OPERATO
member of ELES Group

System-wide rollout of Dynamic Line Rating Technology

HOW DID **ELES** INCREASE THE **CAPACITY** OF **33 EXISTING TRANSMISSION LINES?**

For **Operators.**

From **Operato.**

Managing the TSO's operational risk

Understanding and managing operational risk is central to the day-to-day operations of the transmission system Operator. The electricity grid is inherently a dynamic system, and many parameters are orchestrated on a transnational level to ensure a stable energy supply for our societies. While external parameters such as weather, renewable production and consumer behavior are highly volatile and unbounded, key elements of the infrastructure itself have so far been subject to hard static limits. Examples include the maximum currents we allow to flow through transformers and transmission lines: their *static* ampacity.

While using static limits is a conservative approach that has worked well to date, when analyzed closely, it is not the perfectly prudent approach. For example at times when within static rating limits due to exceptionally high ambient temperatures with very low wind speed clearances to ground may drop below safety limits. Nor do static limits best prepare our operators for the future challenges of decarbonization and increased extreme weather: TSO investments must be chosen with great care and the creation of unused capacity should be avoided. Under the right circumstances, can we safely use the line above the static limit and thus unlock extra capacity?

Historic Background of static ampacity limits:

Before the widespread availability of reliable telecommunication networks (80/90s with fiber optics, 90s/00s with 3G/4G mobile), local transient conditions could not be known and used in the operation of the grid. Although scientists were fully aware of the variable cooling effect of meteorological conditions on the lines, the only way to rate the lines was to take the worst case (current) rating under a normal expected range of weather conditions, for example, a hot summer's day with 35 degrees, no clouds and no wind. Operating the circuit in those conditions and with that current would not exceed safety clearances to ground and/or safe working limits of equipment. It would avoid failure and provide an acceptable low risk to workers and the general public. No rating of an equipment or system can guarantee 100% safe operation and that is why acceptable limits have been internationally agreed, codified and applied.

Operation with static limits is in widespread use, at the same time there is an increasing number of operators and regulators taking measures to transit to the use of dynamic limits. There are numerous arguments for this, one of which is climate change itself: rising temperatures and increased volatility of weather undermine the assumptions under which the static limits have been set.

Why Dynamic Line Rating?

At ELES they realized the challenge: sometimes weather conditions such as wind, temperature, and solar radiation on site can cause a scientifically calculated safe (dynamic) limit to actually be lower than the static limit, which is calculated according to the standards (e.g., EN50341) and takes into account also national normative aspects regarding climatology. Is the static limit really a safe one then? At the same time, for the vast majority of time annually, the static limit is a very conservative limit compared to what a line can support safely and without deterioration of equipment lifetime. Notably, given the cooling effect of wind and precipitation that greatly affect the temperature of the line.

They have recognized that with a science-based model and thus understanding of the effects of weather conditions at the local, microscale level on the temperature of the individual infrastructure elements, and by extension on the line as a whole, the actual rating and therefore power flowing can be safely increased. The economic benefits for better capacity planning and operations were quite obvious, as ELES faced a combination of factors, familiar to other European transmission system operators:

- Highly loaded lines, particularly international tie-lines
- Difficulties in building new lines in a short time frame
- Aging infrastructure

These challenges are exacerbated by the prediction of high demand growth in the wake of deep electrification on the consumer side and higher renewables sources on the production side. In other words, making the best use of existing infrastructure is not a choice but a necessity, *a sine qua non*.

Therefore, ELES set out to gather all the scientific, technical and managerial expertise needed to implement the DLR concept, not just in the form of a proof of concept through pilot projects, but in the form of a product-carrying subsidiary, Operato, which could implement the idea from the outset for the benefit of ELES, close partners such as Croatian TSO, HOPS and, more broadly, TSOs in the European ENTSO-E area and beyond.

In this case study, we will examine the steps ELES has taken to incorporate the concept of indirect Dynamic Line Rating (DLR) into their systems.

