Weather-Informed DCOPF: A Case Study of ERCOT

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Introduction

Extreme weather events pose a significant threat to grid reliability by driving peak demand and stressing infrastructure. While traditional **Static Line Ratings (SLRs)** rely on conservative worst-case assumptions, **Dynamic Line Ratings (DLRs)** capture both ambient temperature and wind cooling effects to more accurately represent available physical capacity. Capturing these environmental variables is critical for providing **congestion relief**, especially during extreme weather, allowing for more efficient power dispatch and improved system resilience.

DC Optimal Power Flow (DCOPF) Formulation

The study employs a DCOPF model that minimizes cost including Non-Served Energy (NSE) penalties:

$$\min \sum_{t\in T}\left(\sum_{g\in G} VarCost_g \cdot GEN_{g,t} + \sum_{n\in N} Cost_{nse} \cdot NSE_{n,t}\right)$$

Subject to: Power balance, thermal ramping, network flow physics and weather-dependency, and generation limits.

Case Study: The ERCOT Grid

ERCOT (Texas) serves as an ideal testbed. During **Winter Storm Uri** (2021), the system experienced catastrophic power loss and unprecedented price spikes, highlighting the need for resilient transmission solutions.

- **Network Configuration:** An aggregated 120-node system with 738 transmission lines and 548 generators [1].
- **Scenarios:** Evaluation over the horizon of Feb 12–18:

	SLR	DLR
Base (2016)	(1) Mild baseline	(2) Congestion relief
Uri-like event	(3) Extreme stress	(4) Resilience test

Weather-Adjusted Line Rating Construction

Line ratings were adjusted hourly based on NOAA weather data mapped to line midpoints [2, 3].

Wind Speed (m/s)	Ambient Temperature (°C) 35	25	15	5	−5	−15	−25
0.5	100	113	125	136	146	155	164
1.0	119	135	149	162	174	186	196
2.0	146	166	183	200	215	229	242
3.0	165	188	208	227	245	262	278
4.0	179	204	226	246	264	282	299
5.0	192	218	241	263	283	301	319
6.0	203	230	255	277	299	318	337

Table 1. DLR multipliers [%] used to dynamically adjust SLRs.

Temperature-Adjusted Load Profile Construction

A piecewise linear regression extracted heating residuals to simulate the impact of extreme temperatures on the 2016 load profile.

