Dynamic Line Ratings
for Optimal and Reliable Power Flow

Enhanced Power Flow for the Smart Grid

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Nexans and The Smart Grid

- High Temperature Overhead Transmission Conductors
- Superconductivity
  - World’s First HTS Power Transmission Cable System
    - Energized April 22, 2008 in Long Island, New York
    - Partnership with DOE, LIPA, Nexans, Air Liquide and American Superconductor
- Superconducting fault current limiter (MV)
- **Dynamic Line Ratings**
What are Dynamic Line Ratings?

Reliable Dynamic Line Ratings for the Smart Grid

Why Employ Dynamic Line Ratings?

Tangible Benefits of Dynamic Line Ratings?
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”
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 Conditions in Determining Line Ratings
- Static: Assumes constant weather conditions, over an extended period of time, days, months or years, neglecting weather variability
- Dynamic or Real Time: Takes into account changing weather conditions in real time, especially the random and significant wind variability

Dynamic (Real Time) vs. Static Ratings
- Dynamic Line Ratings provide the operator with the overhead transmission line’s actual ability to carry power at any moment in time while respecting design limits, such as conductor temperature and “next limiting element”
Relative Impact of Ambient Conditions on Line Ratings

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

<table>
<thead>
<tr>
<th>Ambient Temperature:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2°C fluctuation</td>
<td>+/-2% capacity</td>
</tr>
<tr>
<td>10°C drop in ambient</td>
<td>+ 11% capacity... 874 amps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solar Radiation:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud shadowing</td>
<td>+/- a few percent</td>
</tr>
<tr>
<td>Middle of night</td>
<td>+ 18% capacity... 929 amps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind increase 1m/sec:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>45° angle</td>
<td>+ 35% capacity... 1,060 amps</td>
</tr>
<tr>
<td>90° angle</td>
<td>+ 44% capacity</td>
</tr>
</tbody>
</table>

The Un-Harnessed Power of Dynamic Line Ratings
Variability of Wind
Two Sites Along a Transmission Line

Two Sites, 2 Km Apart

Figure 6.1 - 15-Minute Average Wind Speed at CAT A versus Wind Speed at CAT B
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.

Testing at ORNL validates this observation.
“Critical Span” theory is a myth…
Point measurements are unreliable
Why Tension Monitoring?

- Suspension insulator strings swing to equalize horizontal conductor tension
- Monitoring the conductor’s tension resolves the varying wind conditions along the transmission line
- A conductor’s tension is directly related to the average temperature of all the spans in the line section
The Smart Grid and Dynamic Line Rating

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

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Dynamic Line Rating

Design Isotherm

Smart Grid with Dynamic Line Ratings

Today’s Grid with Static Ratings

Risk with Static Line Rating

Percent of Time (%)
What About Grid Reliability?

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

Key Findings of the Task Force

“…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….”

“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]
Reliable Dynamic Line Rating

- Tension-based Real Time Monitoring system for overhead transmission lines
- Tension resolves all environmental factors for accurate results
- Delivers 10% to 30% additional grid capacity 90+% of the time
- Delivers clearance warnings
- Communicates with utility’s Energy Management System
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Flow Chart RTR

Fully integrated solution

CAT-1™ Remote Monitors

Transmission line

Radio Fibre optics

CATMaster™

Substation

Utilities SCADA protocol

IntelliCAT™ for Windows

Control centre

SCADA/EMS Master

Operator's screen

ICCP or DNP

FERC Technical Conference

Business Confidential

June 24, 2010
• A primary goal of rendering today’s transmission grid “smarter” is to optimize and better manage its power transfer capacity, in real time.

• A transmission grid’s power transfer capacity is not constant and is primarily controlled by three elements: **stability, voltage limits, and thermal ratings**
  - All three are critical, and the Smart Grid must have a firm grip on all three elements.
  - Of the three, **thermal ratings (Dynamic Line Ratings)** represent the greatest opportunity to quickly, reliably and economically utilize the grid’s true capacity.

• Dynamic Line Ratings can be used along with other Smart Grid technologies (FACTS, Security Analysis) to reliably optimize and manage the power transfer capacity of the grid in real time.

• The more completely and accurately the grid capacity is known, in real time, the more effective and reliable the management of the Smart Grid will be.
Transmission Line Capabilities
Thermal vs. Voltage and Stability

• Voltage and stability events are essentially instantaneous. They must be avoided.
• Thermal limits are time-dependent. They can be managed.
• Voltage and stability events are reliability concerns.
• Thermal events are reliability concerns, but even more importantly, safety concerns.

________________________________________

Reliable Dynamic Line Ratings Must:
✓ Take advantage of varying environmental conditions, reliably, in real time
✓ Enhance WASA along entire transmission line and interconnections
✓ Optimize the utilization of existing and new transmission lines, while respecting all design limits, 100% of the time
✓ Provide improved visualization and early warning for safe operation
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Impact on Transmission Grid Operations

Real-Time Rating

Operational switching performed

Load

Conductor Temperature

Net Radiation Temperature

Real-Time Rating  Load  Static Rating  Cond. Temp  NRS Temp
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
Impact On Transmission Grid Operations

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

- Reduced Need For Operator Intervention
- Improved Reliability
If this 230 kV line were operated according to present NERC rules:

<table>
<thead>
<tr>
<th>Operator Intervention</th>
<th>Without Dynamic Line Ratings</th>
<th>With Dynamic Line Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Days Required in Month</td>
<td>9 days</td>
<td>2 days</td>
</tr>
<tr>
<td>Number of Hours Required in Month</td>
<td>45 – 65 hrs</td>
<td>4 – 5 hrs</td>
</tr>
<tr>
<td>Longest Curtailment</td>
<td>10 hrs</td>
<td>2 hrs</td>
</tr>
</tbody>
</table>

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

➢ Optimum Dispatch Maintained - Improves Economy
Integration of Wind Energy

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
- Dynamic Line Ratings can be operational in a few weeks, without permits, at less cost than just the permitting process!
Ice Monitoring
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
- Wide Area Situational Awareness (WASA)

A True **Low Hanging Fruit** for the Smart Grid

Green Technology
An Optimized, Reliable, and Happy Grid
Case Studies

- Three Major Utilities
- Same Technology
- Different Applications
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
• Line was operated above static limit for **167 hours** late June to early September:

![Pie chart showing line operation above static: Up to 8%, 8% to 16%, More than 16%]

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

American Electric Power Company, Big Lake - McCamey Line
Dynamic Rating vs. Static Rating, May 2006

Dynamic rating
Static rating
Alternate static rating

Percent Probability

Rating (MVA)

100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250

0.0% 10.0% 20.0% 30.0% 40.0% 50.0% 60.0% 70.0% 80.0% 90.0% 100.0%
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.
• 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
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 awareness of and access to the true capacity for the Smart 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 providing enhanced wide area situational awareness and by enabling operators to reduce the number of times they must intervene to make system adjustments

• Knowing true transfer capacity is essential to efficiently manage the grid’s reliability and economic use
  ➢ whether it be through direct use of Dynamic Line Ratings by system operators or
  ➢ as accurate inputs to integrated Smart Grid technologies

• Quick installation with fast payback
Additional Information

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