

The Valley Group

a Nexans company

Reliability and real time transmission line ratings

Tapani O. Seppa
The Valley Group – A Nexans Company

June 18, 2007

Regarding compliance with Blackout Report Recommendation 27, FERC Order 693, dated April 18, 2007, states:

768. " The Commission recognizes that dynamic line ratings are an innovative application, and directs the ERO to consider the comments from Valley Group in future revisions of this Reliability Standard."

The Valley Group

a Nexans company

Reliability and real time transmission line ratings

Executive summary

Real time transmission line ratings, also called dynamic ratings, are a modern but well-proven tool for enhancing the reliability and improving the capability of transmission systems. Real time rating systems, such as the CAT-1 Transmission Line Monitoring System, can be installed at the fraction of the cost of conventional transmission line enhancements. With The Valley Group's newly announced FASTCAT rapid deployment program, such enhancements can be fully operational within a few weeks. Thus, they provide the fastest and least expensive mitigation method in cases where capacity deficiencies are discovered by reviews or reliability audits; or happen because of unexpected economic conditions, system damage, or delays in construction projects.

In its Order 693, FERC recognized that dynamic line ratings are an innovative application and directed the ERO (NERC) to consider Valley Group's comments (to establish policies and procedures for real time ratings) in future revisions of this Reliability Standard. Work on revision of related standard FAC-008 is now under way.

What are transmission line thermal ratings?

Transmission line thermal rating is the highest current that a line can be operated at without violating safety codes, integrity of the line materials, or reliability of operation. In almost all cases, ratings are limited by line clearances. When the line current increases, the conductor heats, elongates, and causes the spans of the line to sag more. Because the minimum clearances are fixed by NESC or more stringent local codes, any event in which the line sags below its limiting clearance is a code violation.

The sags of the spans of a line depend on the conductor temperature and line construction. They can be calculated with reasonable engineering accuracy with modern line design programs. Sags of older lines are usually calculated less accurately and most transmission owners find it desirable to verify such sags with applicable survey techniques. Nevertheless, the limiting sag condition is generally identified as the maximum conductor temperature at which the line can be operated.

Obviously, conductor temperature depends on both the line current and the prevailing weather conditions. Traditionally, transmission lines have been operated based on fixed ratings, which have usually been established based on a set of very conservative assumptions, i.e. high ambient temperature, high solar radiation, and low wind speed.

The Valley Group

a Nexans company

How were rating conditions selected in the past and what is the situation now?

Until recently, transmission owners have been essentially free to select their own ratings conditions, based on the principle that the asset owners are responsible for the reliability and safety of their facilities. The dangers of such practices were highlighted by the 2003 Northeast Blackout investigations, which showed that adjacent utilities had very different rating practices. Recommendation 27 of the North American Blackout task Force report clearly tasked NERC to arrive at more uniform rating practices, as well as to consider the option of real time ratings.¹

In its rulemaking regarding reliability standards, FERC has significantly tightened rating requirements. While NERC has not yet proceeded to ballot the new FAC-008 standard, FERC's requirements stated in their October 2006 NOPR and in later clarifications make it clear that transmission owners are required to:

- Document underlying assumptions and make these assumptions subject to technical review;
- Develop ratings consistent with industry standards developed through open process. In practice, this means either IEEE or CIGRE standards;
- Ratings must include both normal and emergency ratings.

The NOPR gives a special reference to the CIGRE Technical Brochure 299, which was jointly developed by IEEE and CIGRE and gives guidance to the selection of ratings.² The guide presents transmission owners three recommended options:

- They can always use "base" ratings, which assume a high ambient temperature, full sun and a 2 ft/sec perpendicular wind;
- Based on qualified³ studies, they can assume higher wind speeds;
- They can use variable ratings, including real time (dynamic) ratings.

The guide also specifies that the proper selection risk should be based on 1-2% time-risk level, assuming that the lines would be continuously loaded at the rated current. It also shows that the

¹ Recommendation 27 states: "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." The explanation following this includes: "Further, the appropriate use of dynamic line ratings needs to be included in this review because adjusting a line's rating according to the changes in ambient conditions may enable the lines to carry a larger load while still meeting safety requirements."

