Dynamic Line Ratings
for a
Reliable and Optimized Smart Transmission

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- U.S. Department of Energy
  - "Smart Grid System Report", July 2009
    - One of eight Smart Grid Metrics for T&D Infrastructure
    - Nascent Penetration / Maturity
    - "The deployment of dynamic line rating technology is also expected to increase asset utilization and operating efficiency…"
    - "For example, optimized capacity can be attainable with dynamic ratings, which allow assets to be used at greater loads by continuously sensing and rating their capacities."
- Federal Energy Regulatory Commission
  - "Smart Grid Policy"
    - Wind Integration
    - Wide Area Situational Awareness (WASA)
    - "…knowing current state of available resources…and transmission capabilities"

Excerpt from NERC Smart Grid Task Force Report (December 2010)

Integration of Smart Grid Technology into the Bulk Power System

The smart grid integration enables the coordinated and system-wide ability to deploy automation and smart technologies on the bulk power system. Unlike today, where islands of automation are created without the ability to interoperate across their boundaries, smart grid provides the ability to create an overarching, coordinated and hierarchical approach to automation, control and effectiveness. The goal for these deployments has been to better match energy supply with demand, improving asset management and increasing reliability.

Current deployments of smart grid technologies serves as an important example of how new technologies are gradually diffused within the power industry. These technologies have been localized in their implementation for some time at substations (in the form of SCADA, or supervisory control, intelligent electronic devices (IED) and data acquisition) and, more recently, directly on the bulk transmission system. Some examples of this include automated reconfiguration capabilities, Dynamic Thermal Circuit Rating (DTCR), phasor measurement units (PMUs), and Flexible AC Transmission Systems (FACTS).

- Basics of Dynamic Line Ratings (DLR)
- Contingency Management
- Economic Dispatch
- Reliability
- Wind Integration
- Ice Monitoring

- Utility Case Studies

How Weather Conditions Affect Line Ratings

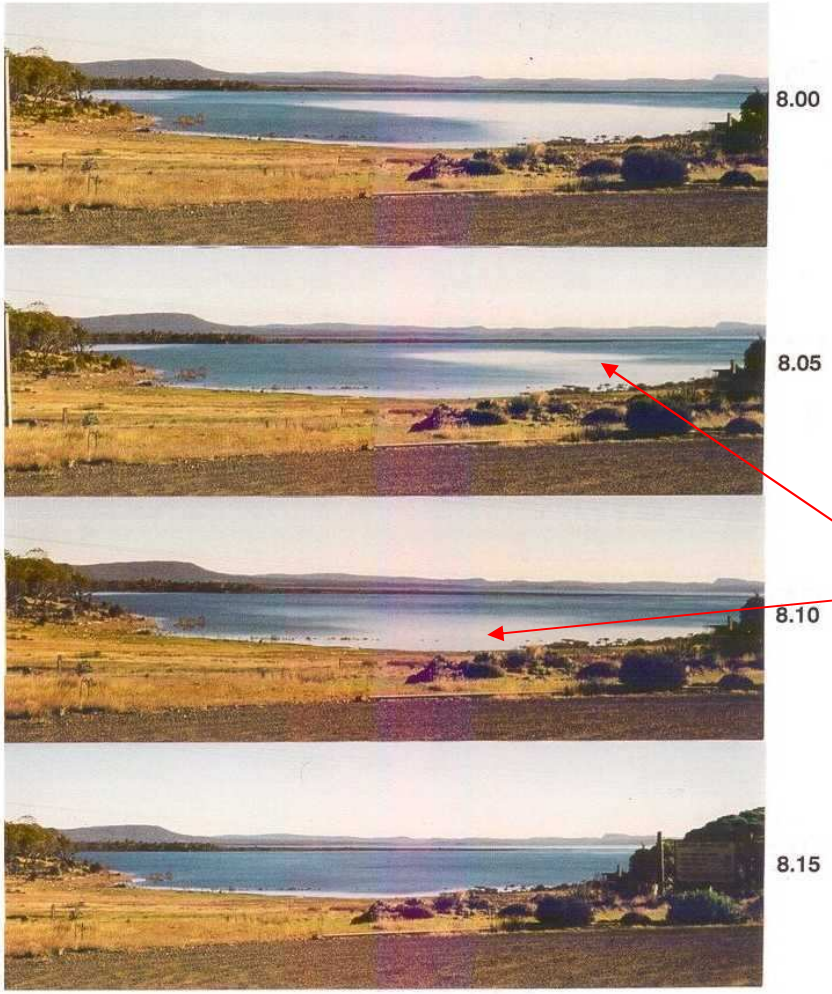
Relative Impact of Ambient Conditions on Line Ratings

20 mile transmission line (795 ACSR) with a static thermal rating of 787 amps **at 40^{0}C ambient, zero wind, and mid-day summer**

Ambient Temperature:			
2^{0}C fluctuation	→	**+/-2% capacity**	
10^{0}C drop in ambient	→	**+ 11% capacity…**	**874 amps**
Solar Radiation:			
Cloud shadowing	→	**+/- a few percent**	
Middle of night	→	**+ 18% capacity…**	**929 amps**
Wind increase 1m/sec:			
45^0 angle	→	**+ 35% capacity…**	1,060 amps
90^0 angle	→	**+ 44% capacity**	