First, we will take a closer look at what constitutes a state-of-the-art Dynamic Line Rating system.

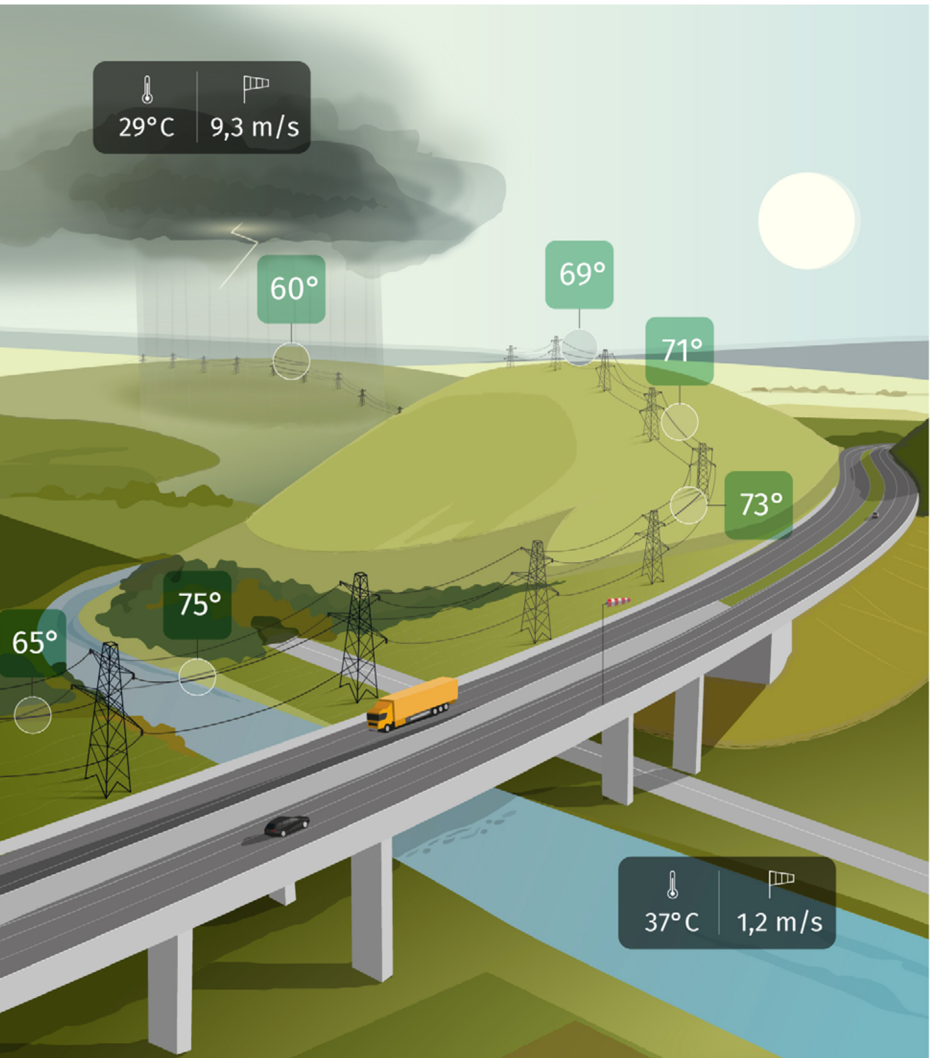
What is DLR?