² CIGRE Technical Brochure 299: *Guide for Selection of Weather Parameters for Overhead Bare Conductor Ratings*, available through CIGRE website www.cigre.org

³ The guide gives specific guidance on what qualifies a study as valid. For example, data based on typical airport sites is not acceptable for rating studies.

The Valley Group

a Nexans company

engineering safety margins for clearances should be 1-3 ft., depending on construction and age of the line.

Overview of present North American practice

A study of North American rating practices conducted several years ago indicates that the substantial majority of transmission owners apply rating practices reasonably close to the CIGRE TB 299 "base case". There are also a number of utilities which base their ratings at substantially higher risk level, as well as some which limit their line ratings to significantly more conservative values.

What is important to realize is that while rating practices have generally remained unchanged over the past few years, actual thermal risk levels have increased. Several studies which were made in the past justified higher rating assumptions (For example, the use of 3 ft/sec or higher wind speeds) by observing that higher wind speeds coincided with load peaks which happened at high ambient temperatures. This is no longer true regarding network lines, which may have high loads coinciding with time periods of low wind speeds. Nor do prior assumptions of the low probability of high line currents coincide with present practices. Many of today's transmission lines have very high loads quite often. This is evidenced by the continuing increase of TLR requests in many systems.

Impact of new mandatory reliability standards

The Sanction Guidelines of NERC, published March 12, 2007, as well as FERC's application of EPACT Penalties published January 18, 2007, indicate that reliability violations can be expected to carry severe penalties. It is important to note that:

- Penalties for intentional violations or concealment of violations are to be severe. Transmission owners/operators are to self-report any recognized violations.
- Economic choices to violate will carry penalties "sufficient to assure that entities...do not find it attractive to make economic choices... EPACT penalties were often several times that of economic gain.
- Immediately self-reporting violations, cooperation with investigation, and proposed rapid mitigation programs are considered in assessing penalties. As indicated by the EPACT ruling, termination of offending employees is also a mitigating factor!

What can we expect under the aegis of this new regulatory regime?

The Valley Group

a Nexans company

- Operators will operate strictly by the book. In the past, exceeding the normal or emergency rating by a minor amount was sometimes ignored.⁴ This is very unlikely to happen anymore.
- Therefore, operator interventions are likely to increase, and highly loaded systems will be dispatched more frequently out of merit. This will increase congestion costs.
- Even more significantly, the more frequent interventions must be handled under significant time pressure. Thus, possibilities of operator errors will likely increase, as systems are operated more frequently out of their normal planned state.⁵ This can have significant reliability consequences.

What are real time ratings?

Real time ratings (also called dynamic ratings) are ratings which are developed in real time based on actual weather and loading conditions, instead of using fixed assumptions. For example, CAT-1 Transmission Line Monitoring Systems monitor multiple line sections along the transmission line, from which data is transmitted to the utility's control center. At the center, computer algorithms calculate the normal, emergency, and transient ratings, provide them to system operators and keep an accurate log of events. This log can be used for analysis of events or verification of actions.

Depending on the length of line, instrumenting a line, including communications and software, typically costs on the order of \$100,000-\$200,000 per line, a small fraction of the cost of physical upgrades. CAT-1 Transmission Line Monitoring systems have been installed by over 100 utilities worldwide, with many of them used for real time ratings.

FERC recognizes the benefits of real time ratings

In FERC's Order 693, April 18, 2007, within the discussion of the new Facility Rating FAC-008 standard, FERC comments on the Blackout Report Recommendation 27⁶ and evaluates the comments by The Valley Group as follows:

767 "Valley Group notes that dynamic ratings offer a very powerful tool both for maximizing the capabilities of transmission paths and for avoiding unnecessary transmission line loading relief...Valley Group states that controlling unnecessary operator interventions with dynamic ratings

⁴ The transcript of operator discussions preceding the August 2003 Blackout included a statement in which one operator states that they should keep a close eye on a certain circuit which was at 103%. To which another operator answered: "Don't worry. I have seen it a lot higher!"

