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CAT-1™

Real Time Rating System

for Overhead Transmission Line

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Objective of Real Time Monitoring

Determine and Harness

Existing, Un-tapped Transmission Capacity

with

Deterministic Safety

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The Product

- Tension-based Real Time Monitoring system for overhead transmission lines
- Tension resolves all environmental factors for accurate results
- Transmission owners can transmit up to **30% more power over 90% of the time**
- Provides **warning for potential overload**
- Communicates with utility's Energy Management System

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Key Concepts

- **Weather conditions affect directly the capacity of an overhead transmission line to transmit power – its rating**
  - Wind speed and direction
  - Solar radiation
  - Ambient temperature

- **Static vs Dynamic Weather Condition in Determining Line Ratings**
  - Static: Assumes constant weather conditions, over an extended period of time, days, months or years
  - Dynamic: Takes into account changing weather conditions in real time and provides transmission capacity in real time.

- **Real Time vs Static Ratings**
  - Real Time Ratings provide the operator the actual capability of the overhead transmission lines to carry power at any moment in time while respecting design limits, such as conductor temperature.

Most overhead transmission lines in the nation are operated based on static assumptions

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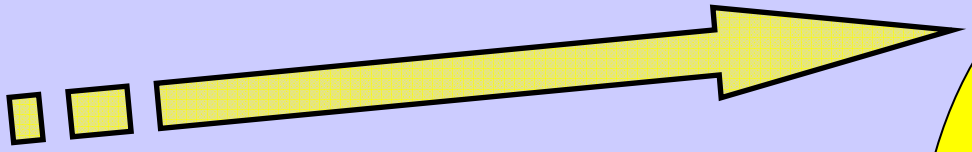
What is Critical in Determining Real Time Ratings

- **Solar Radiation and Ambient Temperature**
  - Do not vary spatially and in time that much
  - Their impact is not as significant as that of wind
- **Wind**
  - Varies spatially substantially and randomly
    - Its intensity (speed) can be very different 100 to 200 m away
    - Its direction can vary dramatically in space
  - …and also
  - Both speed and direction vary in time very rapidly and randomly



Wind speed and direction affect conductor temperature directly, substantially, and randomly, and directly affect its rating

Hence, local measurements of conductor temperature, unless multiple, are inaccurate, can be either too conservative or can be unsafe

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How Weather Conditions Affect Transmission Capacity

Typical Example

20 mile transmission line (795 ACSR) with a typical static thermal rating of **787 amps** at 40°C ambient, zero wind, and mid-day in the summer:

- **Ambient Temperature:**
  - 2°C fluctuation → +/- 2% capacity,
  - 10°C drop in ambient → + 11% capacity… 874 amps
- **Solar Radiation:**
  - Cloud shadowing → +/- a few percent,
  - Total eclipse → + 18% capacity… 929 amps
- **Wind increase 1 m/sec:**
  - 45° angle → + 35% capacity…. 1,060 amps
  - 90° angle → + 44% capacity

Releasing The Un-Harnessed Power of Today's Grid

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Variability of Wind Time & Space

- Wind patterns on a bay of Great Lake, Tasmania
- Five Minute Intervals
- 8:00 a.m. to 8:15 am March 1998

