Swissgrid's proof of concept in the high Alpine

Dynamic Line Rating for Power and Utilities 2022 - Virtual Conference

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Online, 13th May 2022

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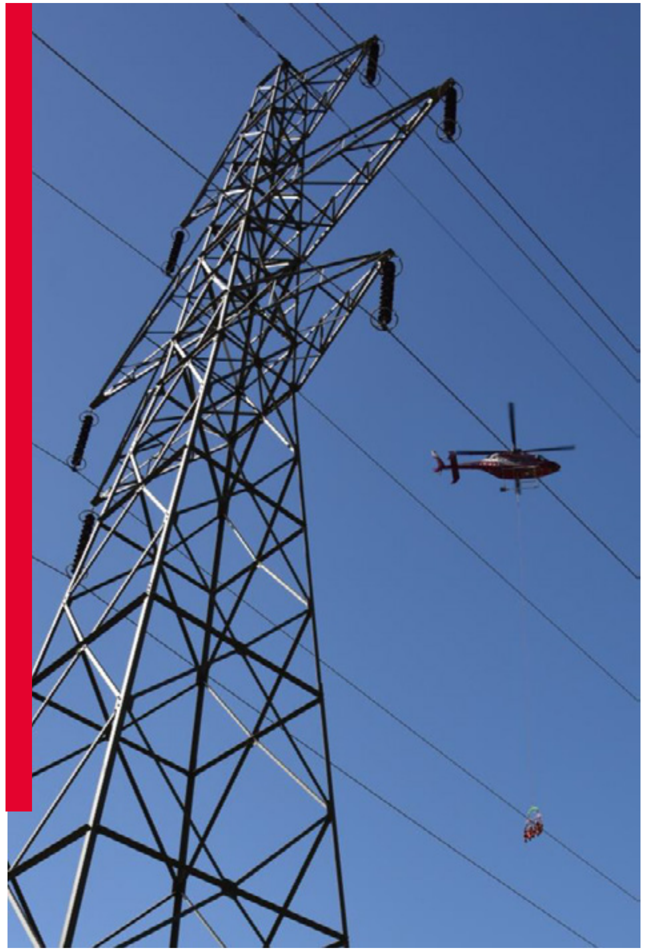
Agenda