The Un-Harnessed Power of Dynamic Line Ratings

Variability of Wind Impact on Line Ratings

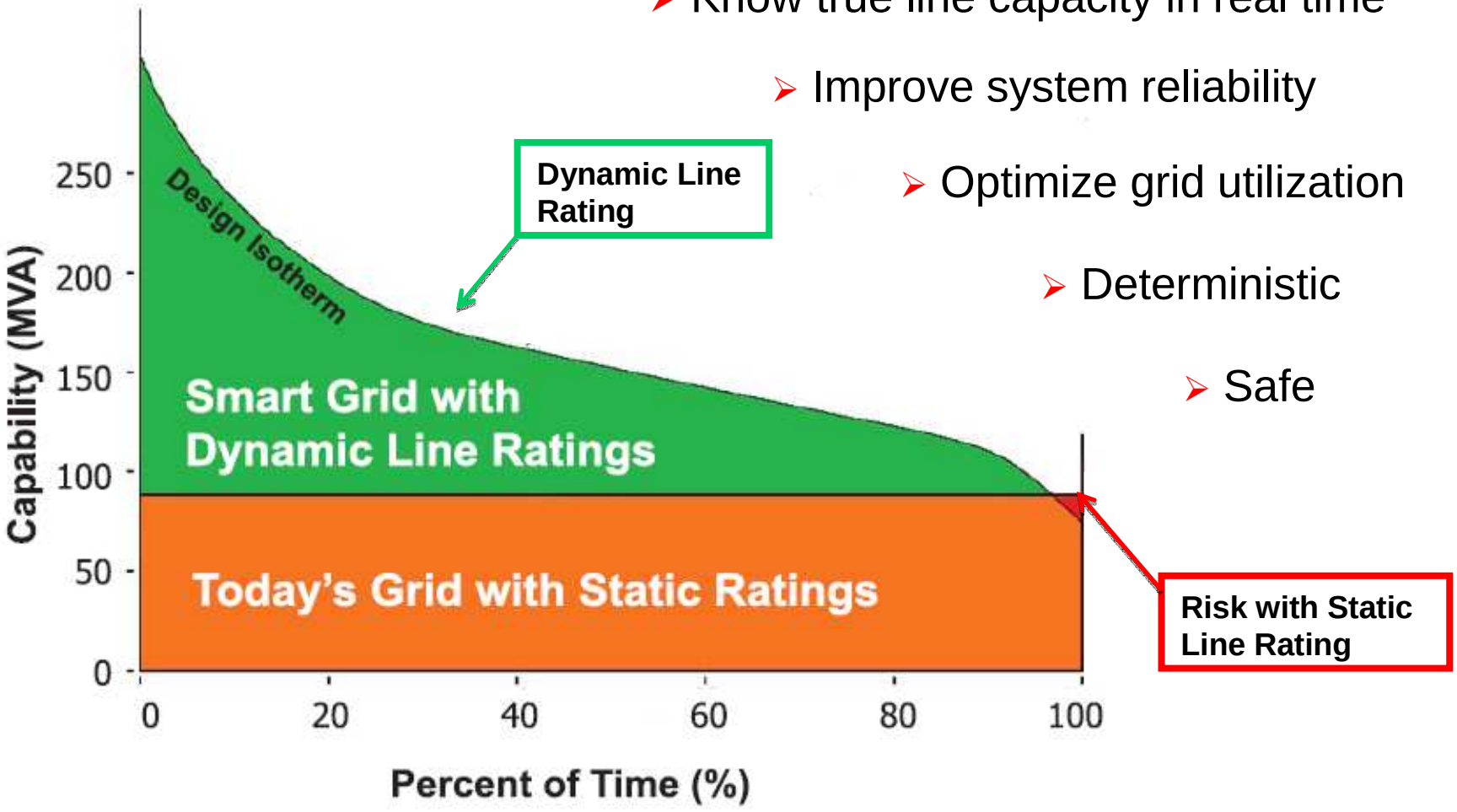


- Wind patterns on a bay of Great Lake, Tasmania
- Five Minute Intervals
- 8:00 a.m. to 8:15 am, 8 March 1998

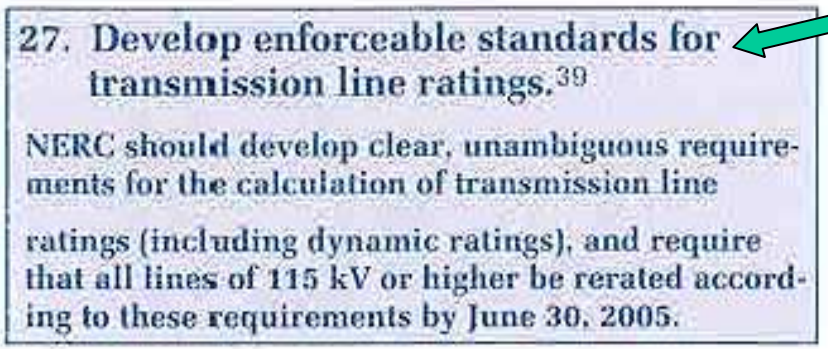
A transmission line across this lake would see different conditions along its length, in that 15 minute period, affecting its transmission transfer capacity

The Smart Grid and Dynamic Line Ratings

- Know true line capacity in real time
- Improve system reliability
- Optimize grid utilization
- Deterministic
- Safe



What About Grid Reliability?



27. Develop enforceable standards for transmission line ratings.[39]

NERC should develop clear, unambiguous requirements for the calculation of transmission line ratings (including dynamic ratings), and require that all lines of 115 kV or higher be rerated according to these requirements by June 30, 2005.

U.S.-Canada Power System Outage Task Force
August 14th Blackout: Causes and Recommendations

Key Findings of the Task Force

"As seen on August 14, inadequate vegetation management can lead to the loss of transmission lines that are not overloaded, at least not according to their rated limits. The investigation of the blackout, however, also found that even after allowing for regional or geographic differences, there is still significant variation in how the ratings of existing lines have been calculated. This variation—in terms of assumed ambient temperatures, wind speeds, conductor strength, and the purposes and duration of normal, seasonal, and emergency ratings—makes the ratings themselves unclear, inconsistent, and unreliable across a region or between regions. This situation creates unnecessary and unacceptable uncertainties about the safe carrying capacity of individual lines on the transmission networks. Further, the appropriate use of dynamic line ratings needs to be included in this review because adjusting a line's rating according to changes in ambient conditions may enable the line to carry a larger load while still meeting safety requirements." [page 162 of the report]

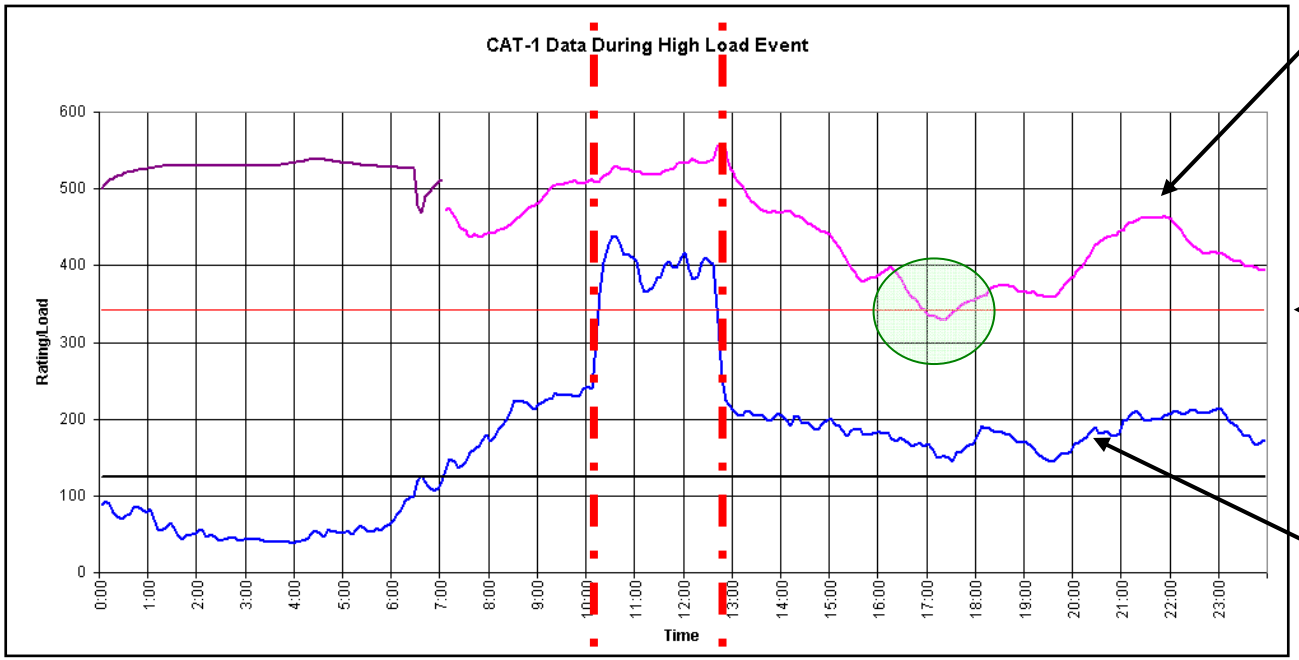
WASA

"…there is still significant variation on how the ratings of existing lines have been calculated…variations in terms of assumed… wind speeds…"

"…ratings themselves unclear, inconsistent and ***unreliable across a region or between regions***…"

"…appropriate use of dynamic line ratings …according to changes in ambient conditions…."