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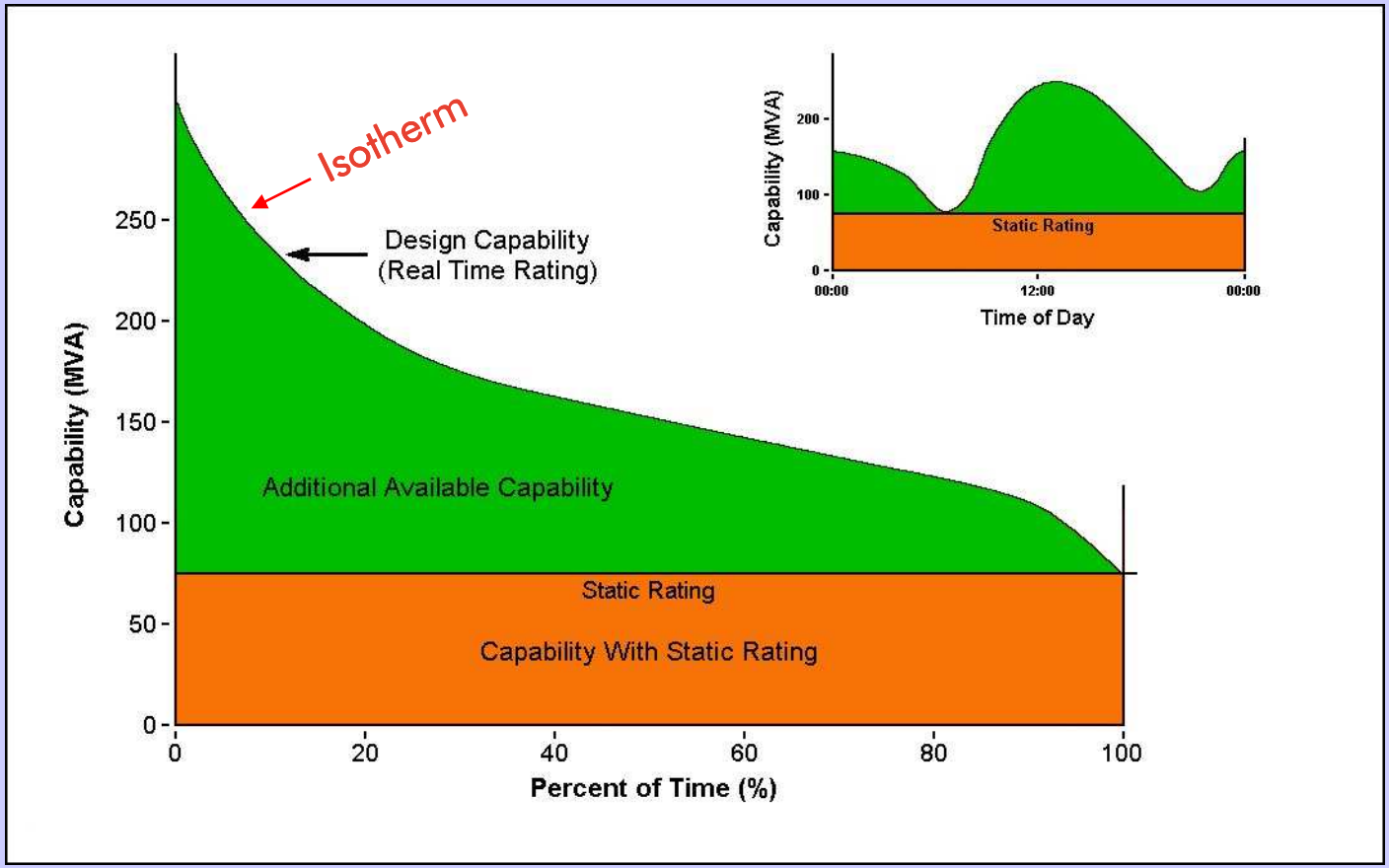
Transmission Line Capabilities
No Wind - High Ambient Temperature