1 About Swissgrid

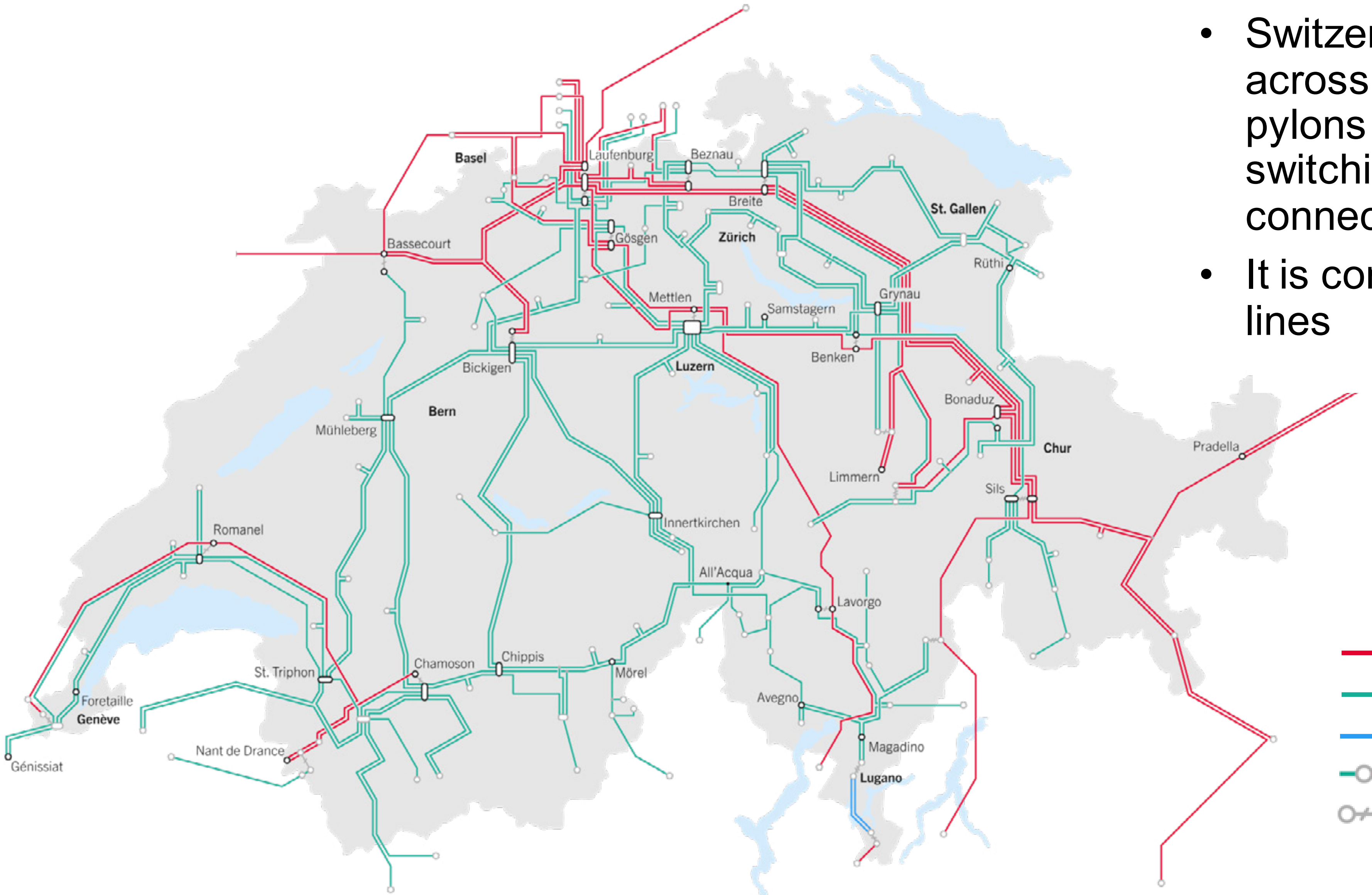
2 DLR pilot on Handeck-Innertkirchen 1&2 lines

3 Experiences from the PoC

4 Results from the Weather Forecast Sensitivity Analysis

5 Outlook to the future

Switzerland's transmission grid



- Switzerland's transmission grid extends across 6,700 kilometres of lines, 12,000 pylons and 125 substations with 147 switching substations, as well as 41 connections abroad
- It is comprised of both 380 kV and 220 kV lines

380 kV
220 kV
150 kV
Switching substations
Switching substations with transformers

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Grid owner with comprehensive responsibility

