# Dynamic Line Rating for Enhanced Transmission Capacity, Security, and Economic Operation: A Case Study of the IEEE 118-Bus Power System

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**ABSTRACT**

*Dynamic Line Rating (DLR) offers a practical means of improving the use of existing transmission infrastructure where Static Line Rating (SLR) may underestimate actual line capacity under favourable weather conditions. This study evaluated the effectiveness of DLR in enhancing transmission capacity, system security, and economic operation of the IEEE 118-bus power system. A weather-based DLR model was developed for the selected branch 141 between buses 89 and 92, and its performance was compared with SLR over 24 hourly weather intervals. The assessment covered line loading, voltage profile, active power losses, congestion, operating cost, N-1 contingencies, and uncertainty. Results showed that DLR increased line capacity by an average of 49.59%, with improvements ranging from 8.06% to 82.91%, while congestion reduced by 87.50%. Voltage profile, losses, and operating cost remained essentially unchanged. All 177 connected N-1 contingencies converged, although some post-contingency overloads remained. The uncertainty-informed 5th-percentile rating of 751.34 A exceeded the static rating of 709.88 A. The study recommends combining DLR with reliable weather monitoring, uncertainty margins, and N-1 security assessment for safe operational application.*

**KEYWORDS**

*Dynamic Line Rating, Transmission Capacity, N-1 Contingency, Transmission Congestion*

## I. INTRODUCTION

### *A. Background of the Study*

Electric power transmission systems must deliver electricity reliably while operating within thermal, voltage, and stability limits. With increasing electricity demand and more variable power flows, improving the use of existing transmission infrastructure has become important. Although new transmission lines can increase network capacity, their development is often costly and time-consuming. This has encouraged the use of operational approaches that can release additional capacity from existing assets without reducing system security.

A major limitation of overhead transmission lines is their thermal rating. Current flow produces heat within the conductor, while convection and radiation remove heat and solar radiation contributes additional heating. Consequently, the safe current-carrying capacity of a transmission line depends strongly on weather conditions such as ambient temperature, wind speed, wind direction, and solar radiation. IEEE Standard 738 provides an established basis for determining conductor capacity from these thermal and environmental conditions.

Conventional transmission operation commonly relies on Static Line Rating (SLR), which assigns a fixed thermal limit based on predetermined environmental assumptions. Although this approach provides a conservative operating margin, the assumed conditions may be more severe than the actual weather for much of the time. As a result, part of the conductor's available capacity may remain unused. Bhattarai et al. (2018) demonstrated that weather-dependent ratings can reveal additional transmission capacity beyond that available under static assumptions. Dynamic Line Rating (DLR) addresses this limitation by adjusting the allowable line current according to actual or forecast weather conditions and conductor thermal behaviour. Favourable cooling conditions, particularly higher wind speeds and lower ambient temperatures, can increase the permissible current, while unfavourable conditions can reduce it. DLR therefore provides a more realistic representation of line capacity than a fixed rating.

Beyond increasing capacity, DLR can influence network congestion, economic dispatch, and system security. Qiu and Wang (2015) showed that dynamic ratings can provide additional flexibility in congestion management. However, the use of increased transmission capacity must also satisfy N-1 security requirements, since line outages may redistribute power flows and create post-contingency overload. In addition, uncertainty in weather measurements and forecasts can affect DLR reliability, making probabilistic assessment important for safe operation. Accordingly, this study evaluates DLR on the IEEE 118-bus system by comparing it with SLR over 24 hourly weather intervals. The assessment considers transmission capacity, line loading, voltage profile, power losses, congestion, operating cost, N-1 security, and the effect of weather and monitoring uncertainty.

### *B. Statement of the Problem*

Static Line Rating may underestimate actual transmission capacity because it relies on fixed environmental assumptions, leading to unused capacity and congestion. Although Dynamic Line Rating can provide additional capacity, its benefits must be assessed against voltage performance, losses, operating cost, N-1 security, and weather uncertainty to ensure reliable system operation.

### *C. Aim and Objectives of the Study Aim*

The study aims to evaluate the effectiveness of Dynamic Line Rating in enhancing transmission capacity, system security, and economic operation of the IEEE 118-bus power system.

*D. Specific Objectives*

The specific objectives are to:

- Develop a weather-based DLR model for the selected transmission line.
- Compare DLR and Static Line Rating in terms of transmission capacity and line loading.
- Assess the impact of DLR on voltage profile, power losses, congestion, and operating cost.
- Evaluate system security under N-1 transmission contingencies.
- Examine the effects of weather and monitoring uncertainties on DLR reliability.

## II. LITERATURE REVIEW

*A. Overview of Power Transmission Systems*

Power transmission systems transfer electricity from generation sources to load centers through high-voltage networks. Their operation must satisfy thermal, voltage, and security limits while responding to changing demand and generation patterns. Power-flow and optimal-power-flow analyses are widely used to evaluate these operating conditions.

