Improving Efficiency with Dynamic Line Ratings

Successes from New York Power Authority's Smart Grid Demonstration Project

Introduction

Comparing dynamic line ratings (DLR) to static line ratings — is a bit like comparing a high-tech video to a black-and-white photograph. Where static line ratings provide seasonally dependent, conservative estimates of overhead transmission-line current capacity, DLR provides real-time, play-by-play data about the effects of air temperature, solar radiation, and wind speed and direction on the transmission line, such as conductor temperature and sag (Figure 1).[1] Armed with this crucial information, along with transmission line physical characteristics, the grid operator is better equipped to target power needs precisely, while safely operating lines that are nearing their thermal limits.

> The project confirmed the presence of real-time capacity above the static rating, in most instances, with up to 25% additional usable capacity made available for system operations.

Line ratings are critical to prevent excessive power-line drooping, which could cause a fault if lines contact vegetation or other objects. The static rating indicates the maximum amount of current that the line's conductors can carry (under a set of assumed weather conditions) without violating clearance safety codes or damaging the conductor. With line ratings, operators can determine how much power can safely be transmitted over a period of time. For example, a line might be rated for 1,000 kilowatts over four hours. Temporary excursions beyond the limit may not cause excessive drooping, but continued operation above the limit is a concern for transmission operators. Dynamic line ratings indicate increased capacity of power lines under favorable weather conditions, such as when it is cool,

Figure 1. Dynamic Thermal Circuit Ratings provide real-time information about capacity in overhead transmission lines, like the one pictured below. *Image courtesy of NYPA.*

[1] When static ratings are adjusted daily, hourly, or even more frequently, to account for different ambient temperatures, they are called ambient-adjusted ratings. Although some transmission owners consider ambient-adjusted ratings to be "dynamic," ambient-adjusted ratings are not considered true dynamic because the only time-sensitive data they consider is ambient air temperature measurements.

cloudy or windy[2] (for an illustration, see Figure 2). These ratings can be used as a check on static or ambient-adjusted ratings, or can be used to allow increased power delivery.

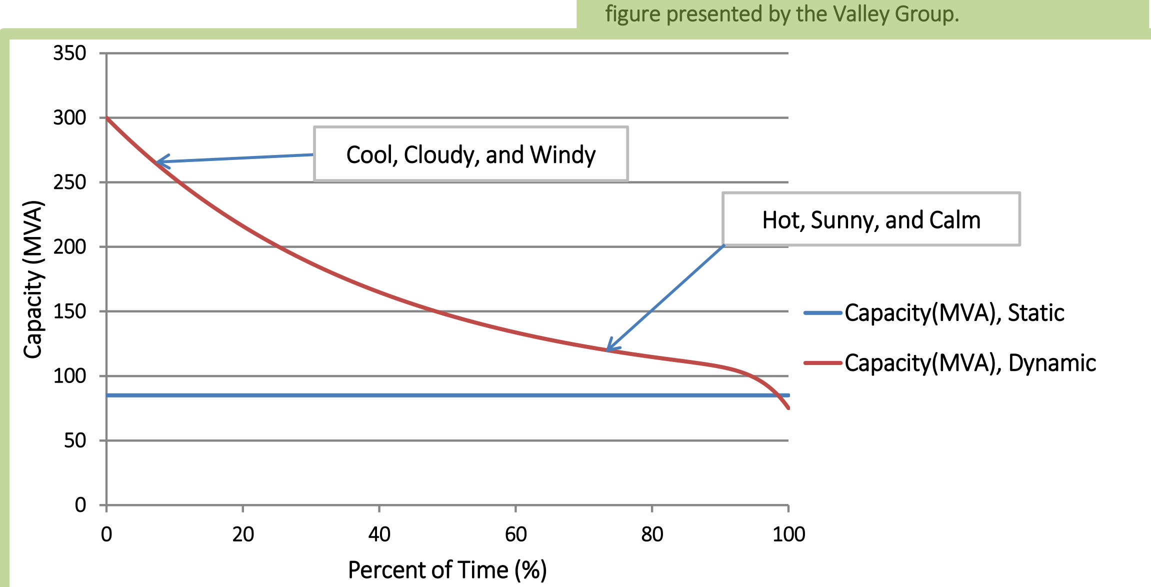
To develop best practices for applying DLR systems, the New York Power Authority (NYPA) recently demonstrated DLR technologies under a cooperative agreement from the U.S. Department of Energy's [Smart Grid Demonstration Program] (SGDP). Under this cooperative agreement, in 2009, NYPA received $720,000 in Recovery Act funding. With a total budget of $1.44 million, NYPA worked with the Electric Power Research Institute (EPRI), to demonstrate how DLR can be used to correlate wind generation with increased transmission-line capacity. Since NYPA used technologies and approaches that EPRI developed, its project was also a test bed for EPRI's DLR technologies.