1
grid

7
locations

6,700
km lines

12,000
electricity pylons

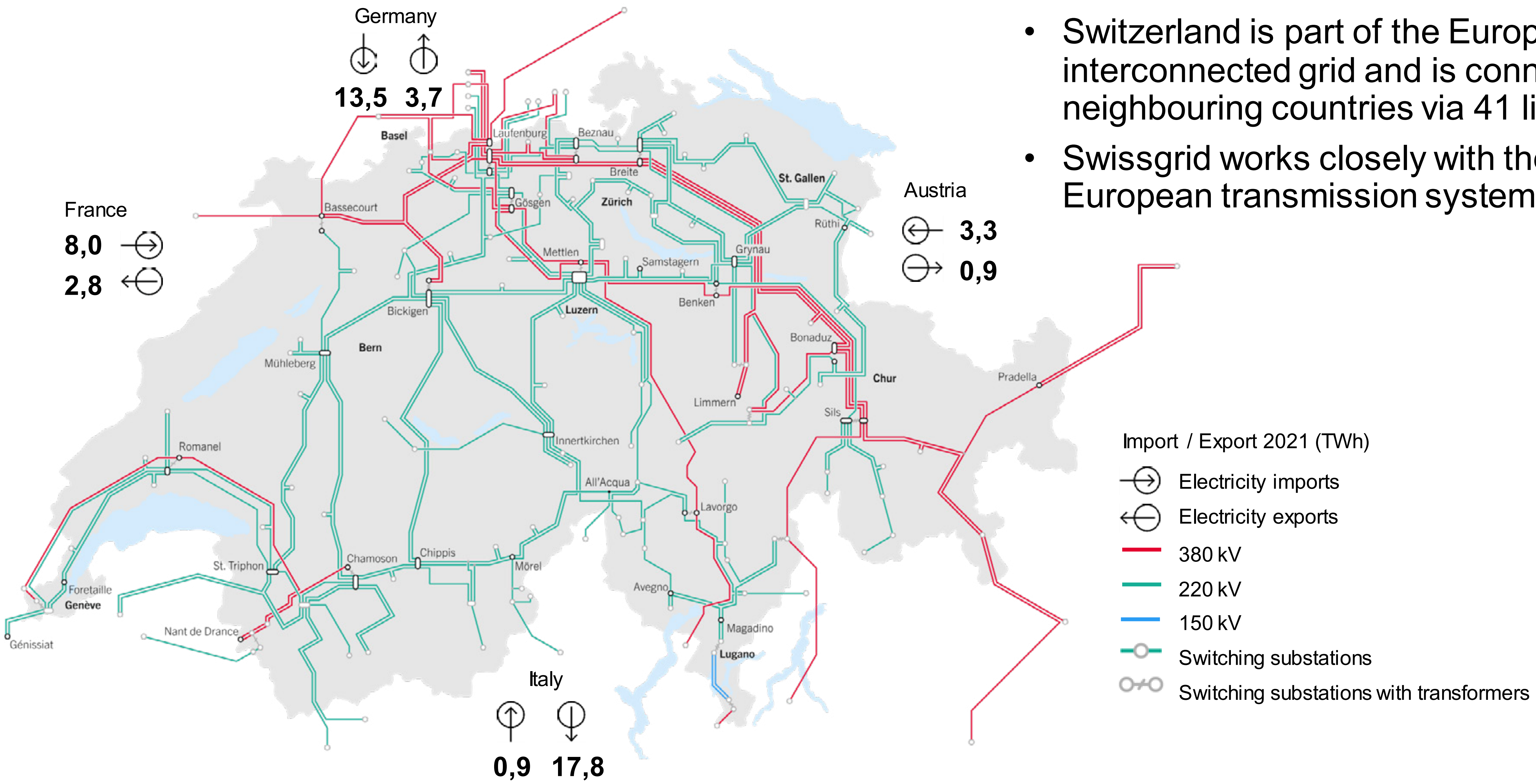
12,000
inspections a year

21
transformers

147
switching substations

41
connections to other countries

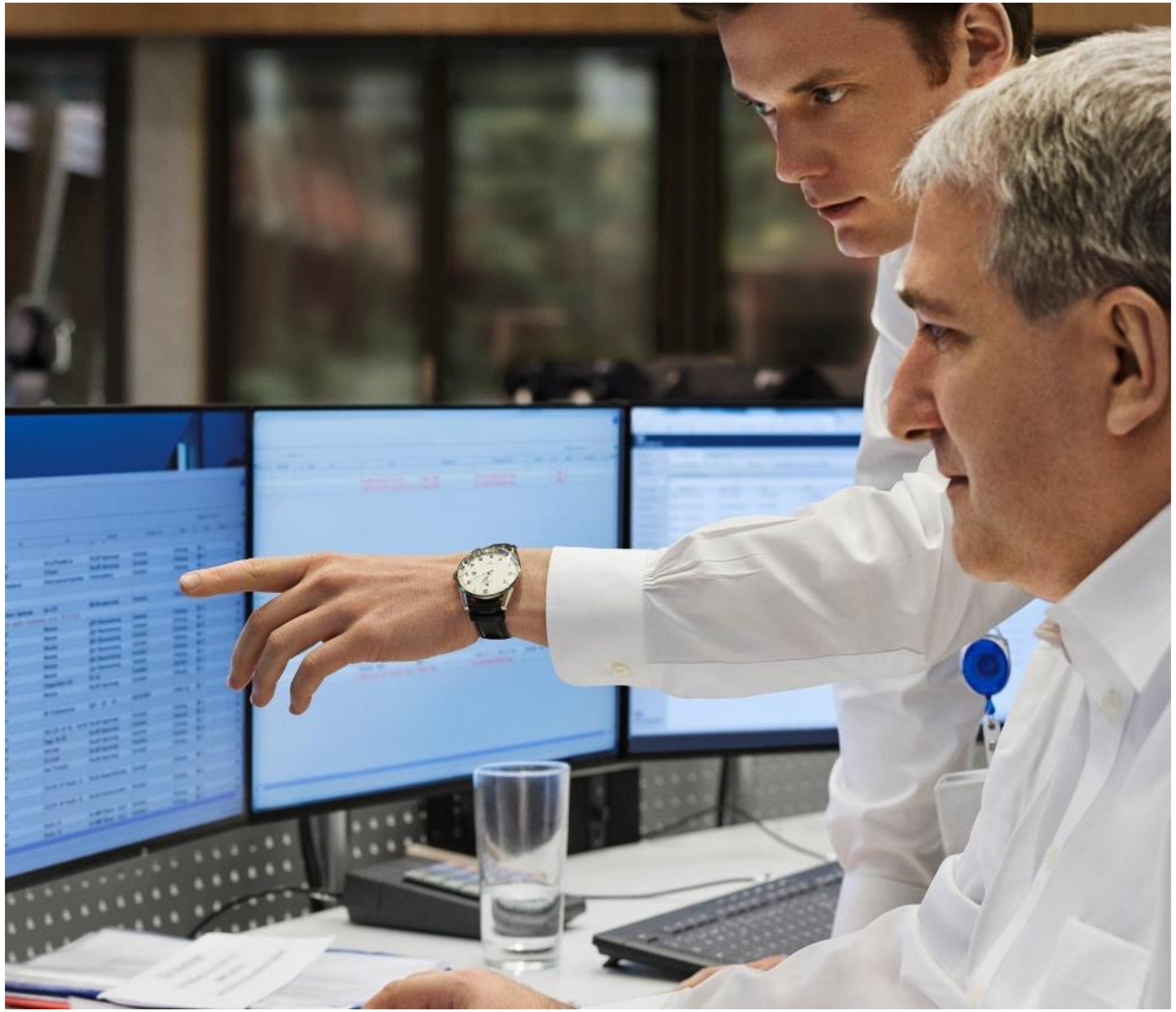
Closely linked with Europe



- Switzerland is part of the European interconnected grid and is connected to neighbouring countries via 41 lines
- Swissgrid works closely with the European transmission system operators

Key drivers and motivation for DLR