*B. Transmission Line Thermal Limits and Ampacity*

Transmission-line ampacity is the maximum current a conductor can carry without exceeding its allowable temperature. It depends on conductor characteristics, electrical heating, solar gain, and heat dissipation through convection and radiation under prevailing weather conditions.

*C. Static Line Rating*

Static Line Rating assigns a fixed thermal limit to a transmission line using assumed conductor and weather conditions. Although simple and conservative, it may underestimate actual line capacity when real weather conditions are more favorable. This can leave usable transmission capacity unexploited and contribute to unnecessary congestion.

*D. Dynamic Line Rating*

Dynamic Line Rating adjusts transmission-line capacity according to changing weather and conductor conditions. It increases the permissible current when cooling is favorable and reduces it when conditions are less favorable. DLR therefore provides a more realistic estimate of available line capacity than a fixed static rating.

*E. Weather Parameters Affecting Dynamic Line Rating*

DLR is strongly influenced by ambient temperature, wind speed, wind direction, and solar radiation. Higher wind speed generally improves conductor cooling and increases ampacity, while high ambient temperature and solar heating can reduce allowable current. Their combined effect causes DLR to vary over time.

*F. Conductor Thermal Behavior and Heat Balance*

Conductor temperature depends on the balance between heat gained and heat dissipated. Electrical resistance and solar radiation produce heating, while convection and radiation provide cooling. Under steady-state conditions, these effects balance at a particular conductor temperature, forming the basis for ampacity calculation.

*G. Application of DLR for Transmission Capacity Enhancement*

Dynamic Line Rating can increase the usable capacity of existing transmission lines without immediate network expansion. By using actual weather conditions instead of conservative fixed assumptions, DLR can identify periods when higher current can be transferred safely. Bhattarai et al. (2018) reported that real-time ratings exceeded seasonal ratings for much of their study period, with an average improvement of about 22%. The achievable gain, however, depends on local weather and conductor characteristics.

*H. Dynamic Line Rating and Transmission Congestion*

Transmission congestion occurs when network limits restrict the desired transfer of power. Since thermal limits are major constraints in system operation, DLR can provide additional transfer flexibility where a line is thermally restricted. Qiu and Wang (2015) showed that incorporating DLR into congestion management can reduce the operational impact of transmission constraints.

*I. Impact of DLR on Power-System Security*

Although DLR can increase available transmission capacity, the additional loading must not compromise system security. Following a transmission outage, power flows may shift and overload other lines. Champion et al. (2016) showed that DLR can support secure operation when combined with post-contingency assessment. Therefore, DLR should be applied alongside existing security procedures.

*J. DLR and Economic Operation of Power Systems*

By relieving transmission constraints, DLR may improve access to lower-cost generation and provide greater dispatch flexibility. However, economic benefits depend on system topology, generation costs, demand patterns, and whether the dynamically rated line is a binding constraint. Teng et al. (2018) therefore emphasized evaluating DLR within system optimization rather than considering increased ampacity alone.

*K. N-1 Contingency Analysis in Transmission Systems*

N-1 analysis determines whether the system can remain within acceptable limits after the loss of one component. For DLR applications, this is necessary because increased pre-contingency transfer can alter post-outage loading. Champion et al. (2016) found that DLR can provide additional flexibility when post-contingency limits remain satisfied.

*L. Weather and Measurement Uncertainty in DLR*

DLR depends on whether measurements, forecasts, and conductor parameters, all of which involve uncertainty. Variations in wind speed and errors in sensing or forecasting can affect the calculated rating. Teng et al. (2018) and Rashkovska et al. (2022) support the use of probabilistic or conservative rating margins to improve the reliability of DLR in practical operation.

*M. Review of Related Studies*

Previous studies have addressed different aspects of DLR. Bhattarai et al. (2018) demonstrated through practical weather-based analysis that dynamic ratings can reveal substantial unused transmission capacity. Qiu and Wang (2015) considered DLR within congestion management, while Teng et al. (2018) examined its operational value under multiple uncertainties. Tschampion et al. (2016) extended the discussion to N-1 security, and Rashkovska et al. (2022) focused on uncertainty suitable for operational implementation. Collectively, these studies demonstrate that the value of DLR depends not only on increased conductor ampacity but also on its interaction with system operation, security, and uncertainty. (OSTI)

*N. Research Gap*

Existing studies show that DLR can increase transmission capacity, reduce congestion, support security, and account for rating uncertainty, but these benefits are often evaluated separately. This study addresses that gap through an integrated assessment on the IEEE 118-bus system, comparing SLR and DLR across line loading, voltage profile, losses, congestion, operating cost, N-1 contingencies, and uncertainty. This provides a broader measure of DLR performance beyond increased ampacity alone.