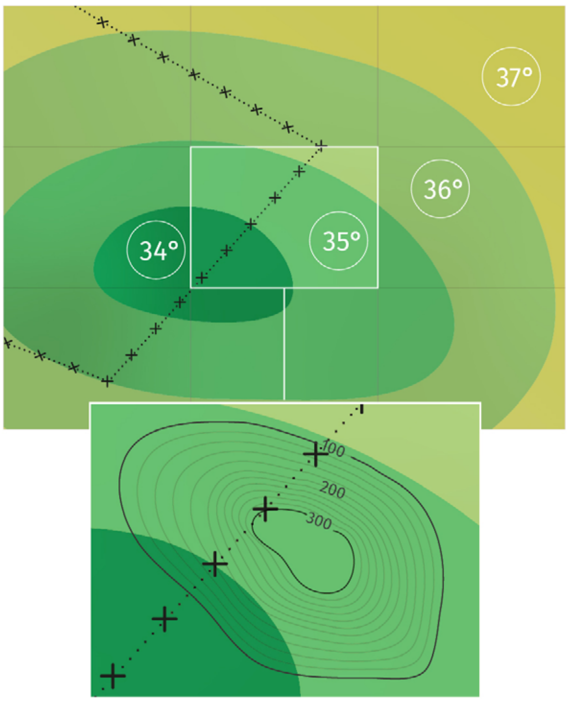
Indirect Dynamic Line Rating builds on reliable micro-scale weather nowcasts and forecasts to model and calculate the effects of environmental parameters on the temperature of overhead lines. When extended to other infrastructure elements such as transformers, the term Dynamic Thermal Rating (DTR) is also used.

Rain, clouds, wind, and its angle of attack all contribute to the temperature of conductors to varying degrees, in addition to the amount of current they carry. Temperature changes do not occur instantaneously, so a good model can also predict the time to reach peak temperature long before it can be measured, observed, or confirmed by a local sensor.

A similar logic applies to other grid elements, such as transformers.

