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FAC-008-2, Real-Time Ratings and Ratings Predictability

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What are line ratings?

- Transmission line rating represents the maximum current which can be applied to a given line without exceeding its design limits. Exceeding the rated current causes the line's temperature and sags to exceed design limits, resulting into reliability and safety hazards.
- Most utilities base their line ratings on fixed weather assumptions. They are assumed to be conservative (high ambient temperature, full solar radiation and a low wind speed).
- Transmission lines have normal and emergency ratings. Emergency ratings are applied in N-1 conditions, when an unforeseen event causes a line's load to increase and it is typically used for 15-30 minutes, until system operators can correct the system status.
- N-1 situations are relatively rare but are the main reason for actual energy dispatch limitations in the transmission system.

Recent Developments

- The major blackouts in 2003 in North America and Europe indicated that one of the leading causes was poor understanding and lax procedures regarding thermal line limits. Thus:
  - FERC instituted a thorough review of reliability standards, now under way by NERC. Similar actions are ongoing in Europe;
  - IEEE and CIGRE formed a Joint Task Force to develop a Guide for selection of ratings, now published as CIGRE TB 299.
  - Many utilities are now revising their rating procedures and considering large scale application of dynamic ratings.

- It is also being realized that because transmission line construction has generally lagged behind load growth, lines are being more heavily loaded, thus increasing the hazards of too optimistic rating assumptions.

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IEEE and CIGRE Recommendations regarding rating selection

- If fixed assumptions are used, the ratings should be selected in such a way that if the line were operated continuously at rated current:
  - The line would not exceed its maximum design temperature for more than 1-2% of time;
  - The highest temperature under the worst conditions should not exceed the maximum design temperature by more than 10°C (18°F);
  - These limits were based on the realistic engineering accuracies regarding line design.

- As a base line recommendation, the Joint Task Force recommended that , unless qualified studies are conducted, the line ratings should be based on the assumption of 2 ft/sec crosswind.

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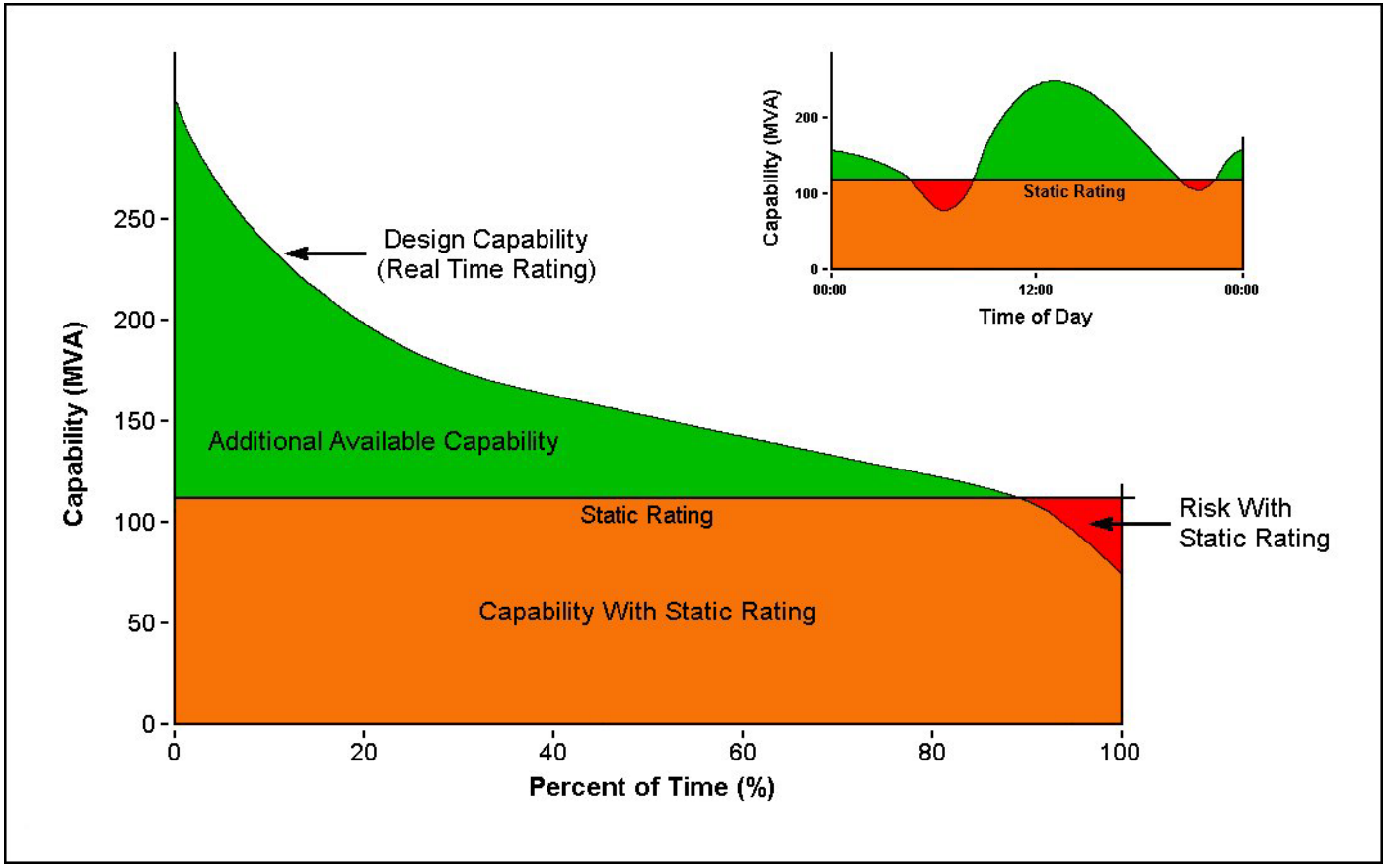
Transmission Line Capabilities
Assumed Constant Wind

IEEE/CIGRE guidelines recommend selection of wind speed so that risk level is 1-2%, if line is continuously operated at rated current.



