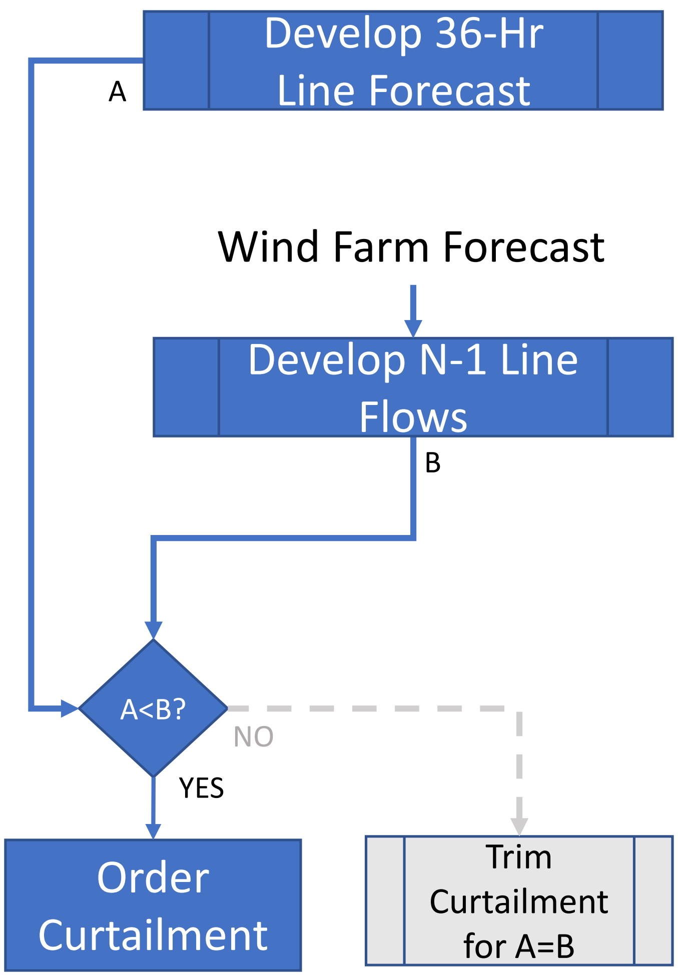
TCF with Pre-Emptive Curtailment

A. Develop 36-hour ahead forecast of line capacities
   - Provides for 24-hour day ahead operation
   - Additional 12 hours for market setting and clearing activities