THE CRITICAL SPAN OF A LINE IS DYNAMIC, IT MOVES ALONG THE LINE WITH CHANGING WEATHER CONDITIONS



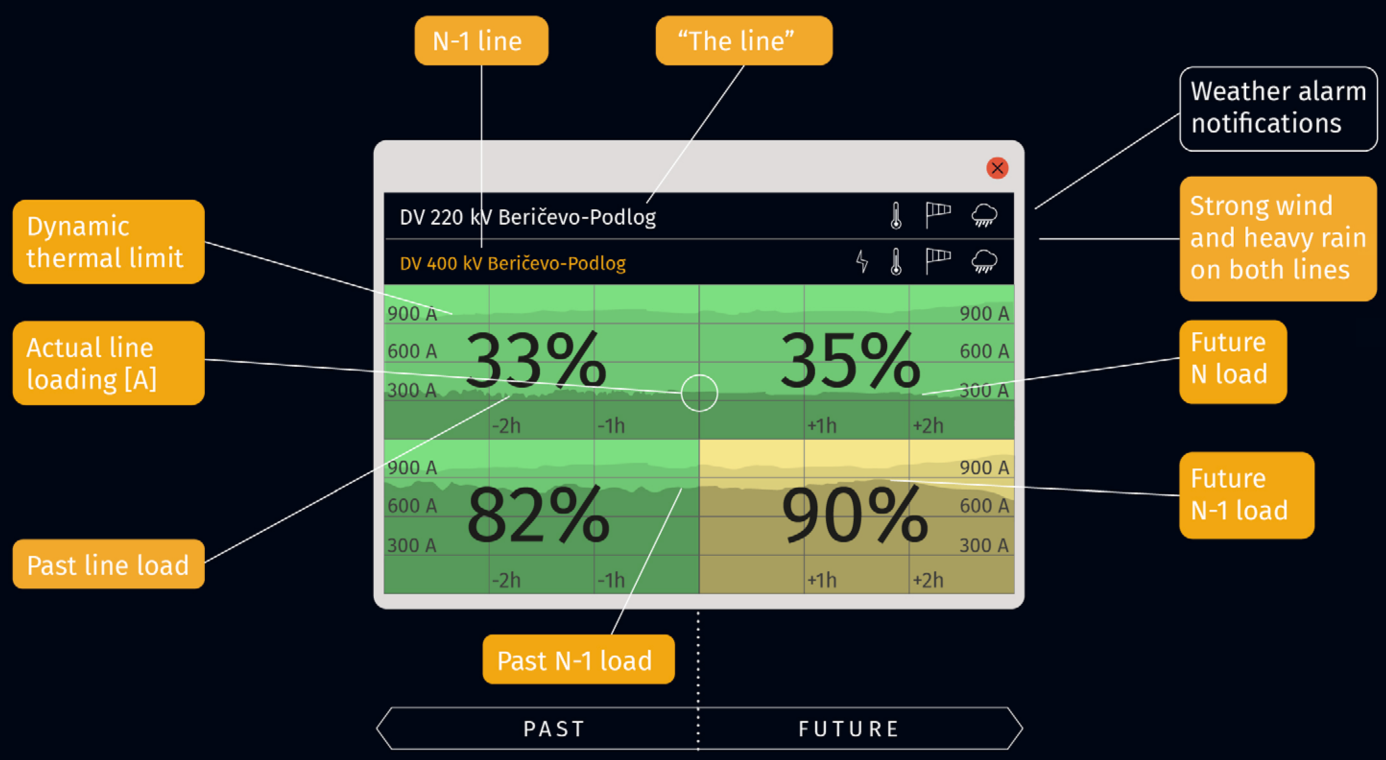


LINE SPAN	100	101	102	103	104	105
STATIC	540	540	540	540	540	540
DLR	600	620	630	640	630	620

UNDERSTANDING THE INTERDEPENDENCE BETWEEN DLR AND N-1

This intricate relation is best understood through the 4-quadrant visualization, which is one of the features of the Operato DLR system.

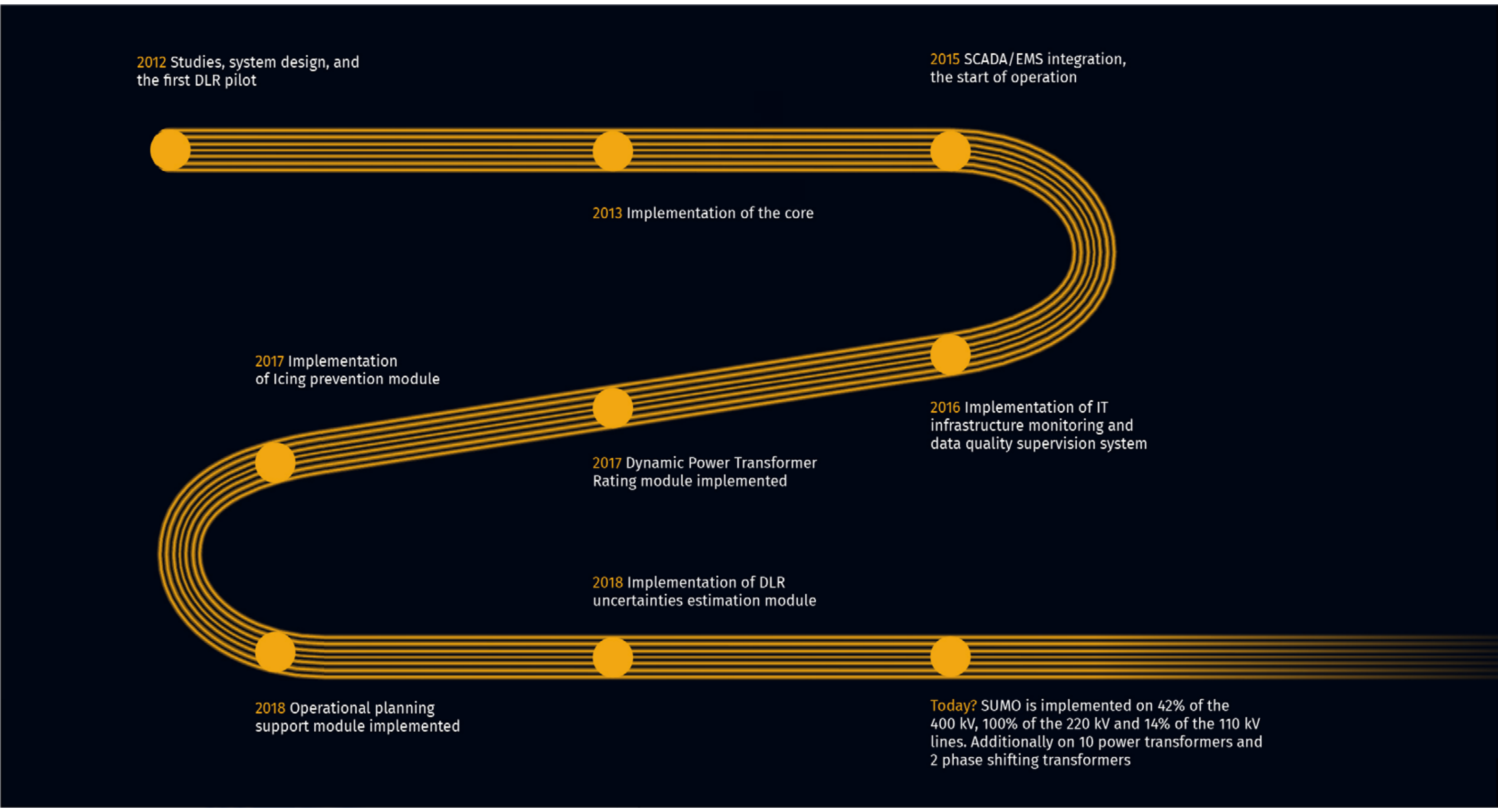
The DLR module not only calculates what is the current and future line loading under the existing topology, it also calculates the worst case N-1 condition load. Simply put, if the most significant other element in the grid goes out, that will result in the highest extra power flow being redirected to the line the DLR is observing and under study, what will be the impact? Not just the immediate change in power flow, but the power flow in the next 3 hours ***given the local weather in that period.*** The changing weather can improve or deteriorate the loading situation, leading to potential overload. No other system on the market can inform and warn the operator in the control room of this system N-1 reality. One could say that without it, the operator is *"left in the dark"*.