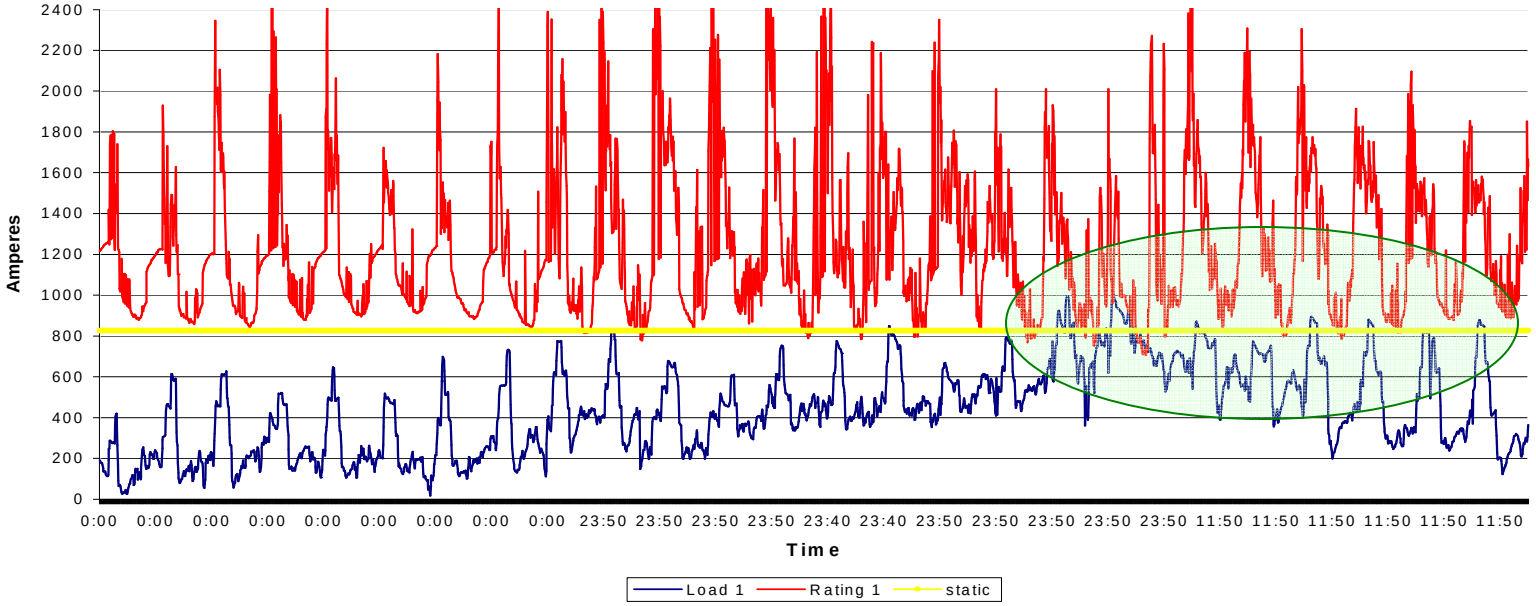
Impact On Transmission Grid Operations



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

- **Example Of Safely Managed Contingency**
- **Improved Transmission Grid Reliability**

230 kV Transmission Line
Load and Dynamic Line Rating vs. Time



- **Reduced Need For Operator Intervention**
- **Improved Reliability**

Impact On Transmission Grid Operations

If this 230 kV line were operated according to present NERC rules:

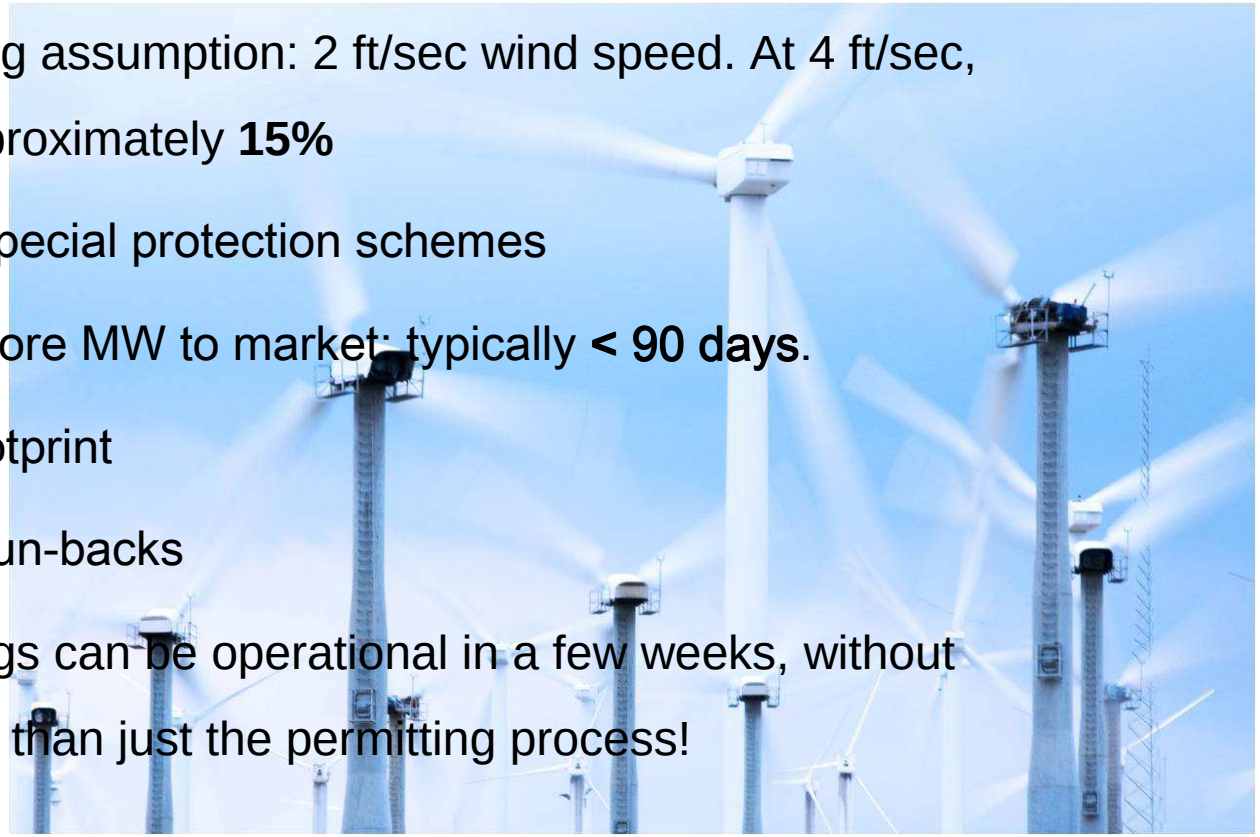
Operator Intervention	Without Dynamic Line Ratings	With Dynamic Line Ratings
Number of Days Required in Month	**9 days**	**2 days**
Number of Hours Required in Month	**45 – 65 hrs**	**4 – 5 hrs**
Longest Curtailment	**10 hrs**	**2 hrs**