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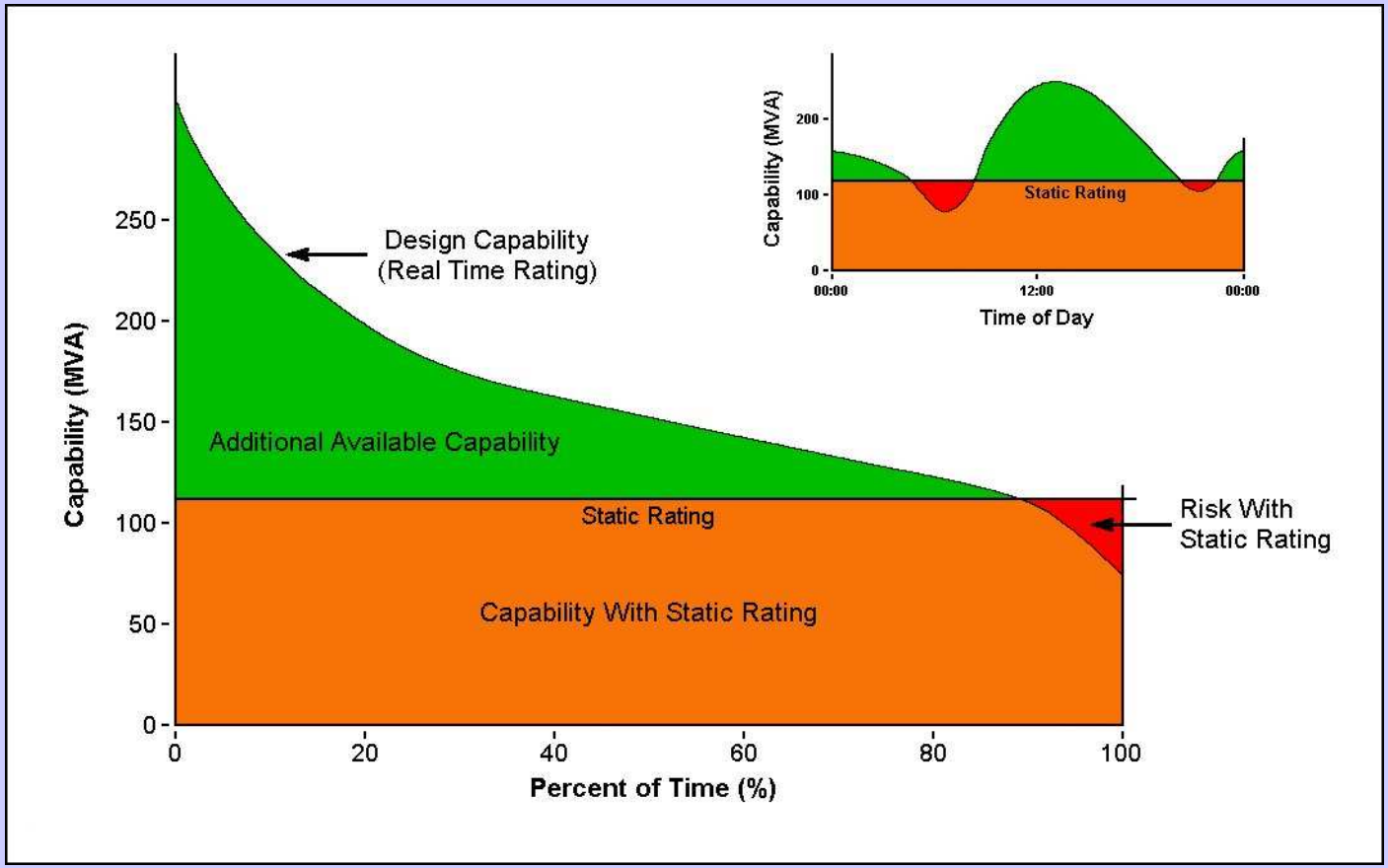
Transmission Line Capabilities Assumed Constant Wind