Project goals included determining whether DLR:

1. Can be assessed accurately by weather and conductor sensing equipment, and tension and sag measurements, which indicate the condition of the line.
2. Is more reliable and economical than ambient adjusted ratings.
3. Can positively affect the transmission of wind energy.

Located in White Plains, New York, NYPA is the largest state public power organization in the country, serving more than 800 customers, including 500 business and industrial customers, and government customers such as the city of New York[3]. NYPA's assets include 16 generating facilities and more than 1,400 circuit-miles of transmission lines.

Figure 2. Dynamic ratings are typically higher than static ratings, with cool, cloudy, and windy conditions leading to the largest difference. Illustrative, based on figure presented by the Valley Group.



[2] Sandy Aivaliotis, The Valley Group, Dynamic Line Ratings, Enhanced Power Flow for the Smart Grid, Slide 11, June 24, 2010, available by internet search, accessed 2/10/15

[3] NYPA, Annual Report, 2013, http://www.nypa.gov/PDFs/AnnRpt2013/B03536BA799F3F2998132DD1CB087896/AnnRpt2013.pdf

Specifically, NYPA's project focused on three types of DLR equipment, including:

- EDM, International, Inc. Video Sagometers which measure conductor sag.
- Temperature and Load Sensors developed by EPRI to directly measure conductor temperature and current. EPRI line inclination sensors were used in an experimental fashion as an independent check on line sag.
- The Pike ThermalRate system which uses replicas of a conductor to mimic how the line behaves thermally in the local weather conditions.

Together, this equipment feeds the control system that determines dynamic line ratings. Weather stations were used as an inexpensive check on the line ratings obtained from the above sensors and systems.

What these results show, according to NYPA researchers, is that wind farm output affects dynamic ratings and load when weather conditions are comparable between nearby transmission lines and wind farms.

Increased Capacity

NYPA's project confirmed the presence of real - time capacity above the static rating, in most instances, with up to 25 percent additional usable capacity made available for system operations.

Better Knowledge, Increased Efficiency

NYPA installed this equipment on three 230 kilo-volt transmission lines close to wind farms in New York State. For each line site, researchers selected open, mostly level terrain to minimize wind-blocking by trees, buildings, or other objects. The 710-foot-long span on the Moses-Willis line in Massena traverses inactive rural land and low hayfields, while the 545-foot span on the same line, 36 miles away, near Chateauguay, is near pastures, natural forests and wetlands. Finally, the 580-foot span on the Willis-Ryan line

Figure 3. Dynamic ratings, static rating, and load compared over a 24-hour period for a particular transmission line. *Image courtesy of NYPA.*

