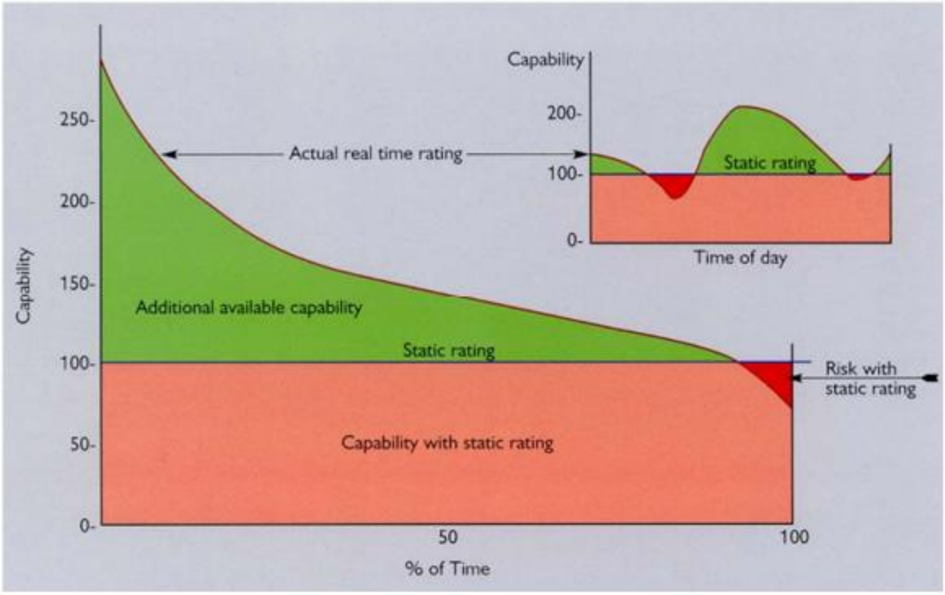
Americans for a Clean Energy Grid

Dynamic Line Ratings

Ampacity of an overhead transmission line is the maximum electrical current that the transmission line can carry under ideal external conditions without: a) reducing the tensile strength of the conductor due to annealing (heating followed by slow cooling), or b) exceeding the maximum sag beyond which minimum electrical clearance requirements to ground and to objects or other conductors below the line are violated [3]. To guarantee that the tensile strength or the clearance requirements of a transmission lines are not violated under time-varying external conditions, transmission lines are given line ratings that determine their maximum power carrying capacities [3]. The line rating of a transmission line is determined by the strength of the current flowing through it, conductor size and resistance, conductor clearance to ground, and ambient weather conditions of temperature, wind speed and direction, and solar radiation [4].

The current-carrying capacity of a transmission line is influenced by line heating and cooling [3]. When current flows through a transmission line, heat is dissipated because of work done against the resistance of a conductor. Current amplitude and heat dissipation have a squared relationship; in other words, doubling the current amplitude quadruples the heat dissipation. When a transmission line heats up, it expands and sags, and its clearance from the ground and/or other conductors decreases. All transmission lines have a sagging limit, and sags beyond this limit are dangerous for public safety. If a transmission line is sagging close to the ground, it can potentially electrocute passersby. Beyond the heat dissipation effects of an increase in flowing current, atmospheric conditions can affect heat dissipation, and thus, line sag, too. Hot air temperatures and solar radiation raise the temperature of a transmission line and cause sag. On the other hand, cooler temperatures lower the temperature of a transmission line, and wind can carry away heat being dissipated by transmission lines; in both cases, the sag of transmission lines decreases. In general, more current can flow through transmission lines on a day with low temperature, clouds (low solar radiation) and wind blowing.

Line ratings were first discussed in a 1930 study in the journal *General Electric Review*, which assumed 40 degree Celsius ambient temperature, high solar radiation, and 2 feet per second wind speeds perpendicular to the conductor [3]. In those days, such conservative assumptions were necessary due to the lack of technology capable of constantly recalculating line ratings based upon changing weather conditions. The idea was that if a transmission line were rated according to the worst possible weather conditions, then the probability of exceeding the line rating on any given time during a day would be minimized. Today, line ratings are *still* commonly defined using these conservative weather assumptions [3]. Yet, we know that weather conditions change significantly during the day, and hence, their line ratings also vary considerably. Static line ratings based upon conservative weather conditions therefore lead to underutilization of transmission lines, because suboptimal weather conditions rarely last an entire day. As discussed before, transmission lines can carry more current in the presence of moderate to high winds because the wind carries away the heat being dissipated by the transmission lines. But if a transmission line has static line ratings, grid operators cannot put more current on that transmission line even though the winds safely permits it. The graph to the right depicts the underutilization of transmission lines due to static line ratings. [3]