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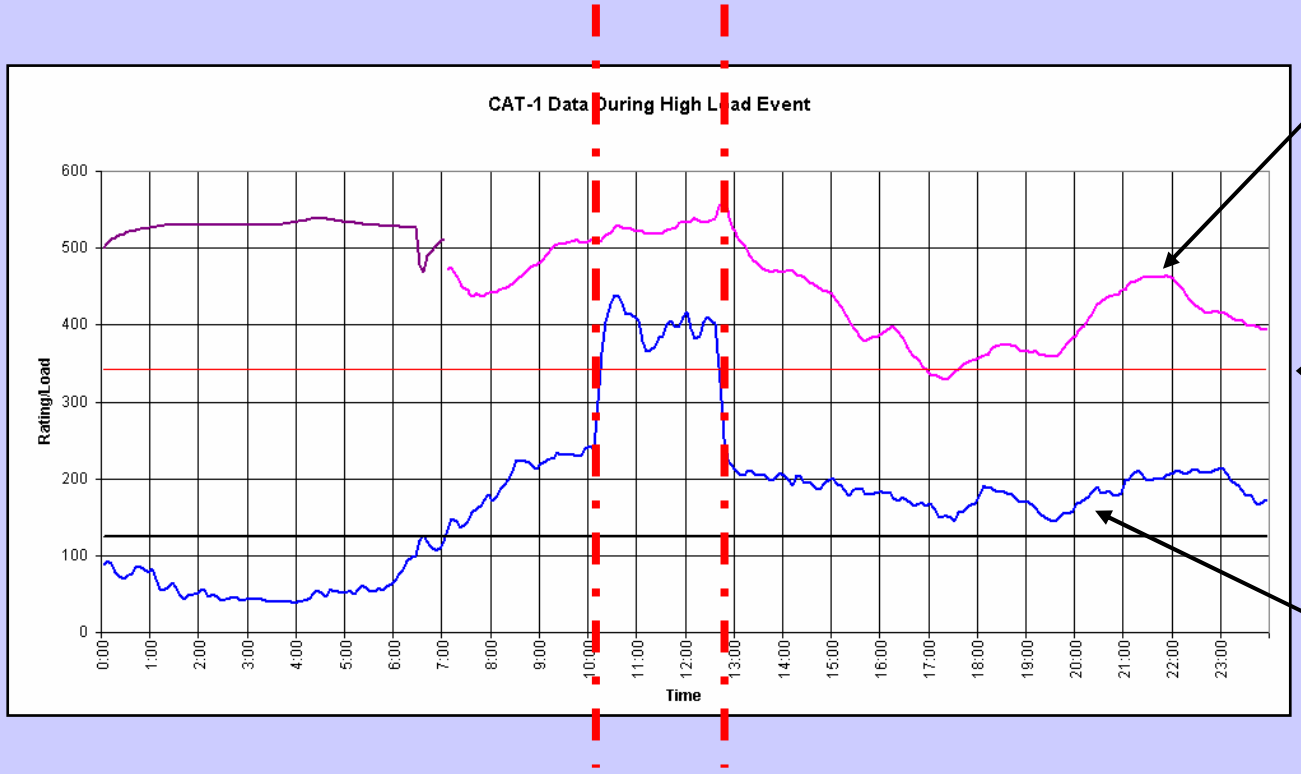
Real Time Ratings Effective Use
Example of safely managed contingency



- Line was operating within limits in accordance with NERC standards
- Without RTR, this event must be reported as a violation
- The operator would have been forced to move the grid off its optimum (most secure) dispatch

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Real Time Ratings in Operational Use

- Two Major Utilities
- Same Technology
- Different Applications

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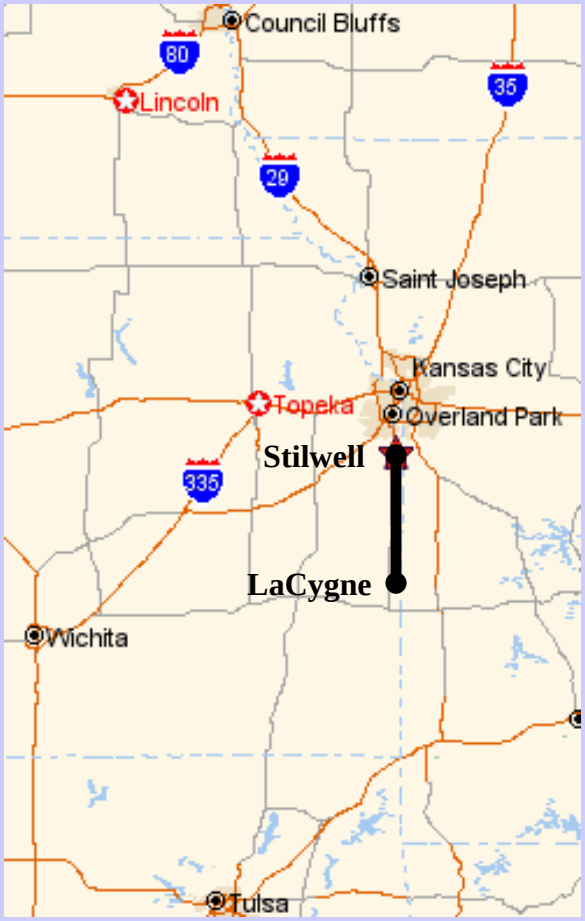
KCP&L – Congestion Relief
Actual Line Application