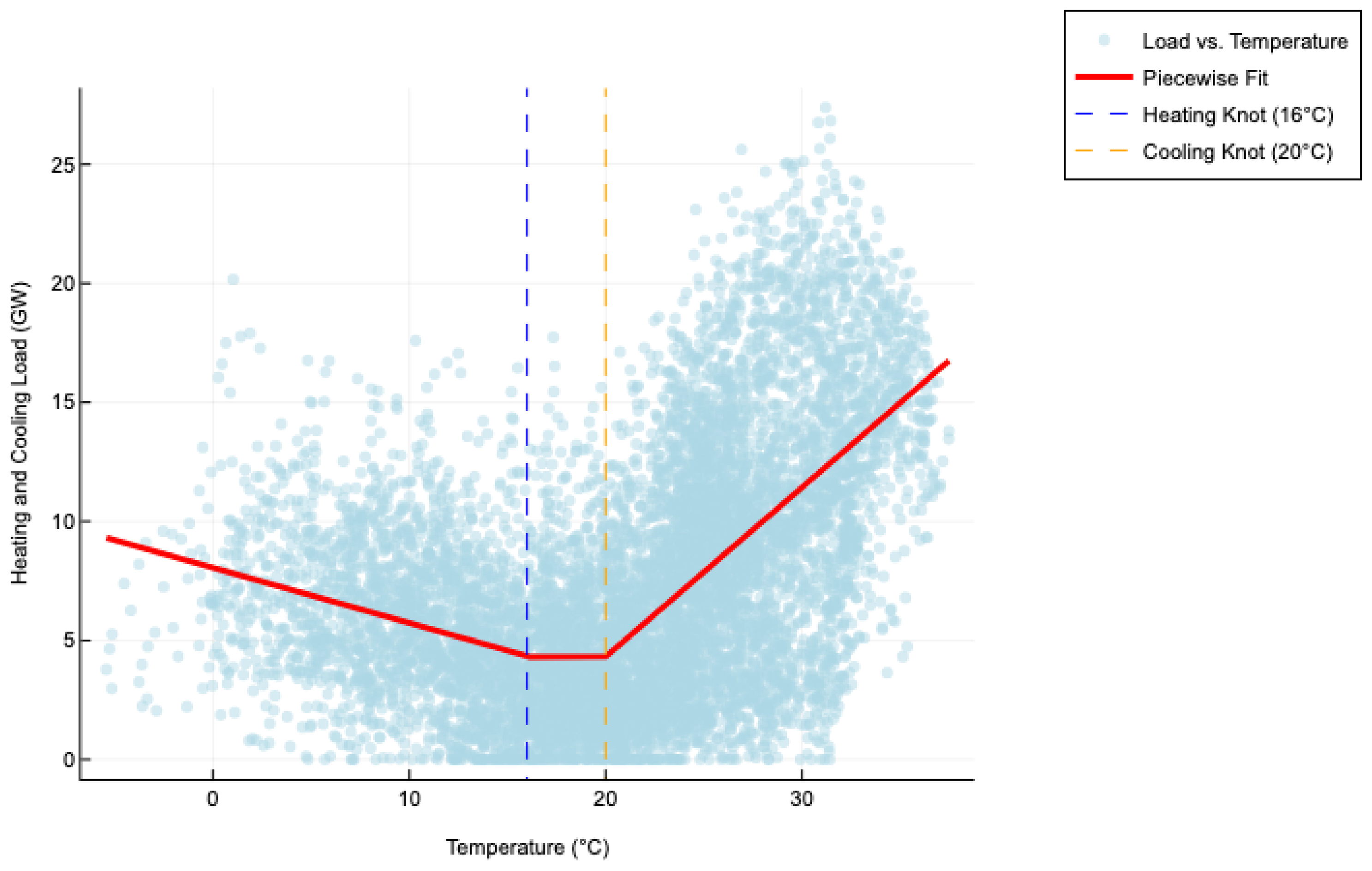

Figure 1. U-shaped relationship between temperature and heating/cooling load.