4-quadrant visualization (DLR)

The success factors for a successful DLR integration

As pioneers in the field of dynamic thermal capacity of transmission lines, the successful integration of this new technology into ELES's daily operations was the result of painstaking planning and hard work over many years, beginning in 2012 and expanding ever since.



As a first of a kind the learning from this system deployment was experimental and phased in its approach and with its learning need not be repeated. This time span can now be compressed by the *productization of the indirect DLR* into a much shorter project for other users, containing the following essential phases.

- Technical Requirements and economic benefits study phase
- Collection of actual overhead line data to be used for DLR using e.g. using LiDAR scanning, as these may deviate from parameter values set at design time
- Pilot Project on a single line
- Production, integration into operational environment
- Scale-up, roll-out

At the current state of the product, we are able to implement a pilot project in less then three months, and then scale the equipment the system cover almost on a daily basis, just by configuring additional lines, as with indirect approach there is no need for line sensors, the algorithm does everything. This indirect method has been shown to be crucial for a cost-efficient and time-efficient system-wide implementation.

Important aspects in managing this process are the verification of parameters used in calculation of the static limits and quantification of parameter uncertainties and impact on operational risks.

"At ELES, we had high expectations for the potential of indirect dynamic thermal rating from the beginning. We challenged the scientists and experts to turn the potential into an operational and economic reality. These experts have transitioned into a separate subsidiary, Operato, whose mission is to bring the benefits of indirect DLR, as we experience them daily, to our colleagues in electrical infrastructures worldwide."

DR. JURIJ KLANČNIK
DIRECTOR OF OPERATIONS AT ELES

Additional findings

MICROSCALE WEATHER DATA REFINEMENT

Of course, to calculate the maximum rating for a line, you must determine it for each segment of the line and maintain the lowest value. If you do this calculation based on (predicted) weather data, that data must be valid for the particular section of the line segment and not at a 5 kilometers distance. This means that middle-scale weather data that can be obtained from meteorological services must be refined to the micro-scale. For Slovenia, with its mountainous terrain of small valleys and steep slopes, it is a particular challenge to model how and at what speed air masses move and “take the air temperature from one place to the other”. ELES and Operato have succeeded in refining the weather data to the required local granularity using microscale weather processing and local weather stations. On the one hand, they can confirm the accuracy of the model’s predictions, and on the other hand, they allow further refinement for real-time use cases by allowing better calibration.