In addition, curtailments would have been less severe using Dynamic Line Ratings.

➢ **Optimum Dispatch Maintained - Improves Economy**

Wind generators are located in windy regions, which can benefit *substantially* from Dynamic Line Ratings

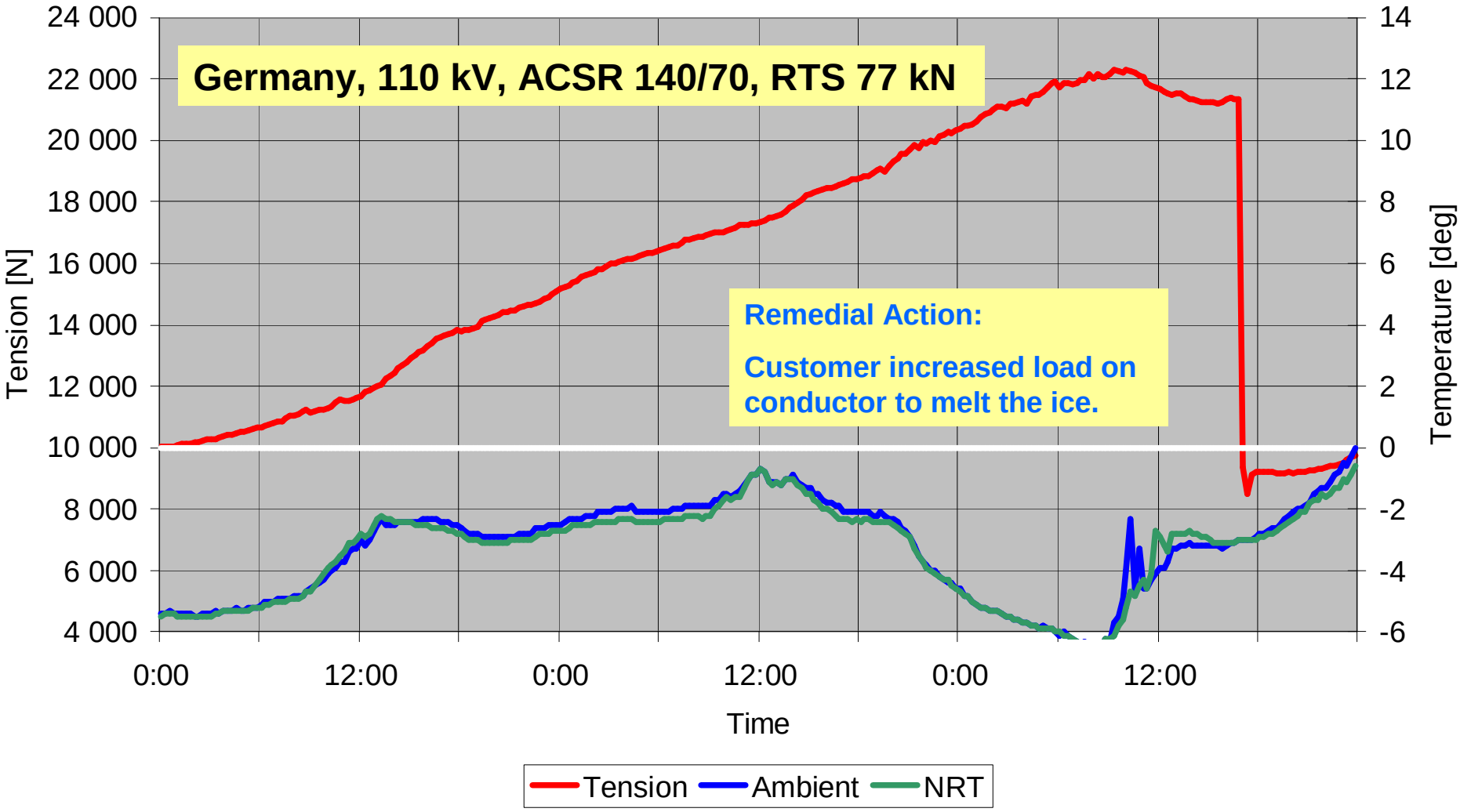
- Increased line ratings on existing **and** new transmission lines
- Common static rating assumption: 2 ft/sec wind speed. At 4 ft/sec, rating increases approximately **15%**
- Reduced need for special protection schemes
- Earlier delivery of more MW to market: typically **< 90 days**.
- Reduced carbon footprint
- Reduce wind farm run-backs
- Dynamic Line Ratings can be operational in a few weeks, without permits, at less cost than just the permitting process!