## III. MATERIALS AND METHODS

*A. Study Framework and Data*

The IEEE 118-bus test system was used to evaluate the effect of Dynamic Line Rating (DLR) on transmission capacity, system security, and economic operation. The study was implemented in MATLAB using MATPOWER and comprised thermal rating estimation, AC power flow, optimal power flow, N-1 contingency assessment, and uncertainty analysis.

The input data consisted of network parameters, conductor characteristics, hourly meteorological conditions, and load variation. The selected transmission corridor was represented by an illustrative ACSR 795-kcmil-class conductor with a diameter of 0.02814 m, emissivity and solar absorptivity of 0.50, a normal temperature limit of 75°C, and an emergency limit of 100°C. Weather variables included ambient temperature, wind speed, wind direction, solar radiation, cloud cover, and rainfall, while hourly load scaling represented changes in system demand.

*B. Dynamic Line Rating Estimation*

The DLR was determined from the thermal balance of the conductor, in which electrical and solar heat gains were balanced against convective and radiative heat losses. This relationship was expressed as:

$$qj + qs = qc + qr \qquad (1)$$

Where qj is Joule heating, qs is solar heat gain, QC is convective cooling, and qr is radiative cooling.

The allowable dynamic current was estimated as:

$$I_{DLR} = \sqrt{\frac{qc + qr + qs}{R(T_C)}} \qquad (2)$$

Where I_DLR is the allowable line current and R (Tc) is the conductor resistance at temperature Tc. The model therefore allowed the line rating to respond to changes in ambient temperature, wind speed, wind direction, and solar radiation. Transient conductor temperature was also evaluated over each hourly interval to confirm that operation remained within the specified thermal limit.

*C. Comparison of Static and Dynamic Line Ratings*

Five rating conditions were evaluated: Static Line Rating (SLR), ambient-adjusted rating, full DLR, favourable-weather rating, and unfavourable-weather rating. The calculated current ratings were converted to transmission capacity using:

$$S_{rating} = \frac{\sqrt{3} V I_{rating}}{1000} \qquad (3)$$

Where S_rating is the transmission capacity in MVA, V is nominal line voltage in kV, and Irating is the allowable line current in amperes.

The percentage change in DLR relative to SLR was calculated as:

$$\Delta R = \left[\frac{(I_{DLR} - I_{SLR})}{I_{SLR}}\right] \times 100 \qquad (4)$$

The rating conditions were then compared using allowable current, MVA capacity, line loading, available capacity, and transfer headroom.

*D. Technical and Economic Assessment*

Hourly AC power-flow analysis was conducted for each rating condition using the corresponding load level. Technical performance was assessed using line loading, minimum and maximum bus voltage, voltage violations, active and reactive power losses, available transmission capacity, and network congestion.

Transmission-line utilisation was expressed as:

$$Li = \left(\frac{Si}{Si_{rating}}\right) \times 100 \qquad (5)$$

Where Li is the percentage loading of branch i, Si is its apparent power flow, and $Si_{rating}$ is the applicable line rating. A loading value above 100% was regarded as a thermal overload.

AC optimal power flow was subsequently used to evaluate economic performance using operating cost, congestion, transmission losses, line utilisation, available capacity, and the shadow price of the selected transmission constraint.

*E. N-1 Security Assessment*

The hour with the highest DLR loading was selected for contingency assessment. Each in-service branch was removed individually under both SLR and full-DLR conditions. Following each outage, network connectivity, power-flow convergence, maximum branch loading, overloaded lines, voltage violations, transmission losses, and selected-corridor loading were evaluated. Contingencies that produced network islanding were identified separately.

*F. Uncertainty and Reliability Analysis*

DLR reliability was assessed using sensitivity analysis and Monte Carlo simulation. The sensitivity cases considered variations in wind speed, wind direction, adverse weather conditions, sensor failure, and communication failure. In the event of monitoring or communication failure, the rating reverted to SLR.

A total of 1,000 Monte Carlo samples were used to represent uncertainty in wind speed, wind direction, ambient temperature, and solar radiation. The fifth percentile of the resulting line-rating distribution was adopted as the conservative uncertainty-informed rating for secure operation.

## IV. RESULTS AND SIMULATION

The simulation was carried out on the IEEE 118-bus test system using 24 hourly weather conditions. Automatic line screening identified branch 141, connecting bus 89 to bus 92, as the study line because it’s loading reached 118.99% of the static line rating (SLR). The line has a static current rating of 709.88 a, equivalent to 169.68 MVA. The following results are presented according to the study objectives.