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Changing regulatory environment may force revisions of ratings

- FERC's Order 693 specified that::
  - **All rating assumptions must be explicit and defensible;**
  - **Ratings are calculated using methods developed by "open" process such as IEEE or CIGRE standards;**
  - **All violations must be self-reported**

- NERC's revised Facilities Rating Standard FAC-008-2 is now in Ballot Review. It is likely to become enforceable in late 2009.
- Some utilities are already revising their ratings to be more conservative.
- But importantly, FAC-008-2 specifically endorses the use of dynamic ratings, as ratings may be based on either "fixed ambient conditions" or "as they vary in real time".

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Changing regulatory environment may force revisions of ratings

- FAC-008-2 is likely to be accepted as currently written. Main objections in the final ballot were:
  - **Certain Generation rating issues;**
  - **Requirements of providing ratings for most limiting and second most limiting elements (R7);**
  - **Review of methodologies used in rating calculation**

- Adoption of FAC-008-2 will cause major operational changes, as operators will operate the system “by the book”.
- This may, paradoxically, negatively affect operational reliability, because this means more operator interventions.
- Some utilities are already revising their ratings to be more conservative.

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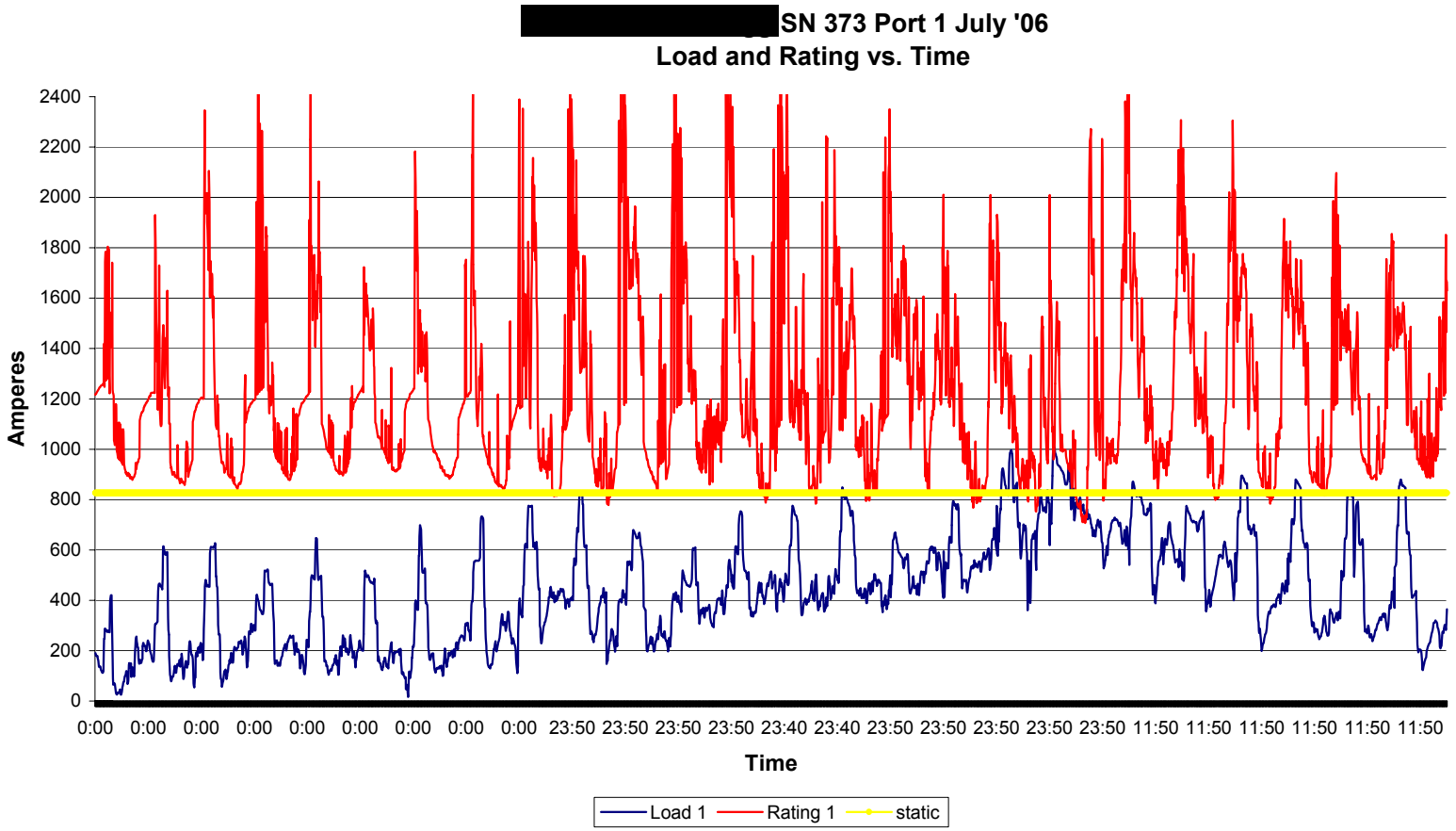
Ratings are not predictable…

230 kV line in California, July 2006.