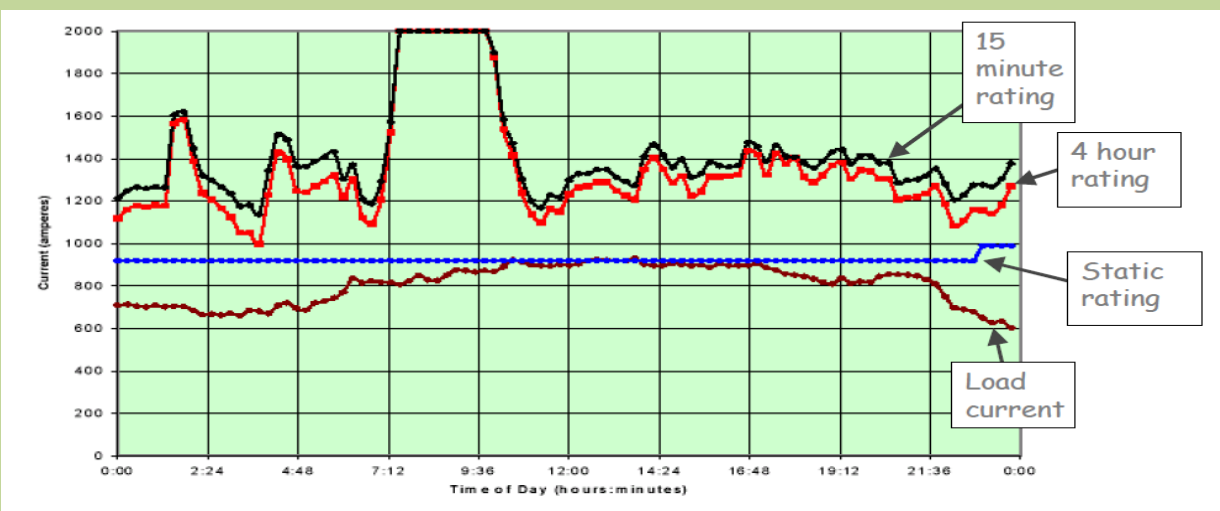
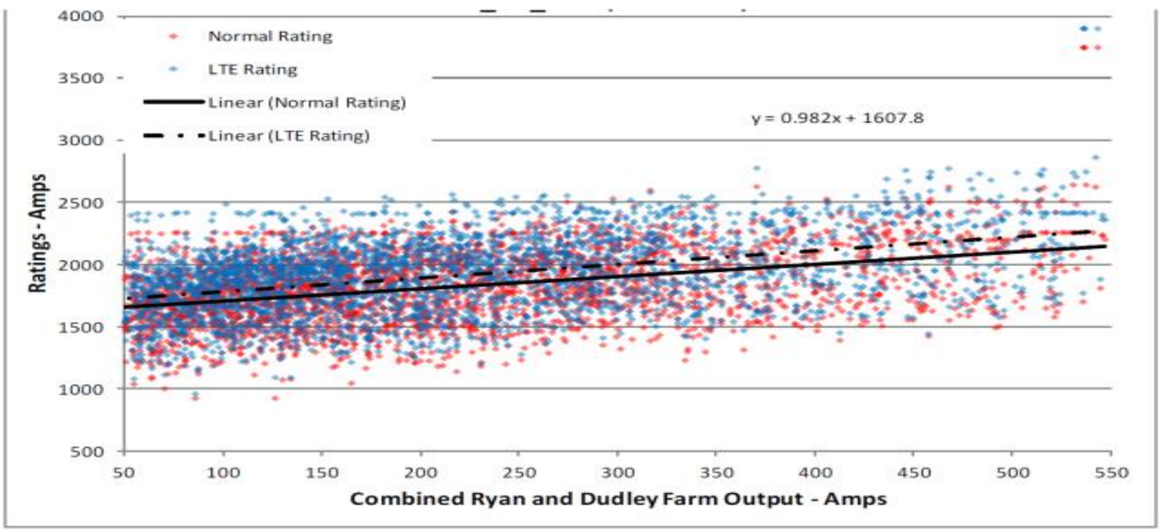