Overcoming the particular challenges of the alpine landscape has increased confidence in the application of the indirect Dynamic Line Rating technique in the lowlands, suitable for wind power generation for example, where it is easier to refine the model from middle to microscale.

“Operato has consistently delivered on their promises and made sure the systems got integrated on time, on budget, and with the expected level of quality. Their attitudes demonstrate a deep understanding of the specifics of the power domain and a commitment to serve this type of customers at a world-class level.”

ALEKSANDER MERVAR
CEO ELES

THE 2014 HAILSTORM

While the DLR project was well underway, in early February 2014, Slovenia was hit by a hailstorm, with high loads of accumulated ice on the power line infrastructure, resulting in severe discomfort to the population and economic damage to the country.

The team at ELES realized that using dynamic thermal rating in reverse, i.e. to increase rather than lower the current flows through the lines, the lines can be kept above critical freezing temperatures and prevent this rare but disastrous natural phenomenon to take such a toll on the electric infrastructure.

The system was adapted and the reverse DTR module is in the use today.

The results

The methodical and well-planned integration approach has resulted in an effective modularization and productization of the SUMO Dynamic Line Rating solution.

The point of contact with the critical SCADA system is reduced to a single point by adding the SUMO bus that allows pre-integration of related applications and realizes a well-managed single interface to the SCADA. This aspect, "feature" of the SUMO eco-system is highly appreciated by the operation side of the TSO organization.

SUMO Dynamic Rating System is used daily on 33 power lines, 10 power transformers, and two phase-shift transformers providing important information for power system operation, and operational planning, both from the aspect of additional capacities that ELES may count on, as well as minimizing the operational risk by providing deeper insight into the power grid.

- Improves resiliency, safety and reliability: mitigates over 50 network events in N, and 500 in N-1 topology on average per year.
- Increased transmission capacity: identifies higher transmission capacity 92-96% of time, with median increase of 15-20 % of the nominal capacity based on real-time and forecasted weather conditions. On the Podlog - Obersielach 220 kV tie-line between Slovenia and Austria, SUMO enables 70 MW more capacity.
- System ready deployment: installation of the core system allows for immediate deployment on every line required in a system, and rapid software configuration for inclusion of future circuits in less than a week. Dependent on existing weather data sources available, this can be done without any further hardware.
- As an example of a cost saving, SUMO increased the transmission capacity on neighbouring 110 kV and 220 kV lines during a 4-month period of a transformer forced outage by 24% to increase network security and deliver cost savings of €270k (avoided curtailments of a hydropower plant and costs of a negative tertiary reserve).
- Prevention of ice: an advanced inverse DLR algorithm provides alarms to operators when there is high risk of icing, enabling system operators to take measures to avoid icing. It calculates the minimal current that keeps conductors heated above the temperatures where ice accretion (ice build-up) would occur.
- Network condition based monitoring: is enabled from the data acquisition, offering improved network reliability and avoidance of complex and/or expensive unnecessary equipment maintenance/replacement.

The Road Ahead

ELES is extending the reach of the dynamic thermal rating system on a continuing basis across its entire high voltage power line infrastructure. Work is also done to apply the principles to transformer limits.

The system has also extended to a nearby country, Croatian TSO, HOPS, creating an even wider system implementation and integration.

The company will continue to learn and improve both the system and the algorithm, though at the same time will try to offer variety of modules that may help TSOs run day-to-day operation, have more control over the system and improve the decision making .

ELES is proud to demonstrate the benefits of the indirect DLR/DTR system in live action to prospective customers of Operato and is more than willing to address any of their concerns with testimonies of their experience with the system. Feel free to contact us.

Contact us

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