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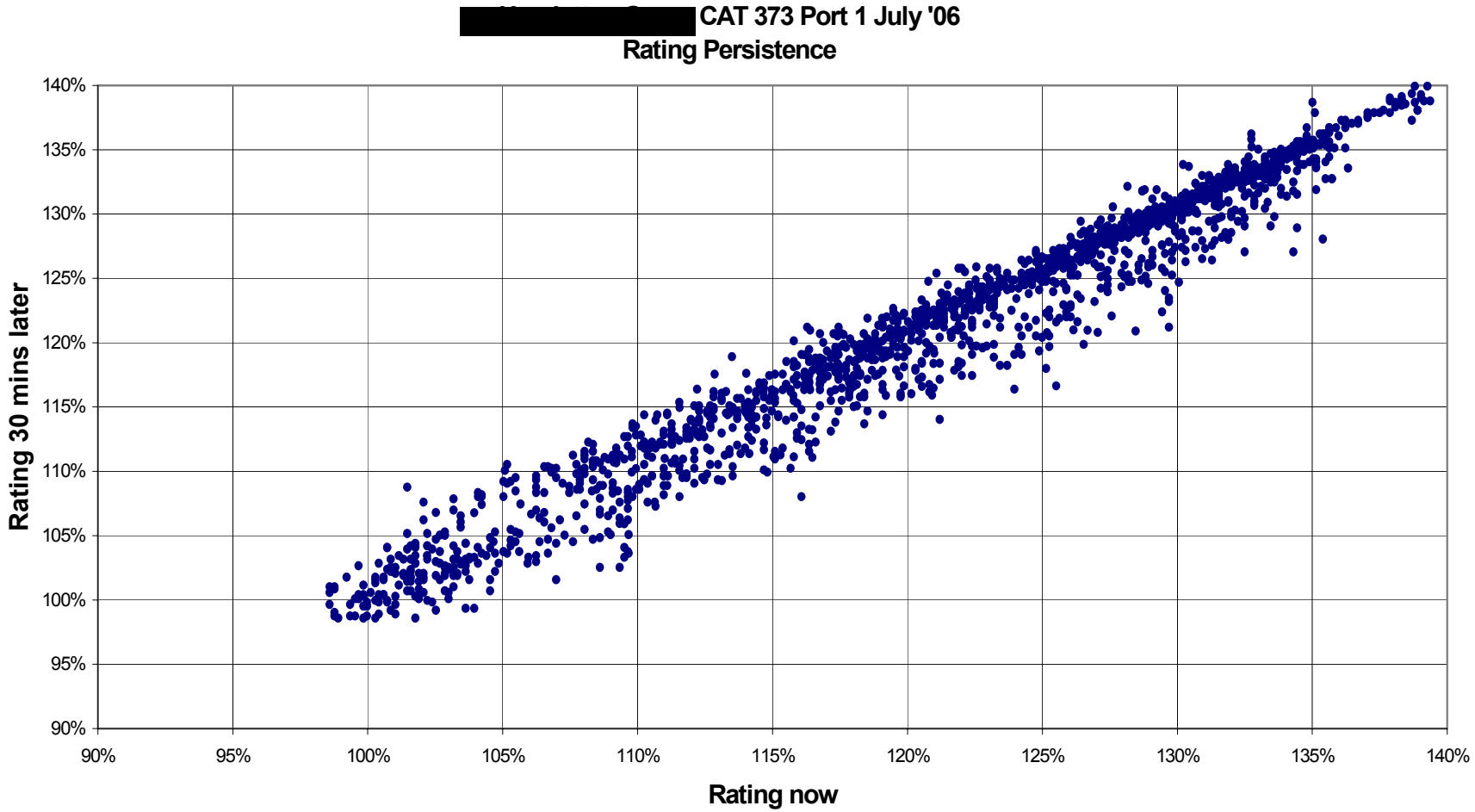
Ratings are not predictable… but they have persistence
230 kV line in California, July 2006.



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Importance of Rating Persistence for Operations

- Rating persistence can be defined e.g. as the 3-sigma limit that real time rating dos not decline more than P amperes in 30 minutes.
- Thus, if the present Real-time rating is R amperes, the operator has t3-sigma confidence that he can operate the line for 30 minutes at P-R.
- For example, if the Real-time rating is 1250 A compared to 1000 A static rating and Persistence is 100 A, the operator has a very high confidence that he can operate the line up to 1150 A for 30 minutes. Note that rather few contingencies last more than 30 minutes.
- In studied cases, 30-minute persistence seems to be typically between 6% and 12% of static rating, while median Real-time rating is typically between 130-140%.
- This means that using real-time ratings, lines could be typically be operated with 3-sigma certainty at 115-130% of their static ratings.

