# The Benefits of Dynamic Line Rating in Reducing U.S. Transmission Congestion Costs

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## Abstract

*Dynamic Line Rating (DLR) systems leverage real-time weather data to safely increase transmission line ampacity, promising to enhance utilization of existing U.S. grid infrastructure while saving billions in congestion costs and reducing curtailment.*


## 1. Congestion, Curtailment, and Dynamic Line Ratings

Congestion occurs when a transmission line reaches its thermal rating due to high current, preventing additional power flow that would cause dangerous sagging. This forces curtailment of cheap (often renewable) generators, driving up wholesale electricity prices that are ultimately passed to ratepayers. Transmission congestion costs approximately $13 billion annually (Sherman, 2023 [1]), and impedes renewable energy integration, prompting interest in Grid Enhancing Technologies (GETs) as cost-effective alternatives to building new infrastructure. Dynamic line ratings (DLRs), a key GET, utilize real-time weather data to safely adjust the ampacity of existing transmission lines, allowing more electricity to flow when ambient conditions permit and thereby increasing grid capacity without the expense and delays of new construction (McGeady 2024 [2]).

Implementation of DLRs during peak demand periods reduces both congestion costs and the risk of blackouts (Lyu et al. 2023 [3]). Case studies show that just 2 mph of wind can increase line ampacity by 30-40%, with additional wind providing diminishing returns in a logarithmic pattern (Fenton et al., 2017 [4]; IRENA, 2020 [5]). Other research indicates that safe ampacity increases of 20% or more are common (U.S. Department of Energy, 2019 [6]). Lawrence Berkeley National Laboratory (LBNL) analyzed potential consumer savings from congestion relief and found a minimum annual savings of $20,000 per MW per year (Millstein et al., 2022 [7]).

## 2. Comparing Static and Dynamic Line Ratings

We conduct a back-of-the-envelope calculation of the savings from implementing DLRs, based on reducing wire congestion when wind cools the wires, and point out existing data challenges. Our analysis focuses exclusively on wind speed impacts, while omitting temperature effects. NOAA research (Fenton et al. 2017 [4]) indicates that wind has a substantially greater influence on ampacity—a maximum effect of +2,300A for wind versus only +200A for temperature.

We use the U.S. Transmission Lines database, which provides critical information on locations, voltage ratings, and overhead/underground status of transmission infrastructure (CMRA, 2022 [8]). A significant limitation is the lack of public data regarding line congestion. While utility market monitors publish total congestion costs and congestion as a percentage of Locational Marginal Pricing (LMP), these metrics cannot effectively inform calculations of potential congestion relief from increased transmission capacity.

In the absence of static ampacity ratings for individual lines, we use representative values based on typical U.S. transmission infrastructure. American transmission lines predominantly use Aluminum Conductor, Steel Reinforced (ACSR) wires, with "Hawk" and "Drake" types being common (static ampacities of 659 and 907 Amperes, respectively). This analysis employs the "Peacock" ACSR specification as a representative middle ground, with a static ampacity of 760 Amperes, which falls within the typical range for long-distance transmission lines (Priority Wire & Cable, n.d. [9]). Starting with a baseline static ampacity of 760 Amperes, we apply a wind speed-based multiplier formula (Fenton et al., 2017 [4]; IRENA, 2020 [5]):

$$[\text{Static Rating}] \times (0.371 \times \ln([\text{Wind Speed mph}] + 1.003) + 1.042) \quad \text{[Eq.1]}$$

Equation 1 demonstrates that wind speed increases line ampacity logarithmically, with the most significant benefits occurring in the first few additional mph. We employ a conservative wind speed estimate of 4 mph, representative of the least windy U.S. regions (NCEI, 2024 [10]). Since manufacturer-provided static line ratings typically assume 2 mph wind conditions, our 4 mph wind speed assumption represents an additional 2 mph of wind cooling the wire. For real-time or day-ahead DLRs' calculations, precise location data should be paired with current or forecasted wind speeds from the NOAA's extensive network of weather stations (US Department of Commerce, 2024 [11]). Thus, Eq. 1 becomes:

$$[760A] \times (0.371 \times \ln(2 + 1.003) + 1.042) = 1{,}101.96\text{A} \quad \text{[Eq.2]}$$