### *A. Development of the Weather-Based Dynamic Line Rating Model*

The first objective was to develop a weather-based DLR model for the selected transmission line. The calculated rating changed considerably throughout the day rather than remaining at the fixed SLR value of 709.88 A

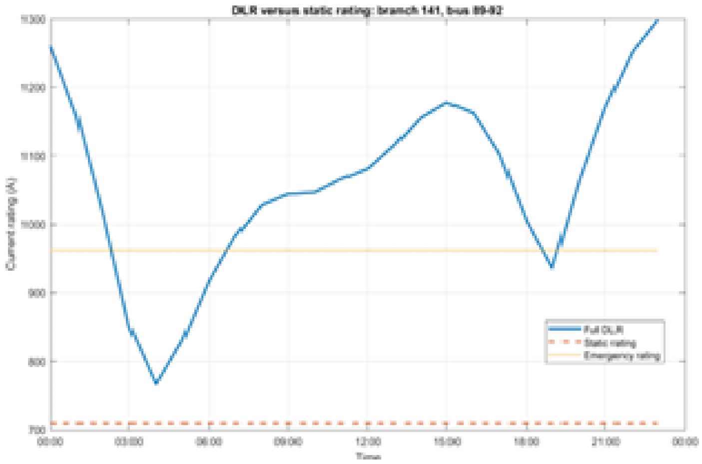


Figure 1: DLR versus static rating for branch 141bus 89-82

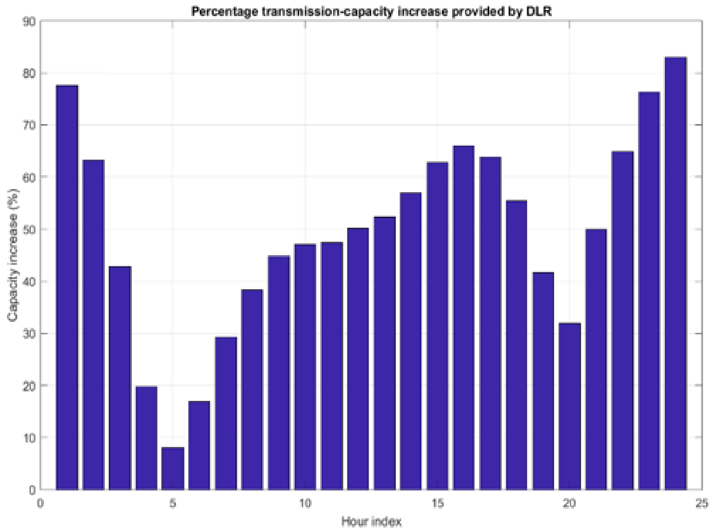


Figure 2: Percentage transmission capacity increase provided by DLR

As shown in Figure 1, the dynamic rating varied from approximately 767 A to 1,300 A, depending on the prevailing weather conditions. The average increase in line rating was 49.59% above the SLR, while the hourly improvement ranged from 8.06% to 82.91%. This demonstrates that the actual thermal capability of the conductor can be substantially higher than its fixed static rating during favourable periods.

Figure 2 further shows that additional capacity was available during every hour considered, although the amount varied considerably. The smallest increase occurred around the critical early-morning period, while the largest increases occurred toward the end of the day.

The influence of weather is illustrated in Figures 3 and 4.

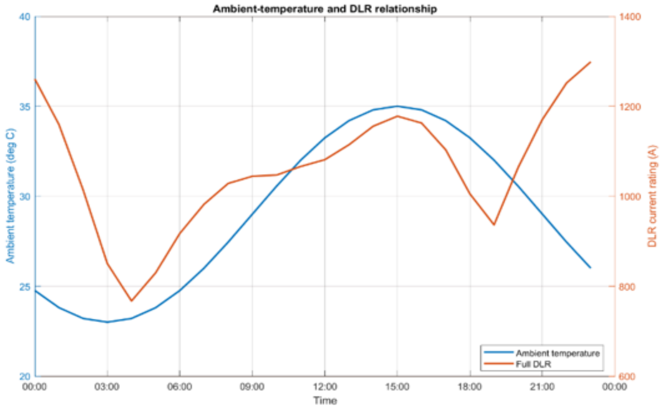


Figure 3: Ambient temperature and DLR relationship

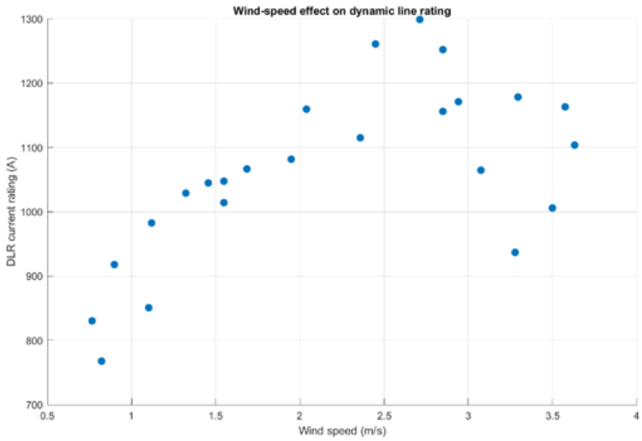


Figure 4: Wind speed effect on dynamic line raring

The results show that DLR is not controlled by ambient temperature alone. Although increasing temperature generally reduces conductor cooling capability, the rating remained relatively high during some warmer periods because other weather factors, particularly wind speed, improved heat removal. Figure 4.4 shows a generally increasing DLR with higher wind speed, although the relationship is not perfectly linear because the final rating reflects the combined effect of several weather variables.