Ice Monitoring

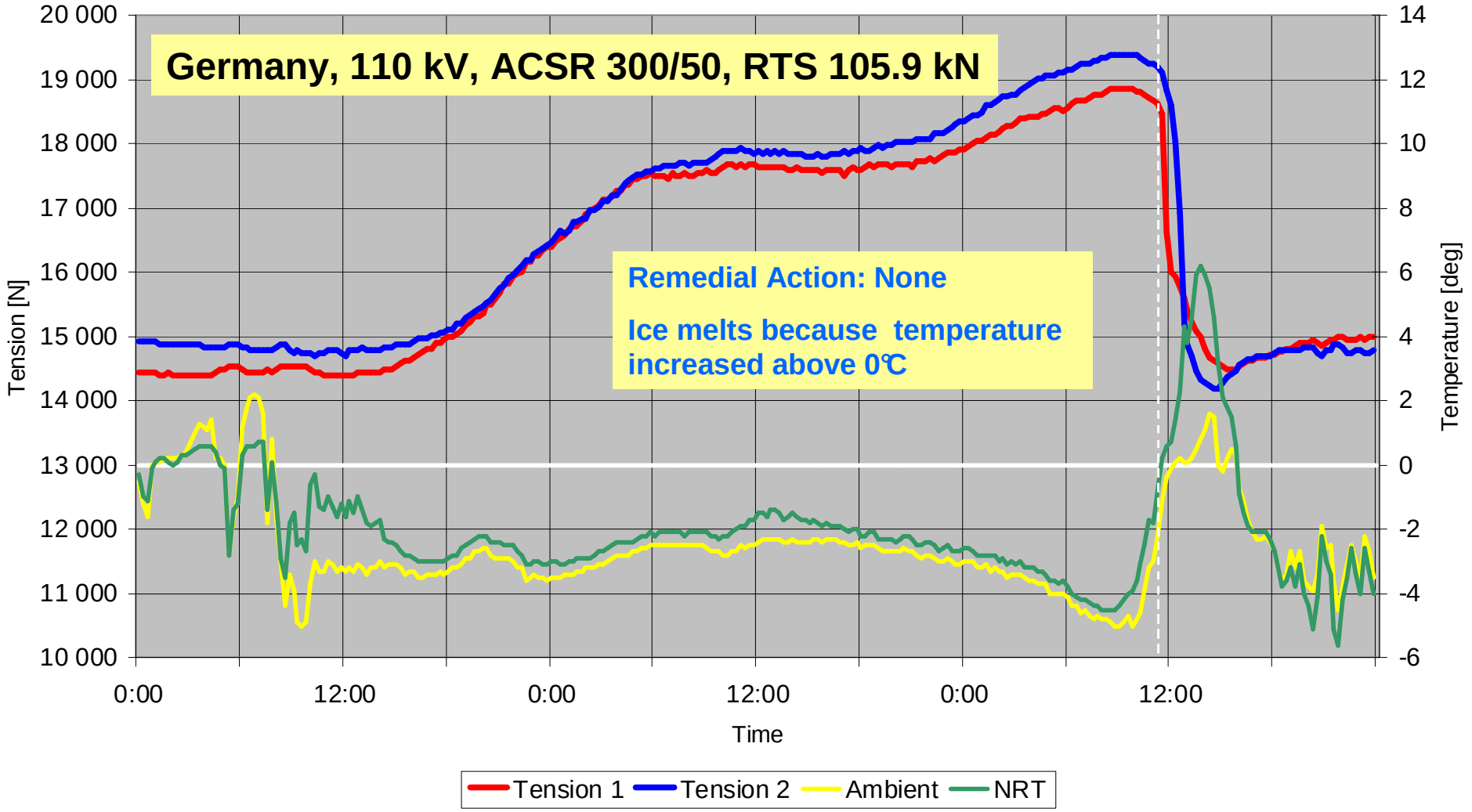
Actual Ice Monitoring Example 1

27. - 29. December 2007



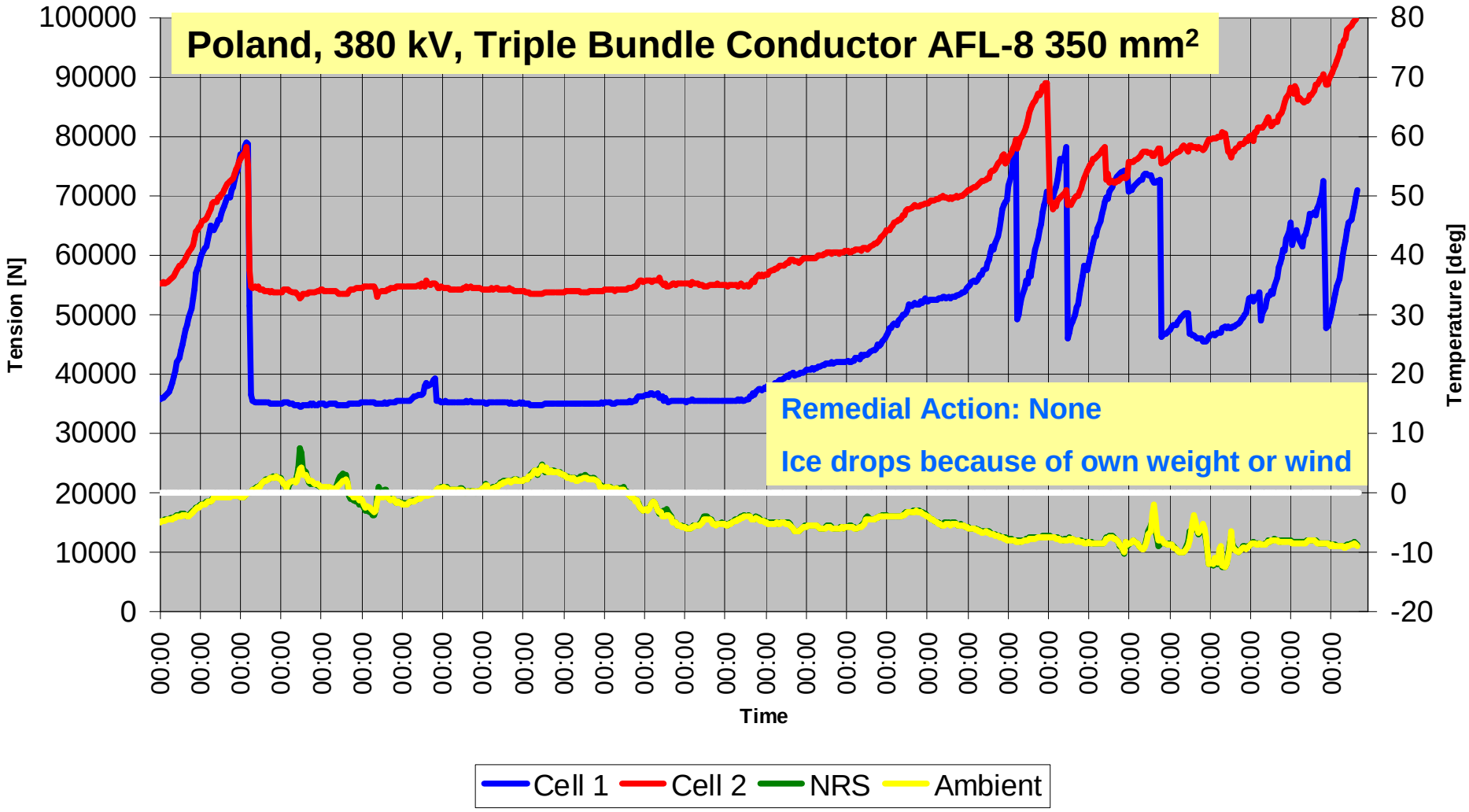
Actual Ice Monitoring Example 2

25. - 27. December 2006



Actual Ice Monitoring Example 3

1. - 30. December 2007



So, Why Dynamic Line Ratings?