- Reduction of congestions in the grid caused by integration of renewables, construction works or network element failure.
- Increase of Network Security, improved management of N-1 violations and N-1 violation scenarios.
- Reduction of Redispatch Costs to maintain N-1 network security.
- Asset Protection (sag and ice load monitoring) and Lifetime Optimization (avoid accelerated ageing).



Increased network security and reduced redispatching costs.

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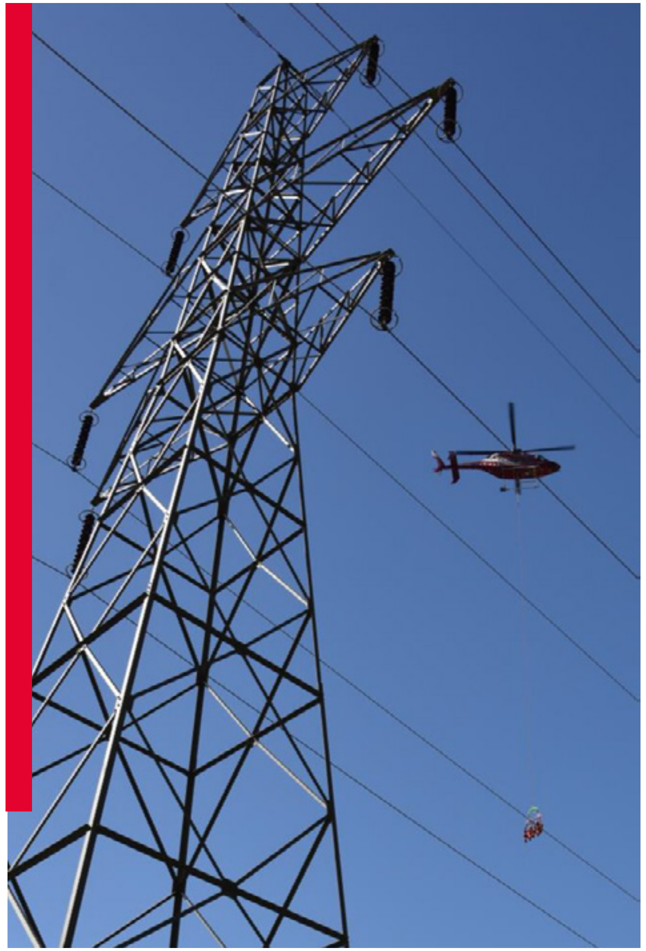