B. Take day ahead forecasted wind farm output to forecast flows on lines of concern during N-1

C. If A<B, then order pre-emptive curtailment

D. Alternatively, order a lower level curtailment to match A and B



SPP Southwest Power Pool

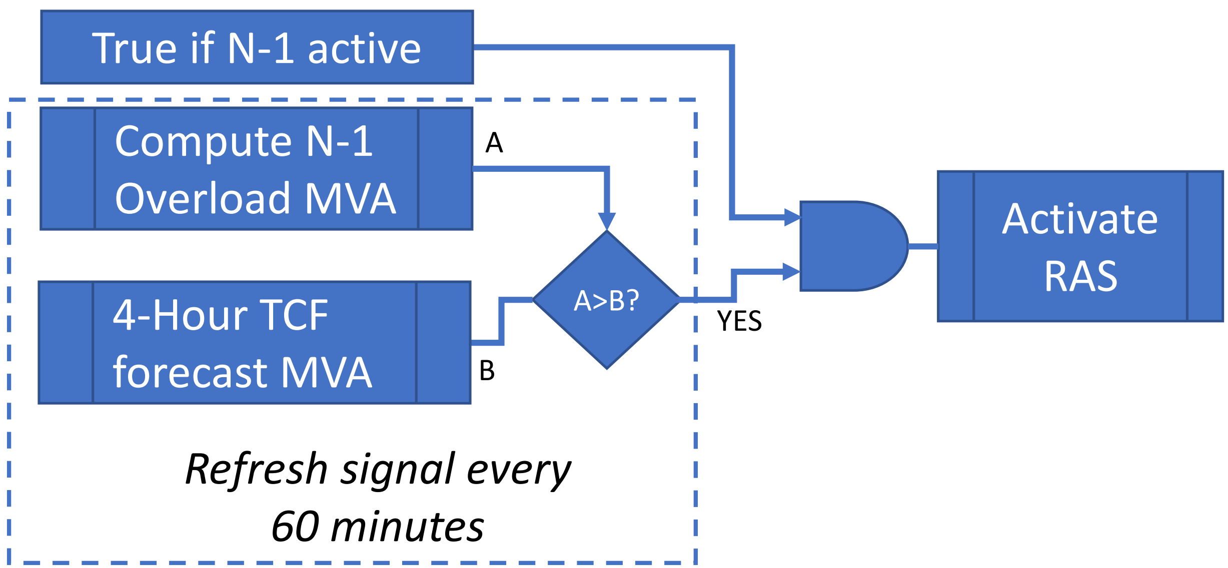
LINDSEY

TCF with RAS Reactive Curtailment

Recall the RAS was to curtail within cycles of line trip

A. Develop 4-hour ahead forecast of line capacities
B. Take day ahead forecasted wind farm output to forecast flows on lines of concern during N-1

- If A>B, then INHIBIT curtailment IF an N-1 event occurs
- Refresh signals periodically to continue to inhibit or allow curtailment to be issued.

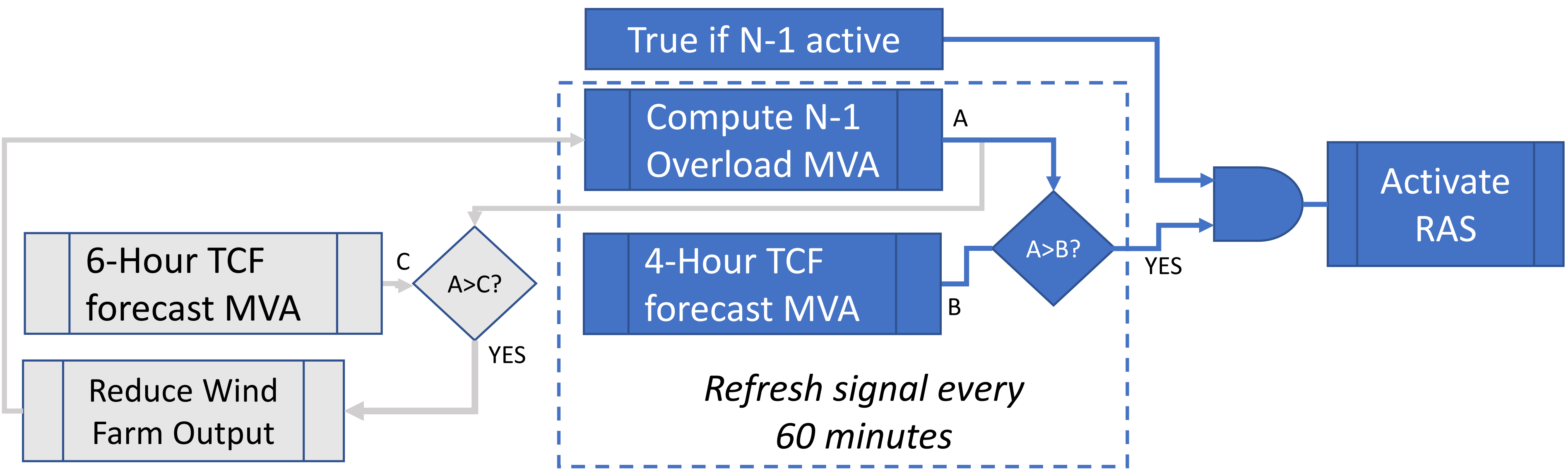


Enhancing RAS Curtailment with TCF

Recall the RAS was to curtail within cycles of line trip.

C. Develop <u>6-hour</u> ahead forecast of line capacities

- Check if A is close to the forecast flows on lines of concern during N-1
- If A≅B, then pre-emptively reduce wind farm output so that A>B to avoid initiating the instantaneous RAS curtailment in the event of a N-1 event



Who Pays | Who Benefits

Who Pays	Financial Benefit	Operational Benefit	Notes
TO	• If NITS, None • If not, transmission revenue	Enhancement to asset capabilities	Possible addition to rate base
RTO	None; Not able to pay	• Great situational awareness • More flexibility in power export • Less congestion	Must socialize cost if orders installation
WF	• Energy sales • PTC	Less wear and tear on equipment due to curtailment	Must negotiate with TO to install and operate to forecasted levels

SPP Southwest Power Pool

LINDSEY

Summary

- TCF systems can effectively address transmission constraints that result in curtailment of wind farm output
  - Can supplant and/or enhance traditional curtailment methods
- Allocating costs of deploying and integrating TCF systems is not well defined
- TCF systems, once installed, provide additional operation benefits to TOs and RTOs