- Cost Effective
- Congestion Relief
- Improved Grid Reliability
- Optimized Asset Utilization
- Lower Prices to Consumers
- True Line Capacity in Real Time
- Improved Transmission Efficiency
- Faster Integration of Wind Energy
- *enhanced* Wide Area Situational Awareness (*e*-WASA)

Green Technology

A True Low Hanging Fruit for the Smart Grid

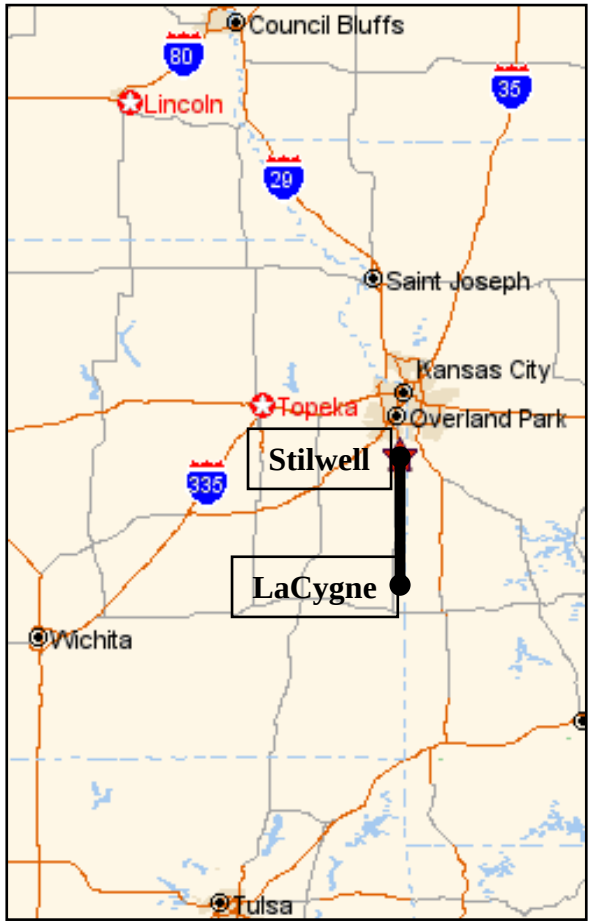
An Optimized Grid is a *Happy* Grid

Case Studies

- Three Major Utilities
- Same Technology
- Different Applications

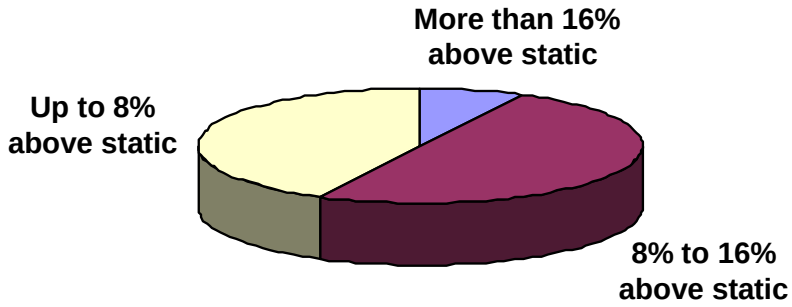
KCP&L – Congestion Relief

- 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



KCP&L – Congestion Relief

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



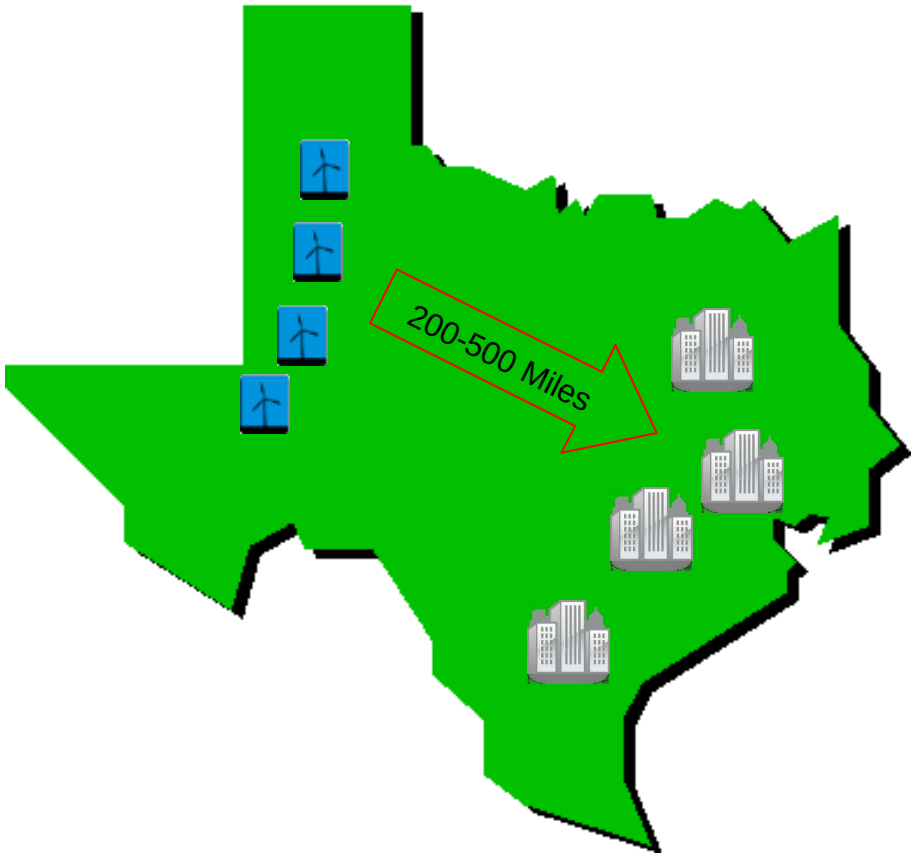
- KCPL avoided “a significant amount” of energy redispatch
- Calculated less than 3-month payback for total installed cost
  - Acquisition, installation and calibration
  - Engineering project management
  - Field verification of readings