### *B. Comparison of DLR and Static Line Rating*

The second objective compared DLR and SLR in terms of available transmission capacity and loading of the selected line.

Table 1: Summary comparison of SLR and DLR results

| Parameter | Static Line Rating (SLR) | Dynamic Line Rating (DLR) | Comparison/Observation |
|---|---|---|---|
| Selected transmission line | Branch 141, Bus 89–92 | Branch 141, Bus 89–92 | Same line assessed under both conditions |
| Static current rating | 709.88 A | Weather-dependent | DLR varied with hourly weather conditions |
| Static apparent power rating | 169.68 MVA | Weather-dependent | DLR provided additional usable capacity |
| Mean change in rating relative to SLR | 0% | +49.59% | Substantial average increase in transmission capacity |
| Minimum DLR improvement | 0% | +8.06% | DLR remained above SLR at the least favourable interval |
| Maximum DLR improvement | 0% | +82.91% | Highest additional capacity occurred under favourable weather |
| Initial screened line loading | 118.99% | Reduced under DLR | The selected line exceeded its static thermal limit |
| Critical DLR loading hour | Not applicable | 01-Jan-2026, 04:00 | Lowest available DLR margin occurred at hour index 5 |
| Congestion performance | Higher | Reduced | Mean congestion decreased by 87.50% under DLR |

Table 1 should present the static rating of 709.88 A, the mean DLR increase of 49.59%, the DLR improvement range of 8.06–82.91%, and the critical loading hour of 04:00 on 1 January 2026.

Figure 5 shows a clear difference between the two rating methods. Under SLR, the selected branch remained at approximately 119–123% loading, indicating persistent thermal overloading. When the weather-based DLR was applied, the loading was below 100% for most of the day. A short period of loading above the DLR limit remained during the early morning, with the most critical condition occurring at 04:00.

These results indicate that using the actual weather-dependent capability of the conductor provides considerably more usable transmission capacity than the fixed static assumption. However, DLR does not necessarily remove every overload because adverse weather can temporarily reduce the available dynamic capacity.

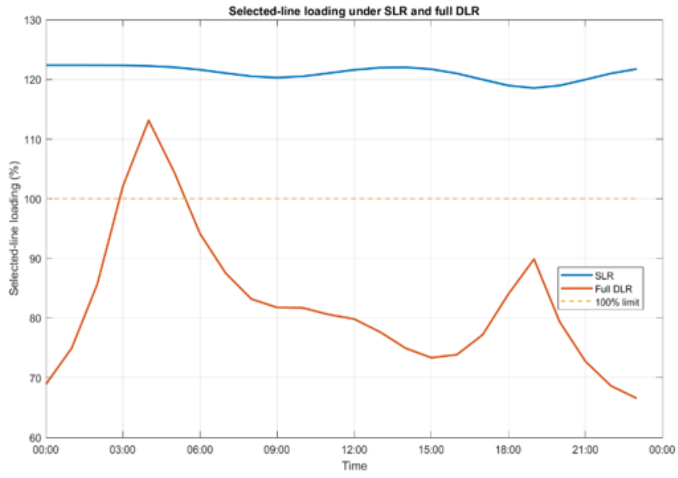


Figure 5: Selected line loading under SLR and full DLR

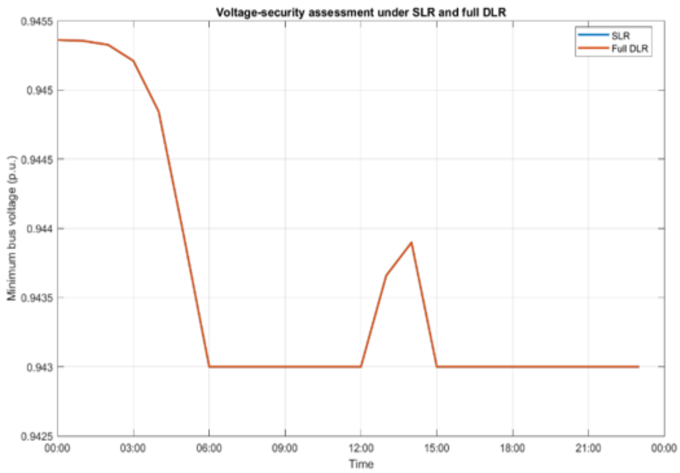


Figure 6: Voltage security assessment under SLR and full DLR

### C. *Effect of DLR on Voltage, Losses, Congestion and Operating Cost*

The third objective examined whether the additional transmission capability affected voltage performance, active power losses, network congestion and operating cost.