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Real-time Monitoring
Proven Technology

- Over 300 units in 18 countries at voltages up to 500 kV.
- Real time ratings provide both reliability and market benefits.
- Systems deliver 10-30% more capacity at only 5-10% of cost of upgrading or new line costs.
- Systems can be installed on a 20 mile circuit in 2-3 days.
- Systems can be relocated. They can be moved to other circuits as needs change.

Technology Outline

CAT-1 Transmission Line Monitoring System

- Dominant real time rating technology, with 200 real time operational installations in U.S. and abroad.
- Equipment installed on transmission structures, to monitor conductor tension and net radiation temperature.
- Data is transmitted via radio or optical fibre to the utility's control center.
- Real time ratings are calculated by EMS/SCADA system and displayed to operators.

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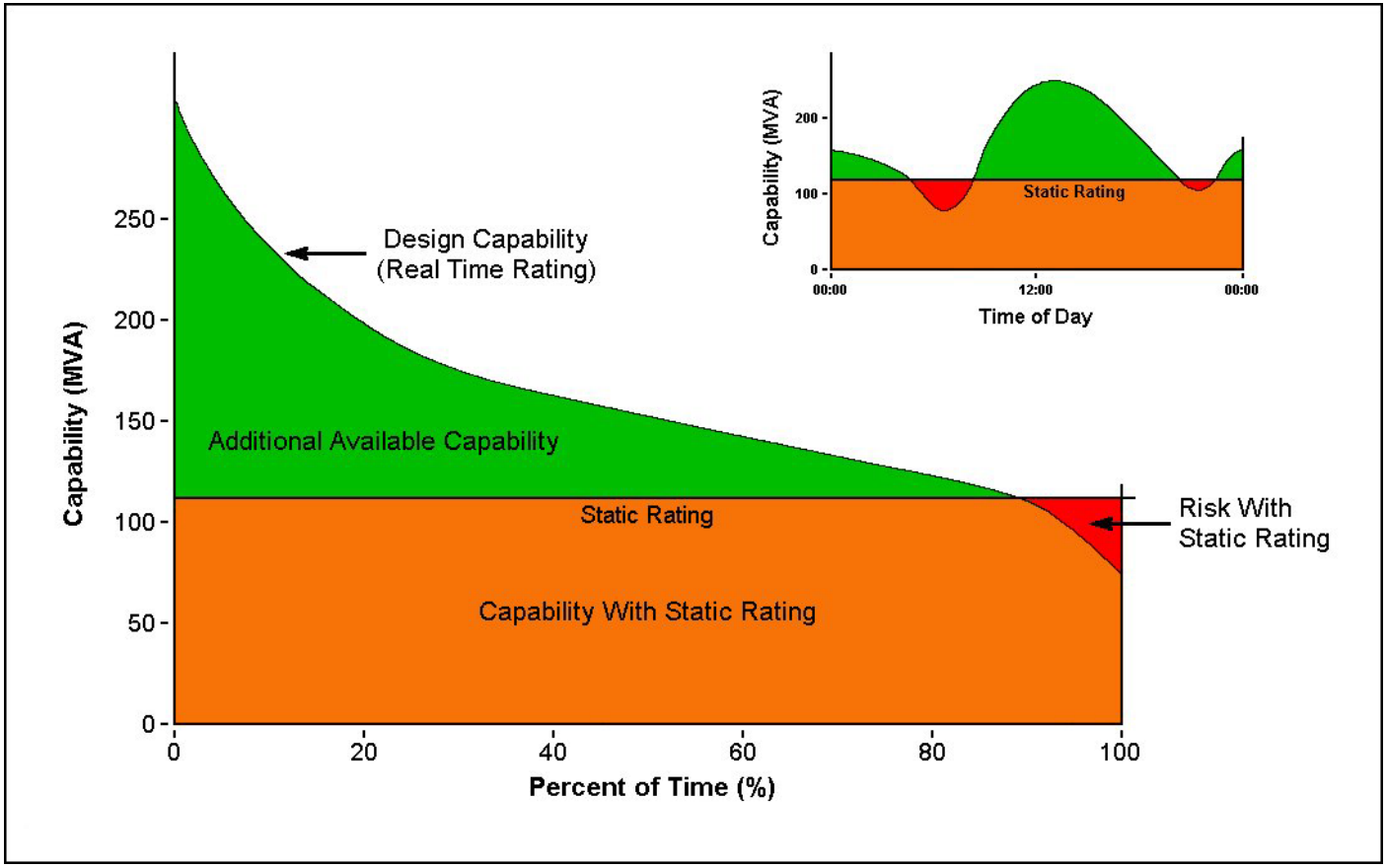
Transmission Line Capabilities
with real time ratings

Real time rating provides increased capability 95-98% of time.