- LaCygne-Stilwell Flowgate in Southwest Power Pool
- 345KV, 32 miles
- 1251 MVA static rating
- 1 of top 5 bottlenecks on Central U.S. North-South power corridor
- Access to low cost power limited by the LaCygne-Stilwell flowgate
  - Summer – Lower cost power in North flows to South to meet cooling demand
  - Winter – Lower cost power in South flows to North to meet heating demand



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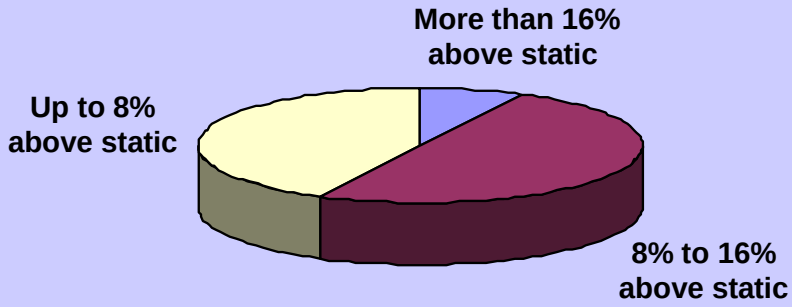
KCP&L – Congestion Relief Benefits

- Line was operated above static limit for **167 hours** late June to early September**:**



- KCPL avoided “a significant amount” of energy redispatch
- Calculated less than 3-month payback for total installed cost
  - Acquisition, installation and calibration
  - Engineering project management
  - Field verification of readings

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KCP&L – Congestion Relief Benefits

- Before installation of real time ratings
  - Firm and Non-firm power contracts were curtailed by the flowgate's constraint
- After installation of real time ratings
  - No curtailment of firm power contracts; increased capacity for non-firm contracts
  - Least cost power delivered to consumers

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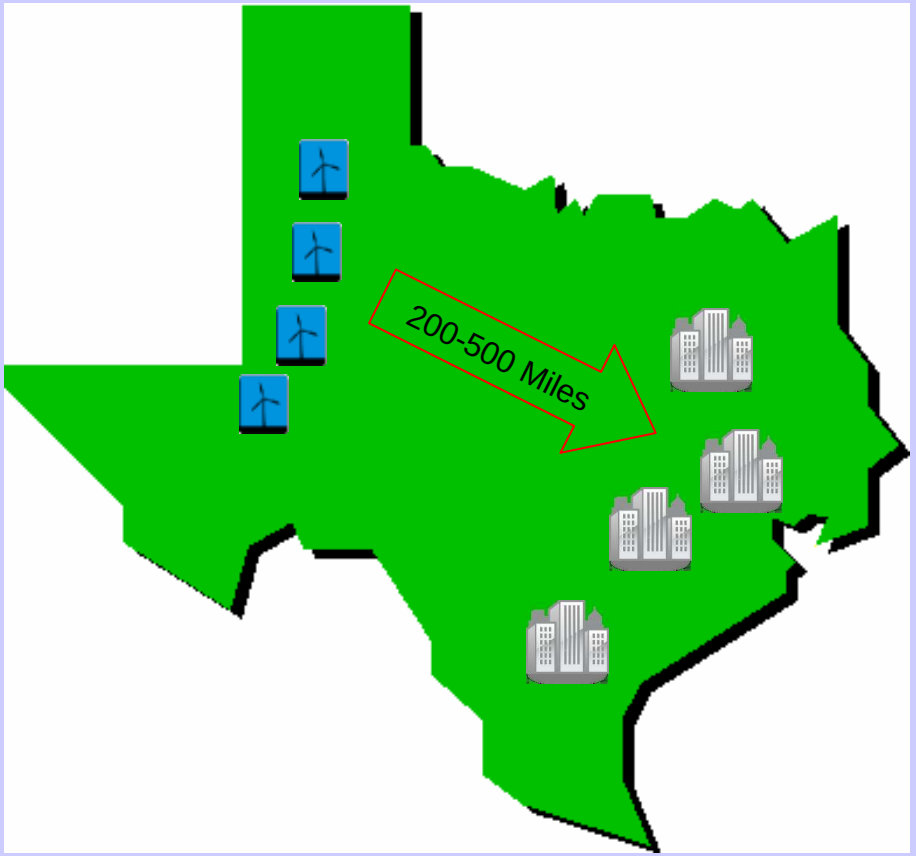
AEP West – Wind Farm Integration
Actual Line Application