The voltage profiles under SLR and DLR were almost identical. The minimum bus voltage remained approximately 0.943–0.945 p.u. throughout the simulation. This indicates that increasing the thermal rating of the selected transmission line did not produce any noticeable deterioration in system voltage performance.

Similarly, the calculated mean changes in active power losses were effectively zero under both the power-flow and optimal-power-flow cases. The overlapping curves in Figure 7 confirm that DLR produced no meaningful change in total active power losses for the operating conditions considered.

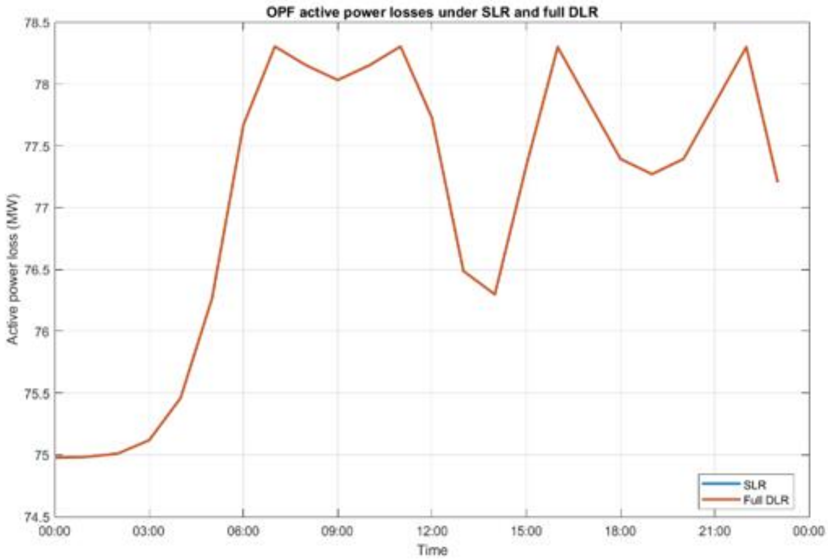


Figure 7: OPF active power losses under SLR and full DLR

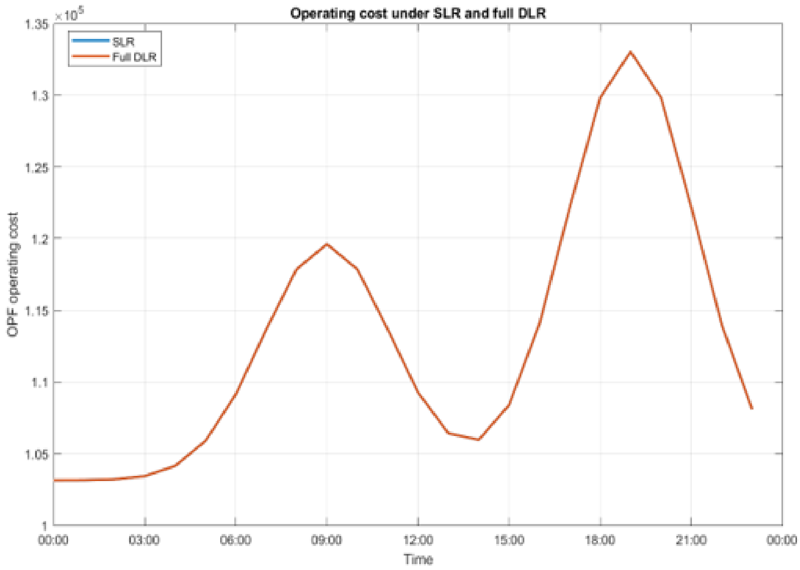


Figure 8: Operating cost under SLR and full DLR

The operating-cost profiles were also practically identical, with the reported mean change being approximately 0.00%. Therefore, the additional rating of the selected line did not lead to a measurable reduction in generation cost in this particular simulation.

The strongest effect of DLR was observed in network congestion.

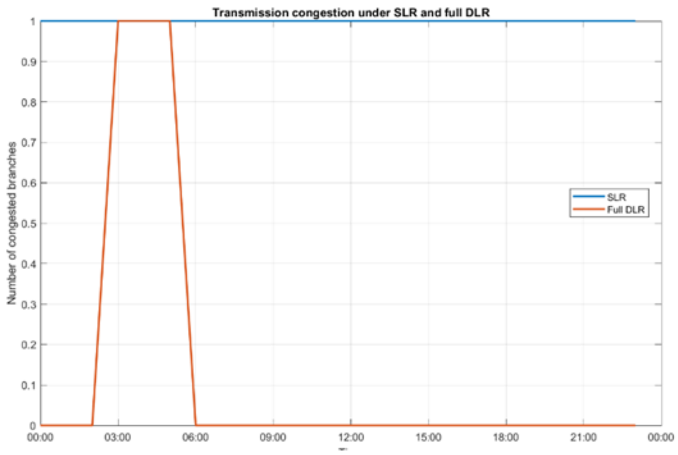


Figure 9: Transmission congestion under SLR and full DLR

Under SLR, the selected transmission constraint remained congested throughout the day. With full DLR, congestion occurred only during the short critical early-morning period. Overall, the mean congestion level was reduced by 87.50%. The result therefore shows that the main operational benefit of DLR in this case was the release of otherwise unavailable transmission capacity rather than a significant reduction in losses or operating cost.