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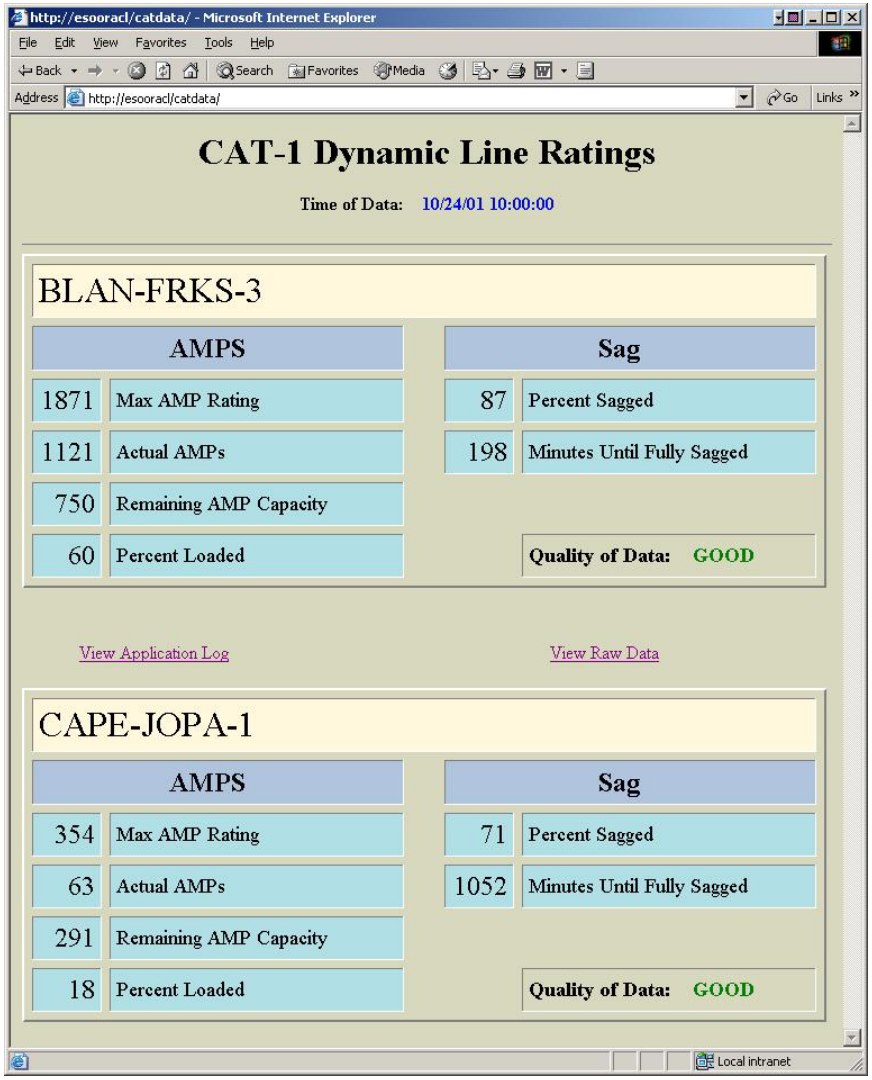
Real time rating systems
Integrated with control center consoles



Ratings are displayed in the format to which the operator is accustomed. This display shows the operator:

- Real time capability of the line
- Present line current
- How much additional capability remains
- Current state vs. real time capability

- How close the line is compared to the allowable sag limit
- Time until the present sag increase might cause a clearance violation

Reliability Benefits (1)

1. Avoiding unnecessary operator actions

- Fixed transmission line ratings are generally selected so that they represent a 1-3% risk of exceeding line's design temperature if the line were continually operated at its rated current.
- Consequently, over 95% of operator corrections caused by thermal contingency limits are either unnecessary or excessive.
- Real time monitoring tells the system operators:
  - ✓ Is the correction necessary and how large correction is needed and how long can they wait to make the correction? It also provides justification for operator actions.
- Note that new FAC-008 definition of ambient (weather) conditions "as they vary in real time" permits the use of real time ratings.

Reliability Benefits (2)

2. Advance warning of clearance violations

- Dynamic alarms give the operator required advance warnings and indicate how soon corrective action should be taken.
- The warning process shows the physically correct time, based on conductor's time constant, compared to current arbitrary time scales which are independent of physical conditions.

3. Dispatch of generation during capacity deficiency

- During 2006 capacity deficiency in California –and high water conditions – a hydro facility was dispatched at 10% over the nominal line rating at all peak load times.

Reliability Benefits (3)

4. Accurate ice monitoring

- Each tension monitor is also – with suitable software- a very accurate ice monitor.
- They can be used to warn the operators of dangerous ice conditions and can even be used for monitoring effectiveness of ice mitigation.
- German Rail reports saving $90K in energy cost last winter by avoiding heating one of their 110 kV lines last winter. The study indicated that the prior weather station based warning system was highly inaccurate.

Reliability Benefits (5)

5. Fastest and most cost-effective mitigation method

- When reliability violations are detected, real-time monitoring can often provide the fastest and most cost-effective mitigation technique.
- The Valley Group's FASTCAT program makes it possible to procure, install and commission real time monitoring systems in a few weeks time with minimal intrusion in system operations.
- With a typical cost of $100-200 K/line, CAT-1 real time monitoring costs only a fraction of available alternatives.
- Because FERC Order 693 considers real time monitoring "an innovative approach", its use in mitigation is likely to be considered favorably by regulators.