- The best wind is located far from load centers.
- Existing transmission capacity is modest in the vicinity of wind farms, and limits the amount of wind power that can be delivered to load centers.
- Wind farms are being added faster than transmission lines can be built.
- New transmission capacity is planned, but will take years to build.



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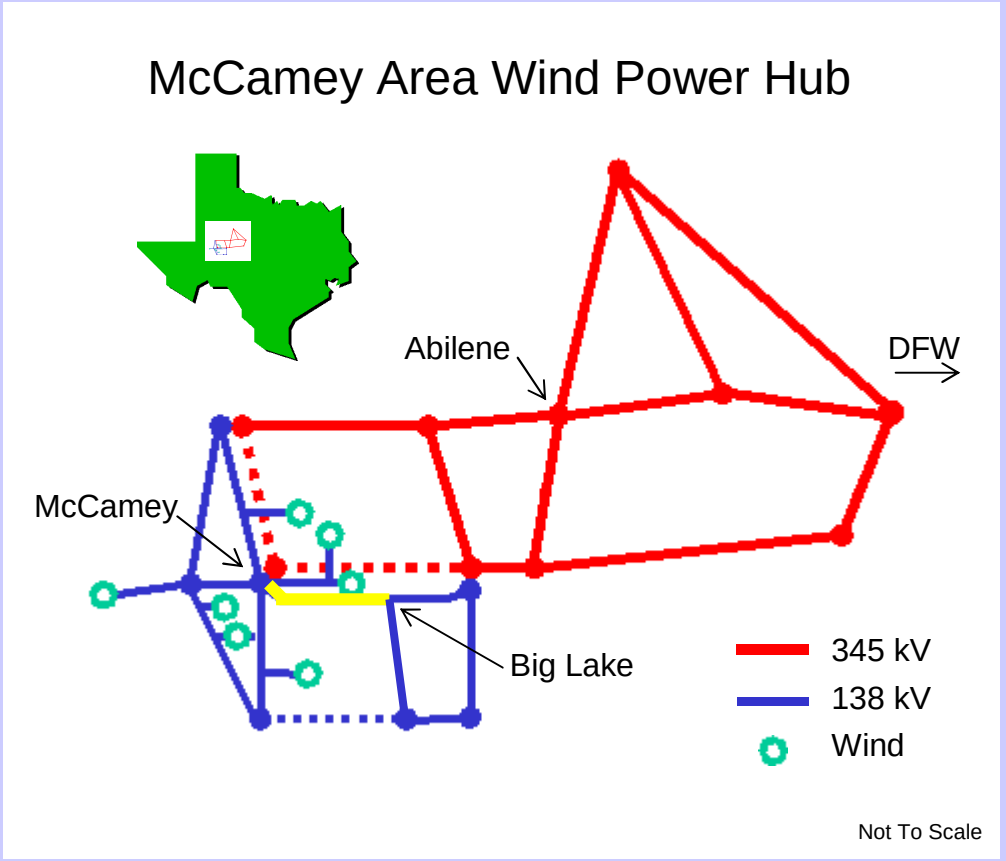
AEP West – Wind Farm Integration
Actual Line Application

- The power output of several wind farms is concentrated at the McCamey transmission hub.
- The amount of wind power that can be delivered to load centers in East Texas is limited by the rating of the 138 kV transmission line from McCamey to Big Lake.