### *D. N-1 Transmission Security Assessment*

The fourth objective assessed system security following individual transmission contingencies.

Table 2: Summary of N-1 contingency analysis

| N-1 Contingency Indicator | SLR Case | Full DLR Case | Observation |
|---|---|---|---|
| Connected contingencies that converged | 177 | 177 | All connected cases converged under both rating methods |
| Islanding contingencies | 9 | 9 | Same number of islanding events occurred in both cases |
| Non-converged connected contingencies | 0 | 0 | No numerical convergence failure was recorded |
| Total contingencies assessed | 186 | 186 | Same contingency set was applied to both cases |
| Worst connected post-contingency loading | Above 100% | Above 100% | Some thermal overloads remained after contingencies |
| Approximate maximum post-contingency loading | About 155% | About 155% | Severe loading remained in the most critical connected contingency |
| Overall security observation | Post-contingency overloads present | Post-contingency overloads present | DLR improved available capacity but did not eliminate all N-1 violations |

For both the SLR and full-DLR cases, 177 connected contingencies converged successfully, while 9 contingencies resulted in islanding. No connected contingency failed to converge. The same convergence pattern for both cases indicates that the introduction of DLR did not create additional numerical or network-separation problems.

However, Figure 10 shows that several of the most severe connected contingencies still produced branch loadings above 100%, with the worst case reaching approximately 155%. Therefore, although DLR provides additional capacity during normal operation, it does not remove the need for contingency assessment and corrective actions. The results suggest that DLR should be applied together with N-1 security constraints rather than being treated as a replacement for conventional security assessment.

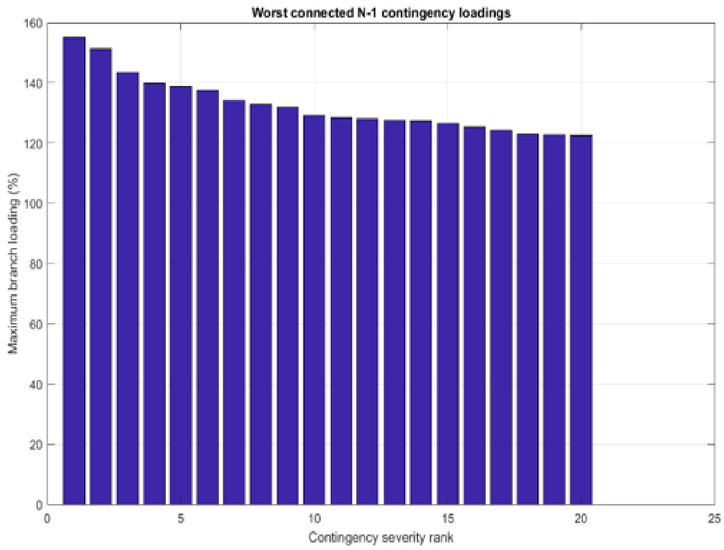


Figure 10: Worst connected N-1 contingency loadings

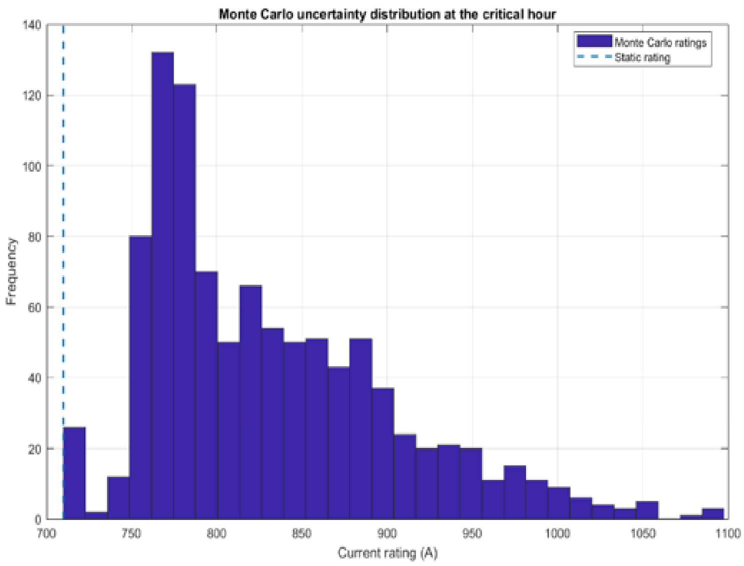


Figure 11: Monte Carlo uncertainty disturbance at the critical hour

*E. Effect of Weather and Monitoring Uncertainty on DLR Reliability*

The final objective examined the reliability of DLR when uncertainty in weather and monitoring conditions is considered. The uncertainty analysis focused on the critical DLR loading hour identified as 04:00.