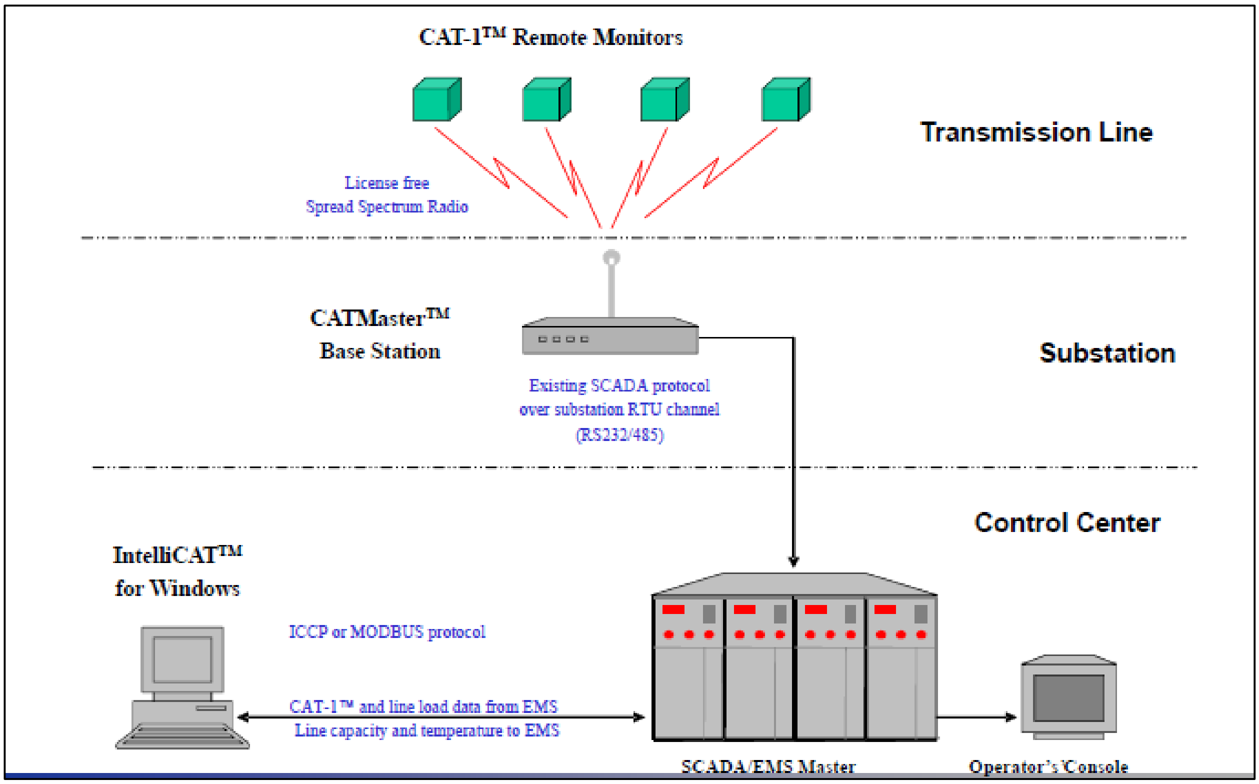


Small changes in weather conditions can have a considerable impact on the ampacity of a transmission line. This can be demonstrated with an example laid out by Sandy K. Aivaliotis, Senior Vice President of The Valley Group: assuming a 20-mile long aluminum conductor steel reinforced (ACSR) transmission line with a static line rating of 787 amperes at 40 degrees Celsius, zero wind, and mid-day summer, we can see changes in the ampacity under various changes in weather conditions in the table below [2]:

	Change in Ampacity	**New Ampacity**
Ambient Temperature		
2°C fluctuation	+/- 2 % capacity	
10°C drop in ambient	+ 11 % capacity	874 Amperes
Solar Radiation		
Cloud shadowing	+/- a few percent	
Middle of night	+ 18 % capacity	929 Amperes
Wind Increase of 1 m/s		
45° angle	+ 35 % capacity	1060 Amperes
95° angle	+ 44 % capacity	1130 Amperes

How do we address this underutilization of transmission lines arising from static line ratings? Dynamic line ratings. Dynamic line rating (DLR) technology uses a real-time monitoring system to constantly calculate the varying line rating of a transmission line due to the changes in weather conditions. DLR technology measures the tension of a transmission line to determine the dynamic line ratings for that transmission line [4]. Because transmission lines exist in a spatially varying environment, line tension, a spatial measure, most accurately represents that current state of a transmission line [4]. Unlike line tension, line sag and temperature are point measures and are not suitable for calculating dynamic line ratings [4].