Result 1: DLRs Narrow Price Spread

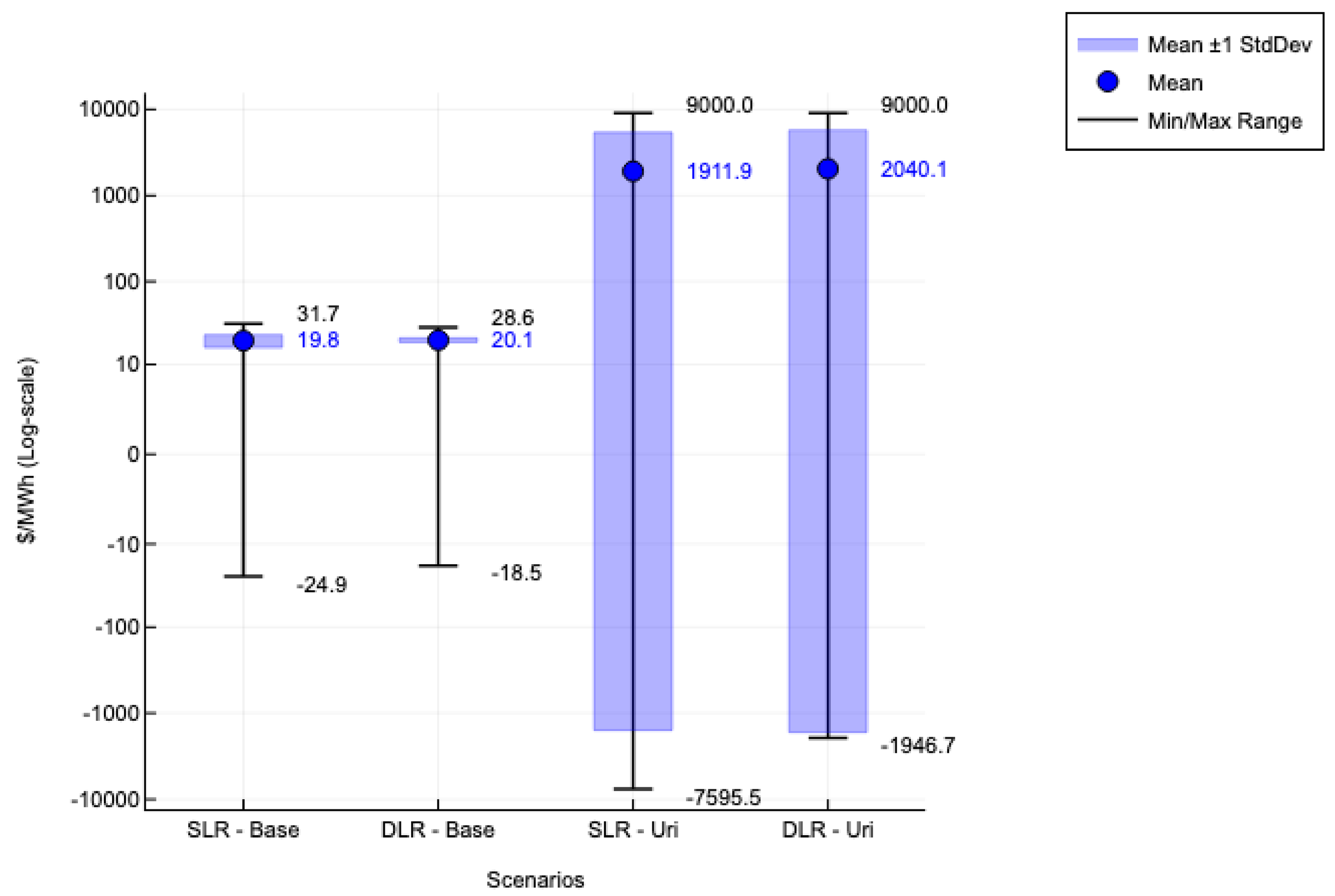

Figure 2. Log-scale distribution of locational marginal prices (LMPs) across ERCOT nodes.

- **Congestion Relief:** DLRs reduce transmission-driven price differentiation, reducing LMP standard deviation by nearly threefold in mild weather and mitigating negative LMPs in extreme weather.
- **Unlocks Hidden Capacity:** Facilitates transmission across Texas to connect remote wind (West) to load centers (East), displacing expensive natural gas peaker generation.