Figure 4. Wind farm output is positively correlated to dynamic line ratings, although the correlation is weak. "LTE Rating" refers to long-term-emergency rating. *Image courtesy of NYPA.*



also near Chateauguay spans cultivated rural areas. With information from these three line segments, NYPA showed that DLR records a greater capacity than static line ratings which are designed so that the load current exceeds the rating less than 2 percent of the time (Figure 2). This "98 percent reliability criterion" ensures that the lines are not overheated.[4] DLR could allow more power to be transmitted through lines most of the time, while maintaining the same 98 percent reliability criterion, a direct consequence of the increased situational awareness provided by DLR. Data analyses showed that wind farm output is positively correlated to dynamic line ratings, although the correlation is weak (Figure 4).[5] For all three study lines, researchers identified correlation coefficients ranging from 0.373 to 0.462 in normal weather conditions.

What these results show, according to NYPA researchers, is that wind farm output affects dynamic ratings and load when weather conditions are comparable between transmission lines and nearby wind farms.

Technology Transfer

By the end of NYPA's SGDP project in January 2013, NYPA had successfully transferred a fully operational DLR to its own control center. As part of this effort, researchers gave staff a live demonstration of the technology, complete with hands-on training, which the project showed is critical to establishing DLR technology. Researchers found that data must be accurate and secure before it reaches the control room, if system operators are to trust, and, eventually, accept, DLR technology.

[4] DOE Topical Report: Dynamic Line Rating Systems for Transmission Lines, April 25, 2014, https://www.smartgrid.gov/sites/default/files/doc/files/SGDP%20Transmission%20DLR%20Topical%20Report_04-25-14_FINAL.pdf, accessed 11/18/14

[5] "A correlation greater than 0.8 is generally described as strong, whereas a correlation less than 0.5 is generally described as weak." Source: http://mathbits.com/MathBits/TISection/Statistics2/correlation.htm

At this time, NYPA's SGDP results, including the DLR server, modems, field instruments, ratings software, and data, are housed at NYPA. Future transmission line loadings are forecasted to increase in the future, and these technologies can mitigate damage to lines while increasing line capacity.

Next Steps

Now, NYPA plans to investigate how to combine DLR technologies with data from phasor measurement unit sensors, which measure voltage, current, and phase angle on the grid.

In addition, NYPA plans to use the large amounts of data collected during its SGDP project to help establish ratings guidelines for transmission lines. The New York State Energy Research and Development Authority (NYSERDA) awarded NYPA a grant to install Nexans' CAT-1 System on transmission lines in central New York. This installation will allow NYPA to research data communication and DLR management options, with a view to potential integration into NYPA operations[6]. NYSERDA is supporting half the funding for the $1 million project, leaving internal NYPA funding responsible for the remainder of the project costs. NYPA has installed the CAT-1 equipment on lines that have frequent heavy loads, which NYPA felt would benefit the most from a DLR system. The project is meant to provide a baseline assessment to examine potential synergies between DLR data and phasor measurement and unit data.

Further Reading

For more information about NYPA's demonstration project, read its final technology performance report, published on the SmartGrid.gov website. A more detailed description of SGDP can be found at SmartGrid.gov.

Under the American Recovery and Reinvestment Act of 2009, the U.S. Department of Energy and the electricity industry have jointly invested over $1.5 billion in 32 cost-shared Smart Grid Demonstration Program projects to modernize the electric grid, strengthen cybersecurity, demonstrate energy storage, improve interoperability, and collect an unprecedented level of data on smart transmission, distribution operations, and customer behavior.

[6] Stefopoulos, G. of NYPA, and Cleaver, T. of NEXANS, New York Power Authority's Experience with Dynamic Line Ratings, EMMOS Users conference, September 7-10, 2014, http://www.emmos.org/prevconf/2014/NYPA%E2%80%99s%20Experience%20With%20Dynamic%20Line%20Rating_EMMOS%20Conference.pdf, accessed 1/7/2015.