⁵ One of the primary underlying causes of the October 2006 major disturbance in Europe was that because of the high load of a line the operators decided to connect two buses at a substation. Instead of reducing the line current, it caused a current increase. Ironically, the operation was unnecessary, because current weather conditions were favorable and the actual capability of the line was higher than its book ratings.

⁶ Blackout Report at 162.

The Valley Group

a Nexans company

both increases the reliability of Bulk-Power system and improves its economy. Valley Group concludes that it would be highly desirable for the ERO to establish policies and procedures regarding dynamic ratings – as recommended by the Blackout Report and recommends that the commission include such guidance in its final rule”.

In response, the Commission Determination states:

768. "The commission recognizes that dynamic line ratings are an innovative application, and directs the ERO to consider the comments from Valley Group in future revisions of this Reliability Standard."

Real time ratings enhance reliability

Correctly selected overhead line ratings are conservative more than 98% of time, and in the remaining 2% of cases result in conductor sags and temperatures which exceed the design limits by less than reasonable engineering design margins.⁷ At the same time, this means that real time ratings provide higher line capabilities 98% of time. Usually, real time ratings exceed static ratings by at least 10-15% for 95% of time and by 20-25% for 85% of time.

Typically, corrective operator actions occur in situations when unanticipated events cause line loads to reach 90-100% of static ratings. These statistics show that most such actions are unnecessary, typically in 19 out of 20 times. Moreover, conventional operating procedures model dynamic actions imperfectly, requiring operators to anticipate events based on fixed time limits. Modern real time rating systems, such as the CAT-1 Transmission Line Monitoring System, monitor the changing ratings and loads, providing advance dynamic warnings and accurately predicting to the operator the time when the line load and its capability converge. This means that the operator can select the most appropriate and the least disruptive method of correction.

Even in well-designed systems, exceptional conditions may cause line overloads. The August 2003 blackout was such an event. Analysis of weather data during the time preceding the blackout indicated extraordinarily calm weather⁸, implying high conductor temperatures and large line sags. If real time rating data had been available for the area's operators, they would have observed unusually high conductor temperatures, which would have warned them of a potentially dangerous situation.

⁷ See CIGRE TB 299, Executive Summary, Section 1.2 (Technical Background)

⁸ See "Fried Wire?" Public Utilities Fortnightly, pp.39-42, December 2003. The report observes that the probability of wind speeds being less than those used by the local utilities' assumptions was between 18-35%.

The Valley Group

a Nexans company

Real time ratings lessen the operators' work load and give them confidence

Many utility operators are reluctant to embrace new systems, fearing that such systems provide them with increased data clutter and increase their workload. This is not the case regarding real time rating systems. Real time rating systems operate "in the background" and provide alarms only when specific conditions occur - or when the operators want to interrogate the systems in anticipation of system changes. Thus, in reality, modern real time rating systems, such as CAT-1 Transmission Line Monitoring System, reduce the operators' workload and give them increased confidence in proper actions.

Moreover, the new regulatory framework requires that operators balance reliability regulations with close adherence to EPACT market rules. Many operating events must be documented and defensible. Curtailment of a generator can easily lead to disputes concerning the necessity of such actions. Data from real time rating systems can provide important support for such actions. For example, if the operator needs to change dispatch, he can use real time data of the loads and ratings of the lines as firm justification of his or her actions.

FASTCAT - the fastest solution to mitigate certain reliability problems

Unexpected things happen. Equipment casualties or damage to lines may cause system capability problems. NERC audits or peer reviews may indicate problems in line rating assumptions. New reliability rules requires self-reporting of such deficiencies and places high importance on credible mitigation plans. The fastest solution to facility rating issues is the CAT-1 Transmission Line Monitoring System and the recently established FASTCAT rapid deployment program. This rapid delivery and installation program allows you to mitigate transmission line capability problems in a few weeks- instead of months or years required by conventional solutions - and to achieve the results at a fraction of the cost of reconductoring or structural changes.

Additional Information:

For additional information, contact the author at tap.seppa@cat-1.com or call him at (203) 431-0262. You can also find more information at www.cat-1.com