Tension of transmission lines accounts for all environmental factors [4]. Measuring line tension is the best way to capture spatial variability of wind, solar radiation and air temperature [4]. Tension-based DLR systems use remote tension monitoring units to send real-time line ratings to a utility's supervisory control and data acquisition system (SCADA) or energy management system (EMS). CAT-1 of Nexans is the most popular tension-based DLR system and is used by over two-thirds of the 30 largest utility companies in North America [3]. According to Nexans, there are over 300 CAT-1 systems installed by over 100 utilities in more than 20 countries on 5 continents [3]. The image below provides a high-level representation of Nexans' CAT-1 tension-based DLR system.



[2]

Tension-based DLR systems offer numerous advantages including congestion relief, asset protection, increased integration of wind energy, improved transmission efficiency and wide area situational awareness. [2]

- **Congestion relief:** Unmonitored tension lines are operated at conservative line ratings, which can lead to underutilization of the existing transmission lines. With DLR systems, grid operators can take advantage of even small increases in line ratings resulting from favorable weather conditions and put more load on specific transmission lines to avoid congestion at other transmission lines. Thus, DLR systems can help utility owners avoid congestion costs.
- **Asset protection:** DLR systems provide real-time data to grid operators who can make fast and informed decisions in case of sudden changes in weather conditions. For

example, if the wind in some area dies down suddenly, the grid operators can reduce the load on the transmission lines in that area to avoid damaging the transmission lines. DLR systems can prolong the life of existing transmission lines by reducing the chances of line overloading.

- **Increased integration of wind energy:** Wind generation is, obviously, located in windy areas and can benefit considerably from dynamic line ratings. A slight increase of 2 feet per second in wind speed can increase the ampacity of a transmission line by 15% [2]. On a windy day, DLR systems can allow grid operators to integrate more wind energy into the system because they would no longer be restricted by conservative static line ratings.
- **Transmission efficiency:** DLR systems can increase the power capacity of the existing grid anywhere from 10%-30% for more than 90% of the time [2]. DLR systems increase transmission efficiency by optimizing the use of transmission network and maximizing the capacity of transmission paths.
- **Wide area situational awareness:** DLR systems deployed over a vast area can provide grid operators with a more precise, higher resolution image of a large portion of the transmission network. If sudden changes in weather in one region change the line ratings there, grid operators can take actions to manage transmission load in neighboring regions to avoid grid stress.

As part of the Department of Energy's Smart Grid Demonstration Project, 2 DLR projects were installed in New York and Texas [5]. The Electric Power Research Institute (EPRI) developed the DLR system for the New York Power Authority (NYPA), while Nexans developed the DLR system for Oncor in Texas [5]. The New York DLR project had an installed cost of $481,000 and a total project budget of $1,440,000 for three 230 kV transmission lines [5]. The Texas project covered five 345 kV and three 138 kV transmission lines; it had an installed cost of $4,833,000 and a total project budget of $7,279,166 [5]. Although DLR projects are expensive, the increase in transmission capacity justifies their high cost. The New York project increased the real-time capacity of the transmission lines by 30%-44% on average [5]. In Texas, the real-time capacity of the 138 kV lines increased by 8%-12% on average, while the 345 kV line experienced 6%-14% increase in real-time capacity on average [5]. Additionally, DLR projects help utility companies avoid congestion costs. On average, line congestion costs the Oncor transmission system in Texas about $250,000 per line per day [5]. Installation of DLR systems on these lines can reduce or eliminate the daily congestions costs for Oncor transmission system and other utilities.

After successfully completing the DLR demonstration project, Oncor deployed additional DLR systems in the Odessa-Midland region of Texas [1]. As part of its $5 billion capital investment program, Oncor evaluated DLR as a potential key component for improving the reliability and efficiency of its infrastructure [1]. Successful completion of the New York and Texas DLR demonstration projects and the deployment of additional DLR projects in Texas proves that DLR technology can be a potential key component of improving the resiliency of our existing grid.

References

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