KCP&L – Congestion Relief

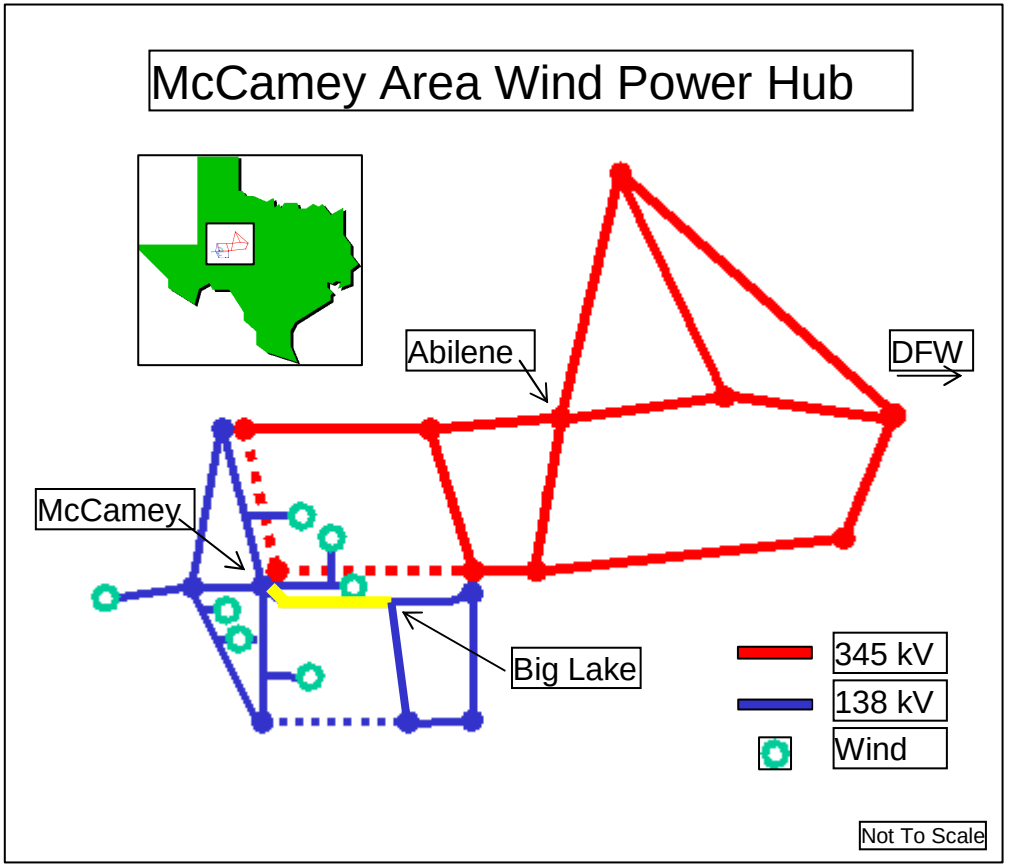
- Before installation of real time ratings
  - Firm and Non-firm power contracts were curtailed by the flowgate's constraint
- After installation of real time ratings
  - No curtailment of firm power contracts; increased capacity for non-firm contracts
  - Least cost power delivered to consumers

AEP West – Wind Farm Integration

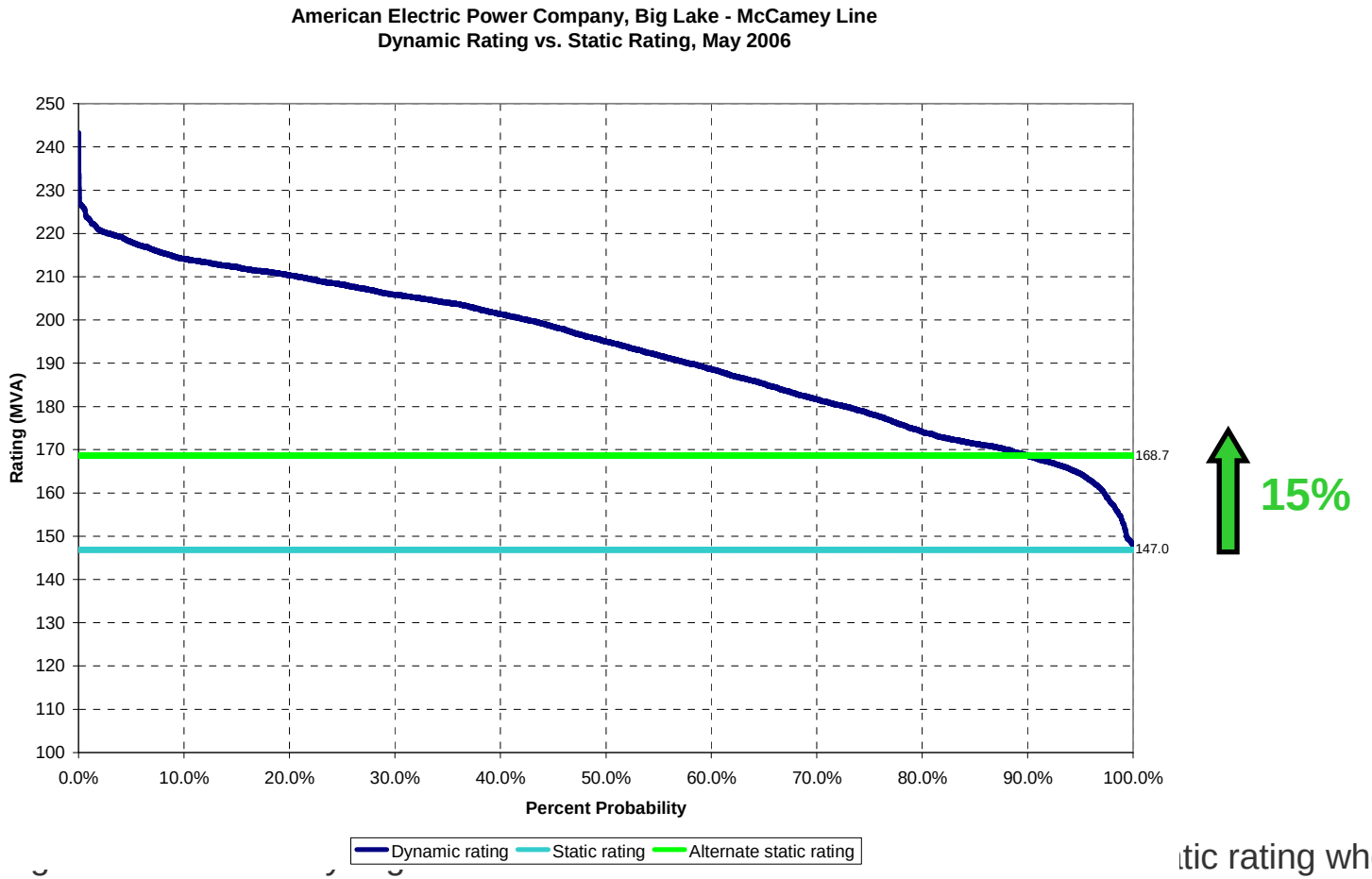
- The best wind is located far from load centers
- Existing transmission capacity is modest in the vicinity of wind farms, and limits the amount of wind power that can be delivered to load centers
- Wind farms are being added faster than transmission lines can be built
- New transmission capacity is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