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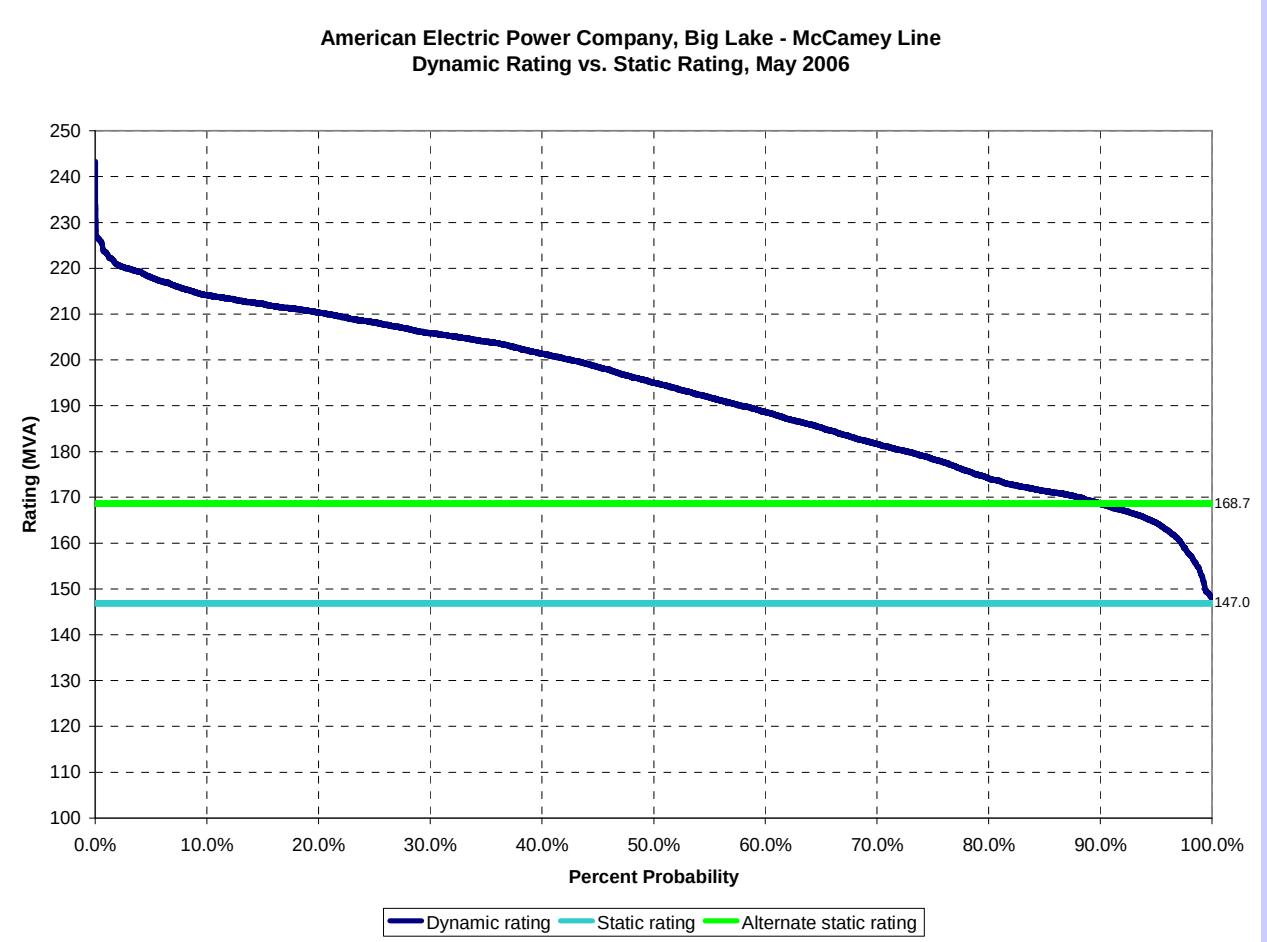
AEP West – Wind Farm Integration Benefits