Using an average static ampacity of 760A, Eq. 2 yields an average dynamic ampacity of 1,101.96A. Our data includes the actual voltage ratings of almost all overhead transmission lines in the United States, so to find a line's static and dynamic MW power rating, we multiply the real voltage rating of the wire by the assumed static ampacity [Eq.3] and the calculated dynamic ampacity [Eq.4], respectively. This process generates both static and dynamic MW ratings for each transmission line using the formulas:

*Static MW rating = Voltage × assumed static ampacity* [Eq. 3]

*Dynamic MW rating = Voltage × calculated dynamic ampacity* [Eq.4]

To find the increased power offered by our dynamic ratings, we calculate the difference between our higher dynamic MW rating and the lower static MW rating. Finally, to quantify the economic benefit of increased transmission capacity, we multiply the difference between each line's dynamic and static MW ratings by the $20,000/MW annual savings factor identified in the LBNL (2020 [7]) study.

## 3. A Multi-Billion-Dollar Opportunity with DLRs

Our results suggest an average potential increase in line ampacity of 45% across U.S. transmission infrastructure, meaning that throughout the year, existing transmission lines could carry 45% more electricity than currently permitted. This increase in U.S. transmission capacity could be achieved without building new infrastructure—a significant advantage considering transmission lines can cost hundreds of thousands of dollars per mile. This substantial untapped capacity exists primarily due to overly conservative static ratings that fail to account for actual environmental conditions surrounding the lines. DLRs would substantially decrease the congestion costs incurred due to "safe" but inaccurate static line ampacity ratings.

Estimated congestion savings are considerable: an average value of $87,318.58 per wire. This translates to total annual U.S. congestion savings of approximately $67.7 billion. This multi-billion-dollar opportunity has significant implications for the electricity market and consumer costs, showing that DLRs represent an exceptionally cost-effective solution. In the current system, absence of DLRs creates market distortions where zero marginal cost generators are curtailed. Clearly, the effectiveness of DLRs varies with regional wind patterns. For example, the American South has consistently lower wind speeds than other U.S. regions (NOAA, 2025 [12]). Additionally, if transmission lines are underground, as is common in densely populated urban areas and environmentally sensitive regions, there is no opportunity for DLR benefits.

It must be noted that our simplified estimate substantially exceeds the previously cited total U.S. congestion costs of $13 billion by a factor of 5.2. This discrepancy stems from several factors. Most significantly, the LBNL (2020) study focused on strategic placement of new transmission lines between nodes with known price differentials—an assumption we were forced to apply across all existing transmission lines. There was also a lack of data on several key variables: the percentage of time each wire experiences congestion, the actual price differentials across transmission paths, and granular data on congestion costs for specific lines at specific times. These data are tightly kept by utilities, which are under no obligation to release them.

Despite these limitations, our findings confirm that increasing transmission capacity would substantially reduce congestion costs, allowing better integration of intermittent resources. Implementing DLRs would undoubtedly deliver significant economic value.

## 4. Regulatory Hurdles

The more significant obstacle to DLR integration stems from the cost-plus pricing model that dominates U.S. utility regulation. Under this framework, utilities receive a guaranteed percentage return on their capital expenditures (Cicala, 2022 [13]), creating an incentive structure that discourages investment in cost-effective system improvements. Instead, utilities are financially motivated to pursue expensive capital projects that maximize their absolute returns through larger investment bases. DLR implementation—potentially achievable through primarily software-based solutions—offers limited opportunity to increase the rate base and, consequently, investor returns. This economic misalignment explains why DLR adoption has been primarily driven by regulatory mandates or reliability concerns rather than economic considerations (Mirzapour et al., 2024 [14]).

FERC Order 1920 represents a significant regulatory advancement that requires transmission providers to plan proactively for long-term demand increases and consider "advanced transmission technologies," including GETs and DLRs (Hewett, 2024 [15]). While this order will likely accelerate GET adoption, it does not address the fundamental barrier to DLR implementation that stems from the Averch-Johnson effect.

Finally, while we primarily focused on supply-side solutions through DLRs, there are significant complementary opportunities in demand response programs, energy storage technologies, microgrids, and other innovations that could work alongside DLRs to further reduce congestion, minimize curtailment, and enhance grid efficiency.

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