Smart Transmission Grid

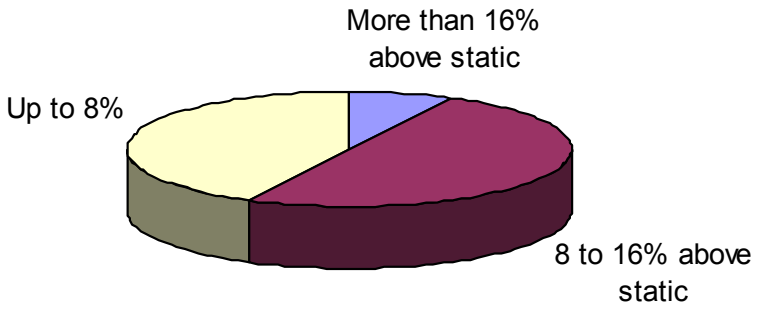
- Smart operation of transmission system allows increased capability with improved reliability.
- This requires more accurate real-time information of voltage, stability and thermal limitations.
- Synchro-phasors can be used to monitor voltage and stability limits but they do not provide useful information of thermal capabilities.
- CAT-1 systems provide a perfect complement to synchro-phasors because they monitor the thermal limitations accurately.

Market Benefits

1. Improving path capabilities
2. Taking advantage of higher daytime ratings
3. Wind power applications
4. Mitigation of market power in load pockets
5. In case of generation uncertainty, allowing postponement of line construction.
6. Avoiding unnecessary TLRs.

Success Story (1)
KCPL Stilwell/LaCygne

- Line was operated above static limit for 167 hours and avoided TLRs:



- 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
  - Equipment repair/re-installation
  - Field verification of readings

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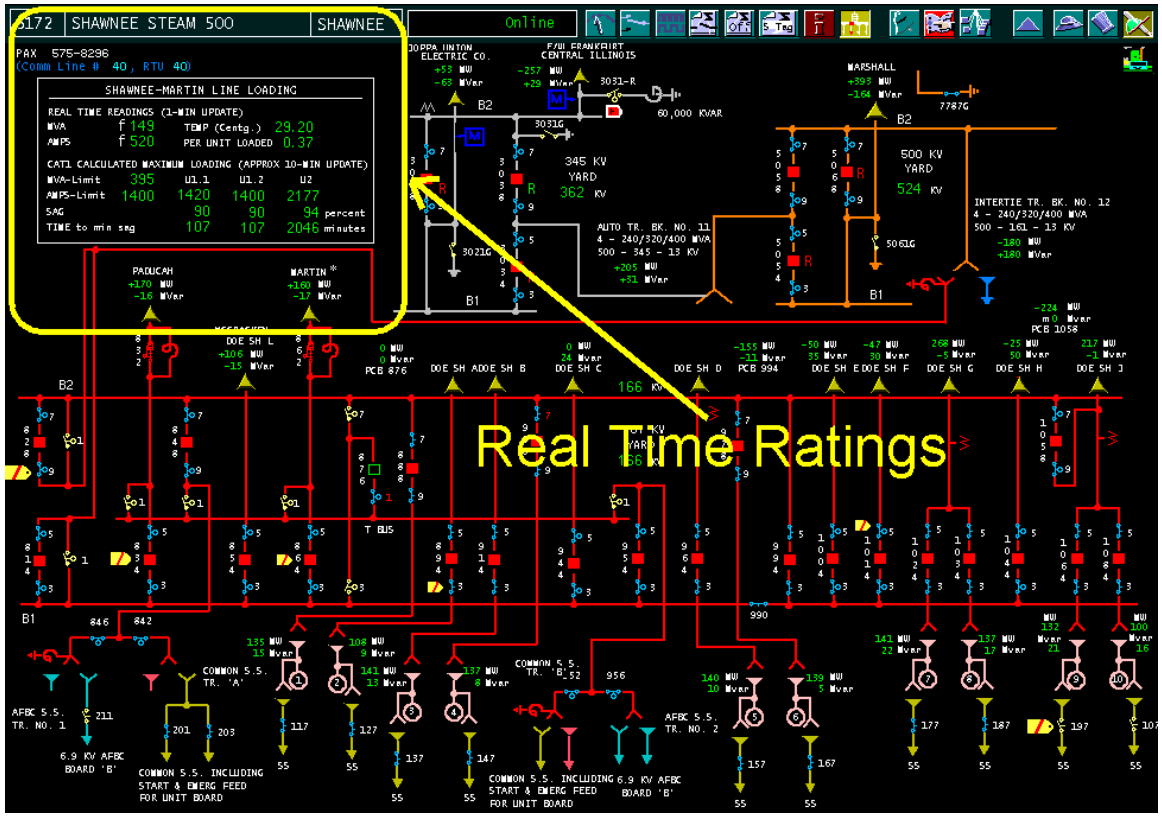
Success Story (2)
TVA



- Deferred $25 million capital investment
- Prevented service interruptions @ $104,000 each
- Six CAT-1 systems now in service at TVA

