COMBINING HIGH RESOLUTION FORECASTS WITH DYNAMIC LINE RATING

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Abstract

We present a Pilot Service using Destination Earth digital twin data demonstrating how high resolution weather forecasts can benefit operations of high-voltage transmission lines and planning grid operations. The Pilot Service "High Resolution forecasts for Next Generation Dynamic Line Rating computation" will contribute to address the challenges faced by operators when implementing Dynamic Line Rating (DLR), and advance methods for managing the use of high voltage transmission lines, which is dependent on weather conditions.

Introduction

Dynamic Line Rating represents an advanced approach to managing the thermal capacity of high-voltage transmission lines. In contrast to static rating methodologies, which rely on conservative assumptions about ambient conditions, DLR dynamically adjusts transmission limits based on real-time weather and operational information. This enables more accurate and often higher ampacity estimates, supporting optimized grid operation and improved integration of variable renewable energy.

Key objectives

The project develops a solution that allows:

- Exploit high-resolution DestinE [1] NWP forecasts for DLR calculations along user-defined overhead line routes.
- Evaluate and adapt detection algorithms from operation ECMWF forecasts to identify favourable and unfavourable atmospheric conditions for DLR operations.
- Complement existing DestinE services with operational data for DLR ampacity estimation to be used for decision-making by TSOs.

Key objectives include:

- User requirements and service definition: Identify and translate operational user needs into a well-specified Pilot Service fully aligned with DestinE system capabilities.
- Pilot service implementation: Develop and deliver a functional, interactive Pilot Service consistent with validated requirements, ensuring seamless integration with Destination Earth components.
- Service operation, maintenance and support: Guarantee reliable service operations, timely data delivery, adequate user support, and regular reporting throughout the project duration.
- User engagement and communication: Actively support DestinE community growth through communication activities, outreach, industry events, and targeted content creation.

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Continuous collaboration with the embedded TSO partner ensures a user-centric, co-design development process and provides insights into the scalability of the service beyond the pilot phase.

Results:

The pilot service successfully demonstrates the integration of DestinE high-resolution forecasts with thermal line rating calculations. Figure 1 shows spatial DLR conditions along a 220 kV transmission line in the Austrian Alps (Westtirol–Zell am Ziller), using AROME forecasts at ~2.5 km resolution. Temperature and wind fields at conductor height (60 m AGL) are extracted along the line geometry, with DLR categories (favorable to very unfavorable) computed based on compound meteorological conditions. The spatial analysis reveals significant heterogeneity along the corridor, with sheltered valley sections showing unfavorable conditions while exposed ridge segments remain favorable.

Figure 2 presents the CIGRE thermal model output for the same line segment. The model calculates maximum permissible current (ampacity) for each segment based on the heat balance equation. For the example timestep, ampacity varies from 763 A at the identified bottleneck (−36% versus baseline) to 2962 A (+147%) at favorable segments. This spatial resolution enables TSOs to identify critical segments that limit the entire corridor's capacity, rather than relying on line-averaged conditions.

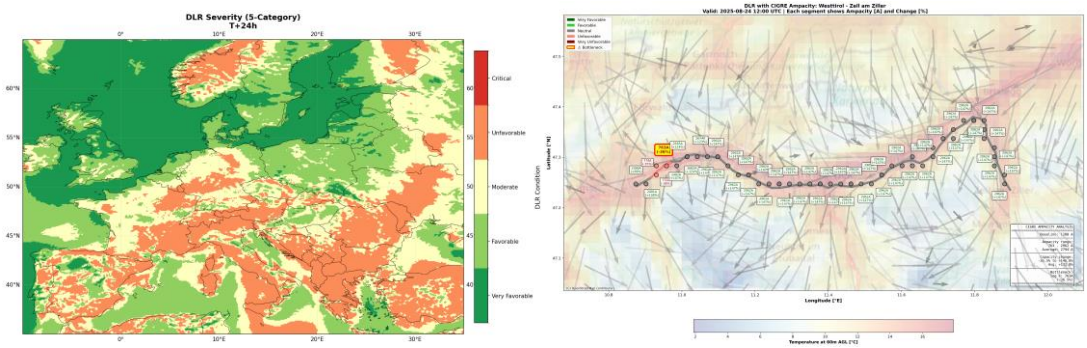

Figure 1: left) Detection of DLR conditions and the severity on a European scale; right) CIGRE ampacity analysis for a line segment in Austria. Each segment shows the calculated maximum allowable current [A] and percentage change versus static rating. The bottleneck (red triangle) at segment 4 limits the entire corridor capacity to 763 A (−36%).

Conclusions:

Combining high-resolution weather forecasts from the DestinE Extremes Digital Twin with the CIGRE thermal model enables spatially resolved DLR forecasting along alpine transmission lines. The pilot service provides TSOs (APG, Energienetze Steiermark, Elia) with quantitative ampacity forecasts and identification of critical line segments. The 48-hour forecasts support day-ahead grid planning and enable optimized utilization of transmission capacity while ensuring grid security.

Referenzen

[1] Destination Earth (DestinE) is a flagship initiative of the European Commission to develop a highly-accurate digital model of the Earth (a digital twin of the Earth) to model, monitor and simulate natural phenomena, hazards and the related human activities, see https://destination-earth.eu/