- 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



AEP West – Wind Farm Integration



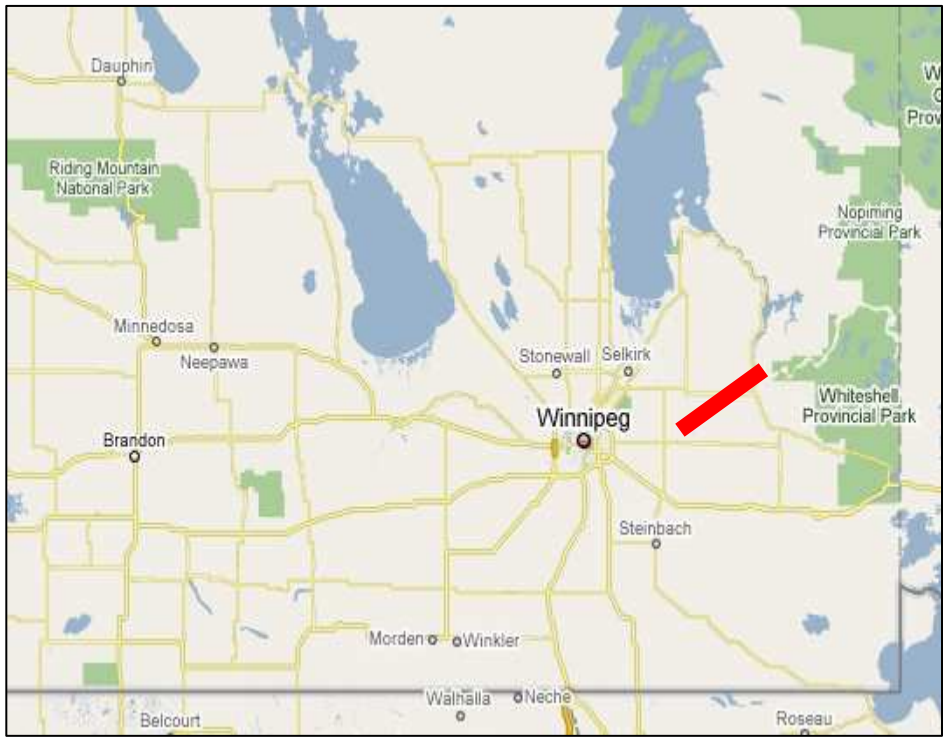
Real time ra tic rating when needed to accommodate wind power

AEP West – Wind Farm Integration

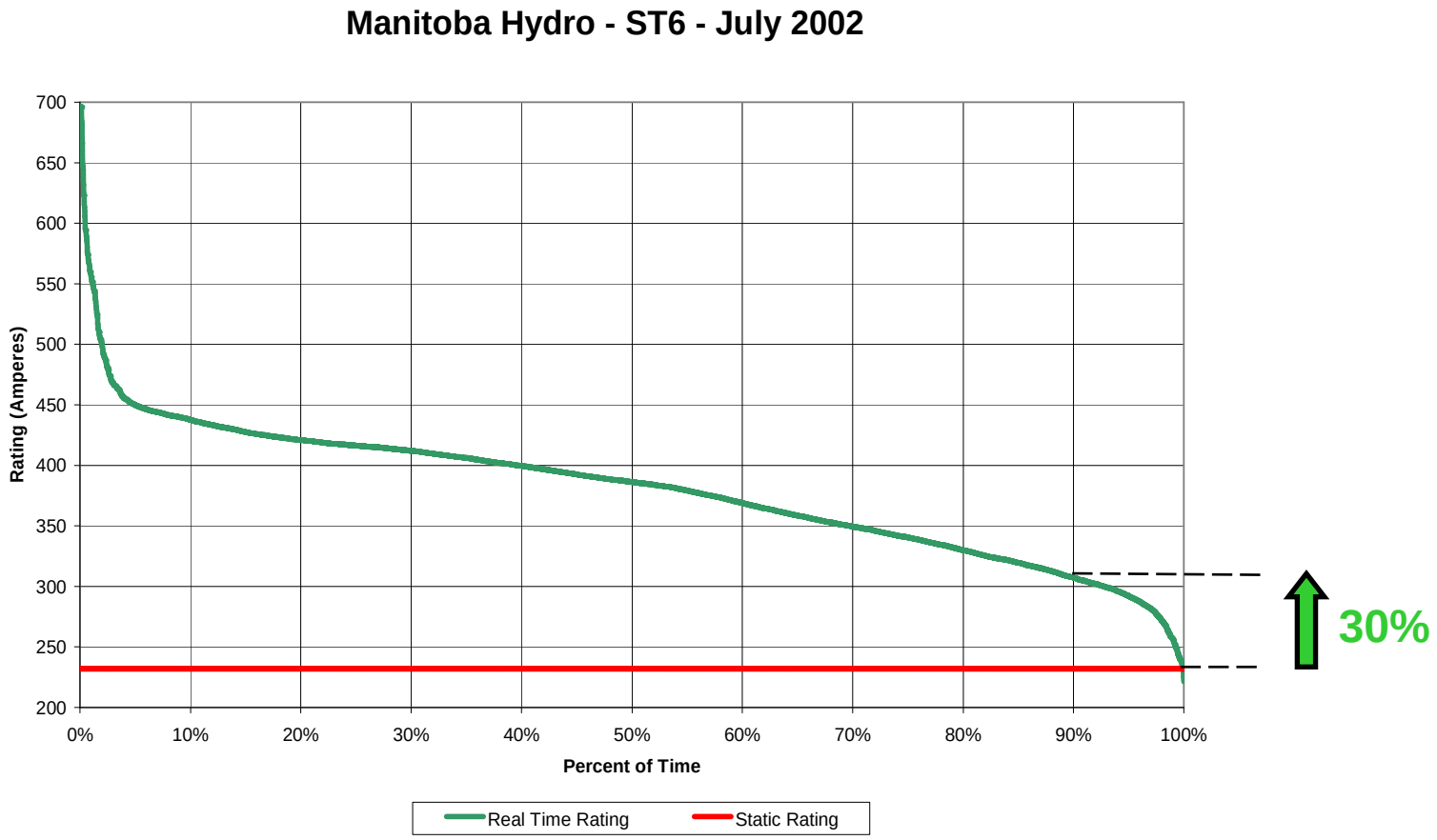
- Real time ratings enabled an immediate 10-15% (minimum) increase in the delivery of wind power over existing transmission assets
  - More renewable energy to market, faster, and at lower cost
  - Maximized use of existing transmission assets
- Real time ratings deferred a physical line upgrade estimated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

Manitoba Hydro – Avoiding Curtailment

- Seven Sisters – Vivian Tap (ST6)
- 115 kV, 45 km
- 232 A static rating
- Intermittent loading constraints result in curtailing low cost hydro generation needed to optimize economic dispatch
- Maintenance and capacity upgrades are planned, but not scheduled for years



Manitoba Hydro – Avoiding Curtailment



Real time ratings on ST6 are above the static rating 99.9% of the time and 30% above the static rating 90% of the time

Manitoba Hydro – Avoiding Curtailment

- Real time ratings provide access to existing transmission capacity above the static rating
  - Curtailment of hydro generation avoided
  - Lowest cost power delivered to consumers
  - Unnecessary, and potentially reliability threatening, redispatch avoided
- Maximum utilization of the existing transmission asset.
  - Greater ROI
  - Planned upgrades stay on schedule. No artificial and costly acceleration to accommodate unexpected constraints

Summary
An Enabling Technology for the Smart Grid

- The technology to accurately measure the dynamic rating of a transmission line has been well established
- Dynamic Line Ratings provide access to the true capacity of the grid in real time
- Dynamic Line Ratings are available at the operator's console and they are a practical tool with which operators can effectively manage the grid
- Dynamic Line Ratings increase grid reliability by enabling operators to reduce the number of times they must intervene to make system adjustments
- The true capacity is essential to efficiently manage the grid's reliability and economic use
  - Whether it be through direct use of the real time ratings by system operators or
  - As accurate inputs to integrated Smart Grid technologies
- Quick installation with fast payback

Additional Information

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