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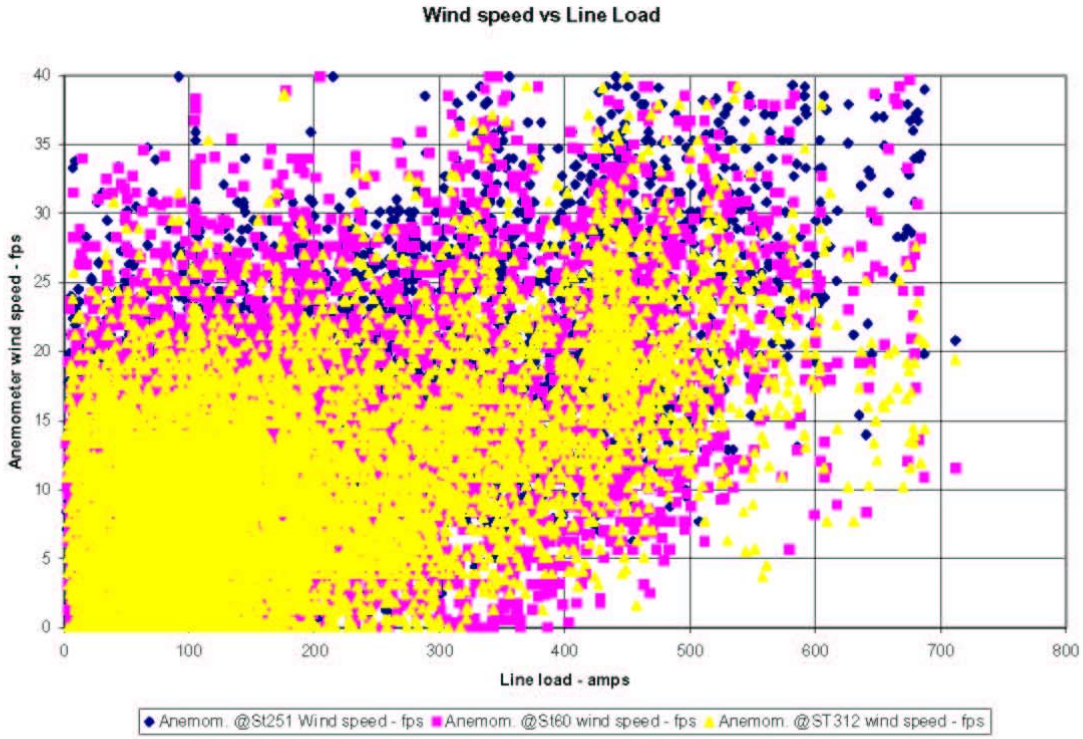
Effective wind speed vs. line current
Line through wind farm in Minnesota

Wind Speed vs Line Current



CIGRE WG B2-12 9/6/03 Edinburgh, Scotland

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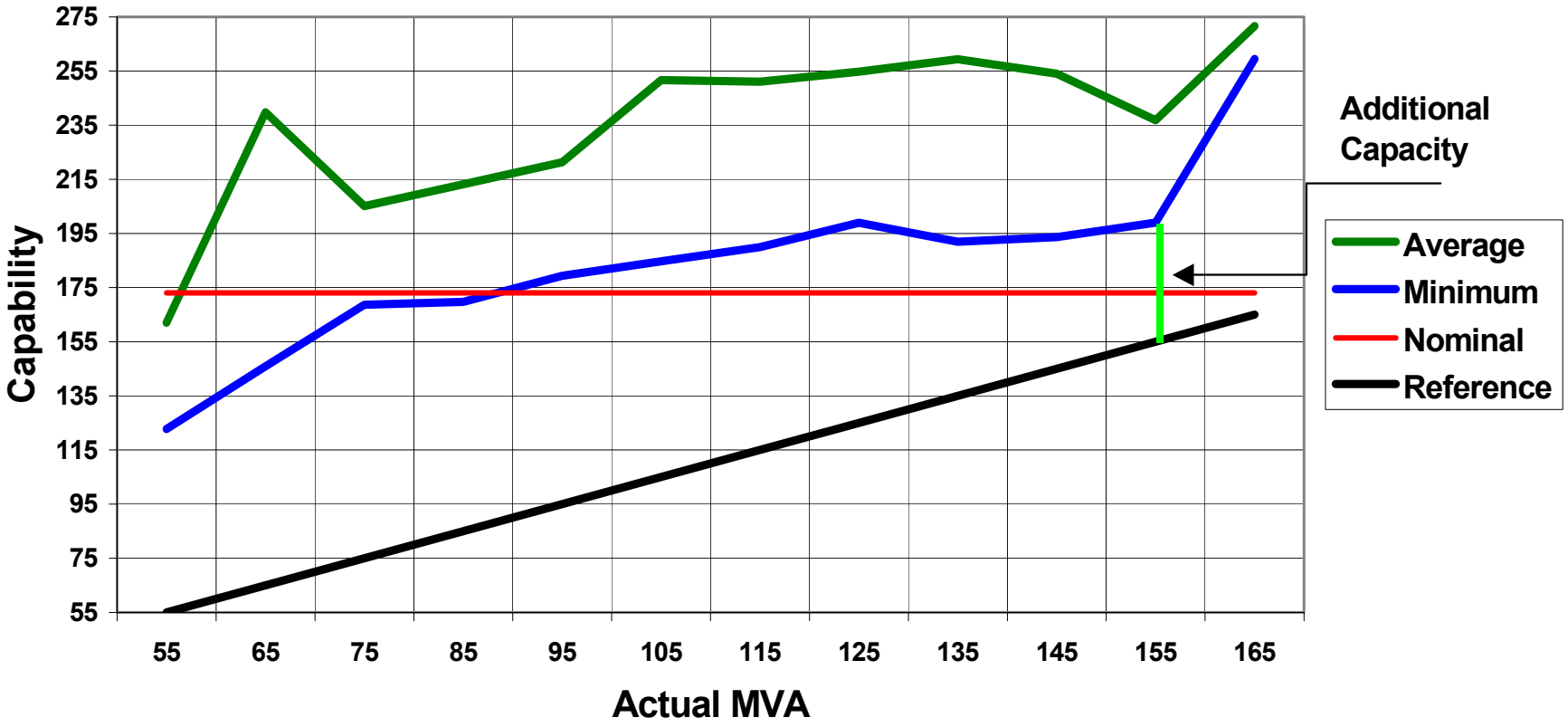
Capability of a 138 kV line to a wind site in Texas