Figure 11 shows the spread of possible current ratings obtained from the uncertainty simulation. Although the predicted ratings varied considerably, most remained above the fixed static rating of 709.88 A. The uncertainty-informed 5th-percentile rating was 751.34 A, approximately 5.8% higher than the SLR.

This result is important because it shows that the full calculated DLR should not always be used directly when weather measurements are uncertain. A lower percentile rating provides a more conservative operating value while still retaining some additional transmission capacity above the static rating. The combination of real-time weather monitoring and an uncertainty allowance can therefore improve the practical reliability of DLR operation.

4.6 Summary of Main Simulation Findings

Table 3: Summary of results according to study objectives

| **Study Objective** | **Main Indicator Assessed** | **Key Result** | **Interpretation** |
|---|---|---|---|
| 1. Develop a weather-based DLR model for the selected transmission line | Hourly dynamic current rating of branch 141, bus 89–92 | Mean DLR increase of 49.59% above the static rating of 709.88 A; improvement ranged from 8.06% to 82.91% | The weather-based model revealed substantial additional transmission capacity that was not captured by the fixed static rating. |
| 2. Compare DLR and SLR in terms of transmission capacity and line loading | Available line capacity and percentage loading | SLR screening loading was 118.99%. DLR reduced loading below the applicable limit for most hourly periods, with the critical DLR loading occurring at 04:00 | DLR improved utilisation of the selected line and relieved the persistent overload observed under SLR for most of the study period. |
| 3. Assess the impact of DLR on voltage profile, power losses, congestion, and operating cost | Voltage, active losses, congestion and OPF cost | Mean PF loss change: 0.00%; mean OPF loss change: 0.00%; mean OPF cost change: approximately 0.00%; congestion reduction: 87.50% | DLR had little effect on voltage, losses and operating cost, but produced a substantial reduction in transmission congestion. |
| 4. Evaluate system security under N-1 | Contingency convergence, islanding and post- | 177 connected contingencies converged, 9 | DLR did not introduce additional |

| | | | |
|---|---|---|---|
| transmission contingencies | contingency loading | caused islanding and 0 connected cases failed to converge under both SLR and DLR | convergence problems, although some post-contingency overloads remained. |
| 5. Examine the effects of weather and monitoring uncertainties on DLR reliability | Uncertainty-informed dynamic rating | The 5th-percentile rating was 751.34 A, compared with the SLR of 709.88 A | Even after allowing for uncertainty, a conservative DLR value remained above the static rating, indicating that additional capacity can be retained with an appropriate safety margin. |

Overall, the simulation showed that weather-based DLR substantially increased the usable capacity of branch 141, with an average improvement of 49.59% over SLR. The increased rating reduced congestion by 87.50% and brought the selected-line loading below its rating during most hours. Voltage profile, active power losses and operating cost remained essentially unchanged. N-1 analysis showed that all connected cases converged, although some post-contingency overloads remained. Finally, the uncertainty analysis produced a conservative 5th-percentile rating of 751.34 a, showing that additional capacity above SLR can still be retained when uncertainty is taken into account.

## V. CONCLUSION

The study showed that Dynamic Line Rating can improve the utilisation of the IEEE 118-bus transmission system. For the selected branch, DLR increased the available line rating by an average of 49.59% and reduced congestion by 87.50% compared with Static Line Rating. Voltage profile, power losses, and operating cost remained almost unchanged, indicating that the main benefit of DLR was increased transmission capacity and congestion relief.

The N-1 analysis confirmed that DLR did not introduce additional convergence problems, although some post-contingency overloads remained. The uncertainty assessment also showed that the conservative 5th-percentile rating of 751.34 A was still above the static rating of 709.88 A. Overall, DLR offers a useful approach for improving transmission capacity, but its application should be supported by reliable weather monitoring, uncertainty assessment, and contingency analysis.

## RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

- Dynamic Line Rating should be considered for heavily loaded transmission corridors, particularly where static ratings create persistent congestion despite favourable weather conditions.

- Real-time weather monitoring should support DLR implementation, with particular attention to wind speed, ambient temperature, and solar conditions because these variables directly influence conductor cooling and allowable current.
- DLR should be applied together with N-1 contingency analysis to ensure that the additional transmission capacity does not lead to unacceptable post-contingency overloads.
- Uncertainty margins should be incorporated into operational DLR values rather than relying only on the maximum calculated rating. Conservative percentile-based ratings can provide additional capacity while improving reliability.
- Further studies should examine DLR across several transmission lines and wider operating conditions, including changing load levels and generation patterns, to determine its broader economic and security benefits.

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