Result 2: System Dispatch & Resilience Bounds

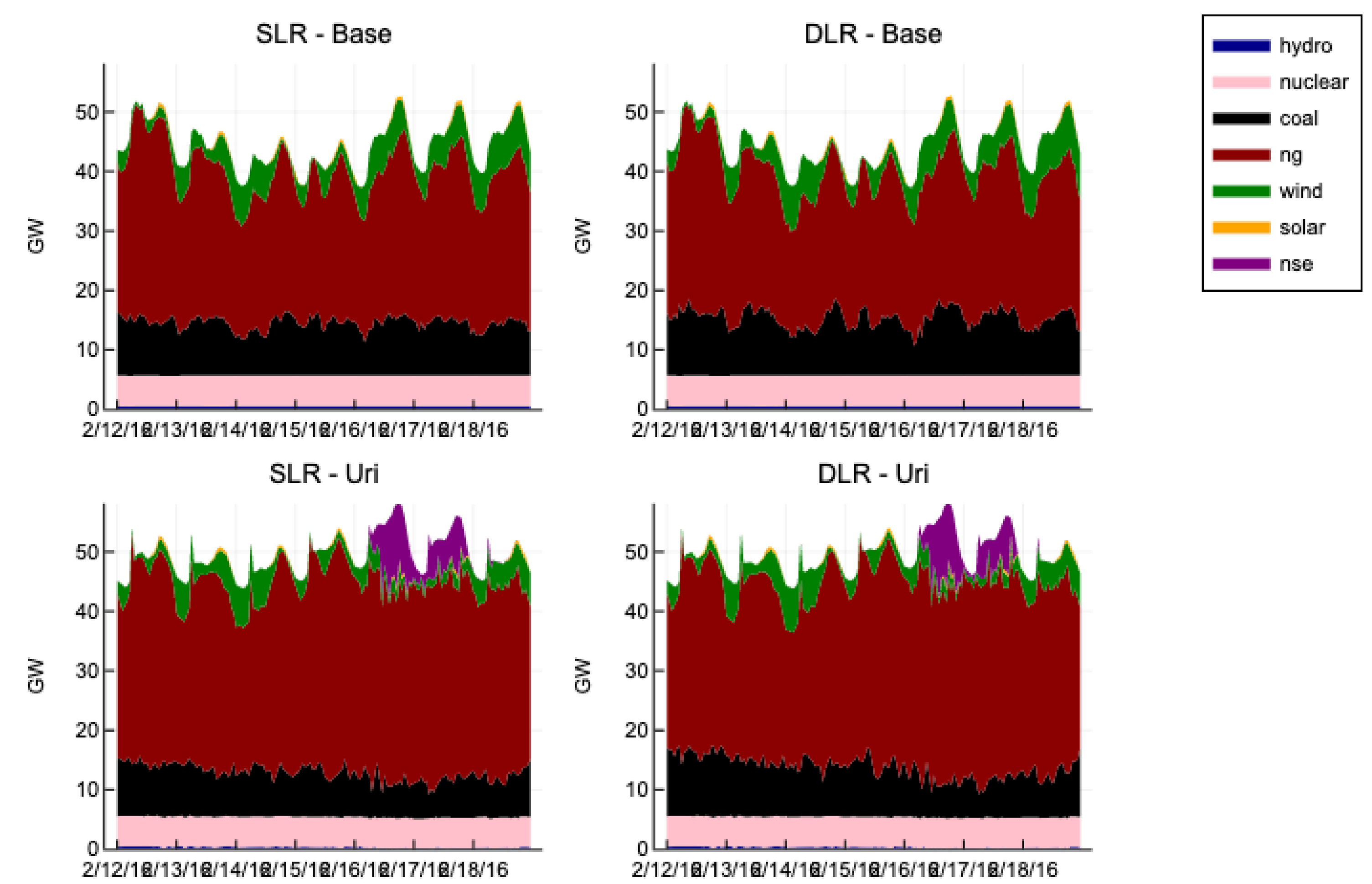

Figure 3. Total generation dispatch and NSE over the week-long study horizon in Texas.

- **NSE Mitigation:** DLRs provide marginal reliability benefits by reducing localized Non-Served Energy (NSE), optimizing the flow of remaining generation to critical load pockets.
- **Resilience Bounds:** The reliability benefit of DLRs is limited by widespread generation outages, which remain the primary driver of failure during extreme weather events.

Key Research Findings

- **Economic and Computational Efficiency:** DLRs are a high-impact, low-cost solution for resolving grid congestion and unlocking cheaper resources.
- **Resilience Strategy:** While DLRs optimize infrastructure to minimize cost and NSE, true resilience also requires generator weatherization to ensure supply availability during extreme weather events.

Future Work

Incorporating $N-1$ security constraints and nodal sensitivities into this framework could help optimize strategic transmission expansion. Furthermore, evaluating impacts on emissions and renewable curtailment provides a pathway toward a cleaner grid. Finally, analyzing NSE price sensitivity could better reflect true reliability costs to inform voluntary conservation programs and more effectively align market incentives.

References

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