Instead of allowing 160 MW of wind power capability, the line could actually manage over 200 MW without curtailment and about 220 MW while curtailed less than 1% of time.



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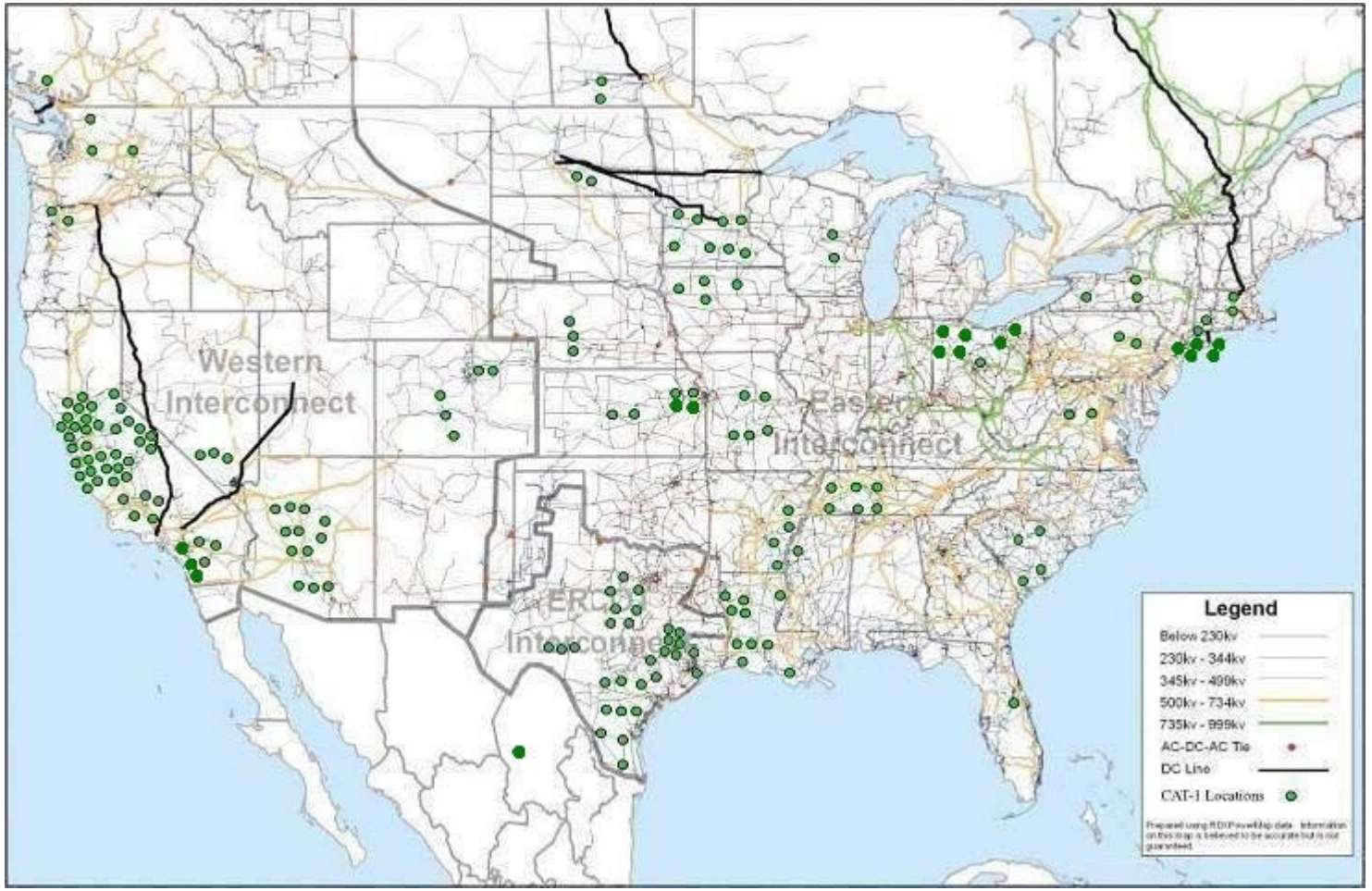
CAT-1 Real-Time Monitoring Systems in U.S.

January, 2007



Real time systems also in: Australia (2), Argentina (2), Belgium (8), Brazil (3), Canada (4), Denmark (2), Finland (1), France (3) Germany (2), Iceland (2), Korea (1), Mexico (2), Poland (2), Portugal (1), Puerto Rico (2)