15%

Real time ratings on the McCamey-Big Lake line deliver a minimum of 10-15% above static rating when needed to accommodate wind power.

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AEP West – Wind Farm Integration Benefits

- Real time ratings enabled an immediate 10-15% (minimum) increase in the delivery of wind power over existing transmission assets.
  - More renewable energy to market, faster, and at lower cost.
  - Maximized use of existing transmission assets.
- Real time ratings deferred a physical line upgrade estimated at $20M
  - The line upgrade would be of no use when planned new transmission lines were completed. A stranded asset was avoided.

6.3.2 Dynamic Rating of Assets

BACKGROUND: Dynamic circuit rating (DCR) refers to the utilization of real-time information to develop accurate ratings of lines, cables and substation components to either increase circuit ratings above design ratings or to maintain transfer capacities at safe levels. In the absence of monitoring, circuit ratings are established in a conservative fashion wherein the most unfavourable conditions are assumed. With dynamic rating, it is possible to increase the thermal capacity of transmission assets such as lines and transformers, based on actual conditions (for example, conductor temperature, loading history, wind speed). In some cases, power flows may be increased by 10-20% (for example, recent up-rating of Vancouver Island 500kV submarine cables). DCR challenges include: reliably determining the conditions that affect asset ratings; cost and complexity of incorporating dynamic rating in operations; limitations in modeling dynamic behaviour to predict circuit ratings into the future; the need to consider the ratings of all components in a circuit to ensure that the "weakest link" is considered; and determination of limiting factor at each instant (thermal, transient stability, voltage stability).

PURPOSE:

(1) Increase power flow over existing static rating
(2) Defer or eliminate the need for more expensive capital expenditures by obtaining greater capacity from existing assets
(3) Integrate independent power producers without costly equipment upgrades
(4) Avoid damage to system components and extend asset life
(5) Identify system constraints as a focus for potential upgrades

ACTIONS:

0 years	5 years	10 years	20 years
Co-fund EPRI, CEATI, PSERC and university research on DCR technologies			
Work with manufacturers on development, demonstration and installation of DCR technologies. Goal: low cost, wide deployment			
Indian Arm 230kV Crossing demonstration of available DCR technologies for thermally limited lines	Implementation in thermally limited lines		
Transformer dynamic thermal rating pilot demonstration (3 sites)	Implementation in transformers approaching maximum		
Develop dynamic models for predictive rating of submarine cables with complex cooling systems	Implementation of "look-ahead" rating system for VI 550kV cable circuits		
Refine dynamic models for predictive rating of subterranean cable circuits	Implementation of "look-ahead" rating system for metro Vancouver and Victoria subterranean cables		
Develop effective control centre operator displays for dynamic ratings			
Develop telecommunications technologies / architecture for remote monitoring of DCR devices			
		Grid automation and optimization using DCR technologies	

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Conclusions

Real Time Ratings allowed both utilities to deliver tangible benefits to electric consumers:

- **Increased access to lower cost/renewable energy**
  - At a fraction of the cost of new line construction
  - In a fraction of the time needed for new line construction
- **Provided a platform to improve grid reliability**
- **Optimized utilization of existing assets**
  - Avoided capital expenditures that would soon become obsolete
  - Extracted full capacity of existing facilities providing a bridge to the construction of new facilities
- **Knowing capacity in real time helps transform overhead transmission from a static asset to a dynamic/smart one, exploring its full design potential**
- **Fast payback**