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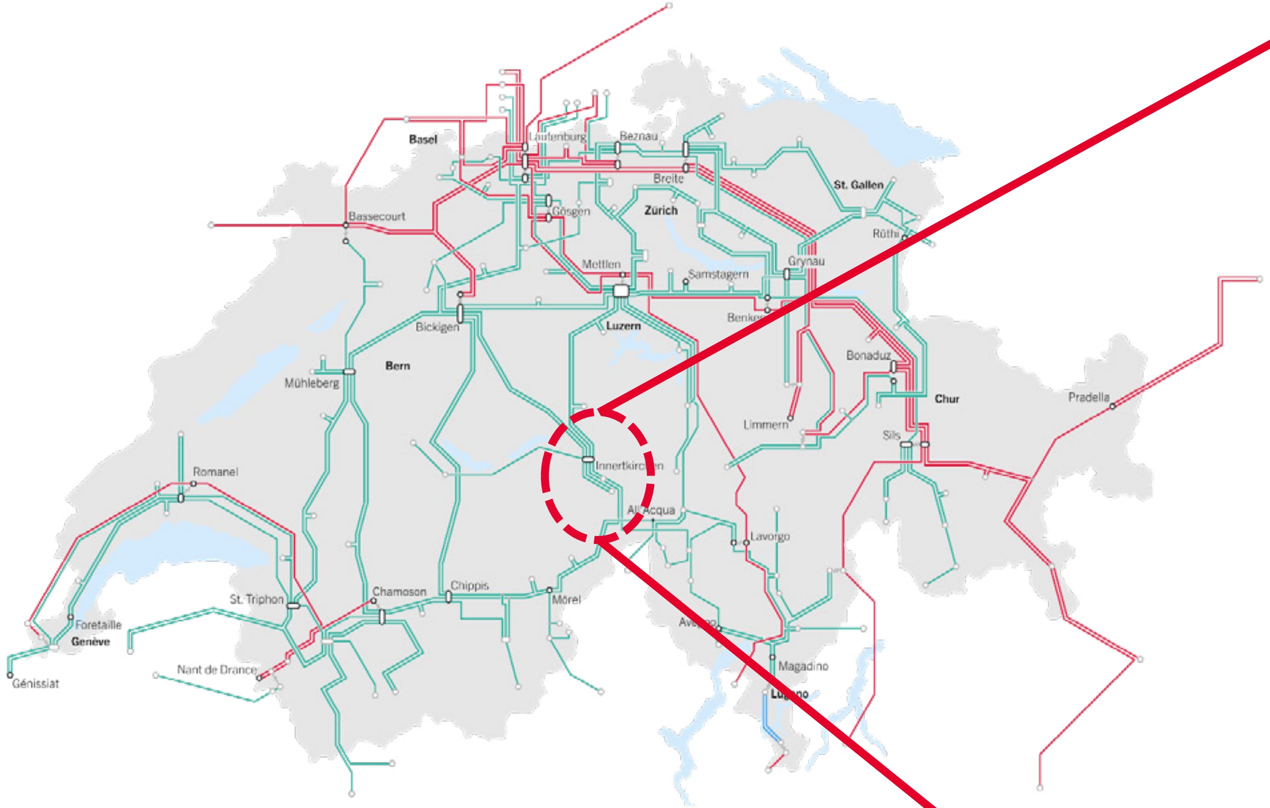
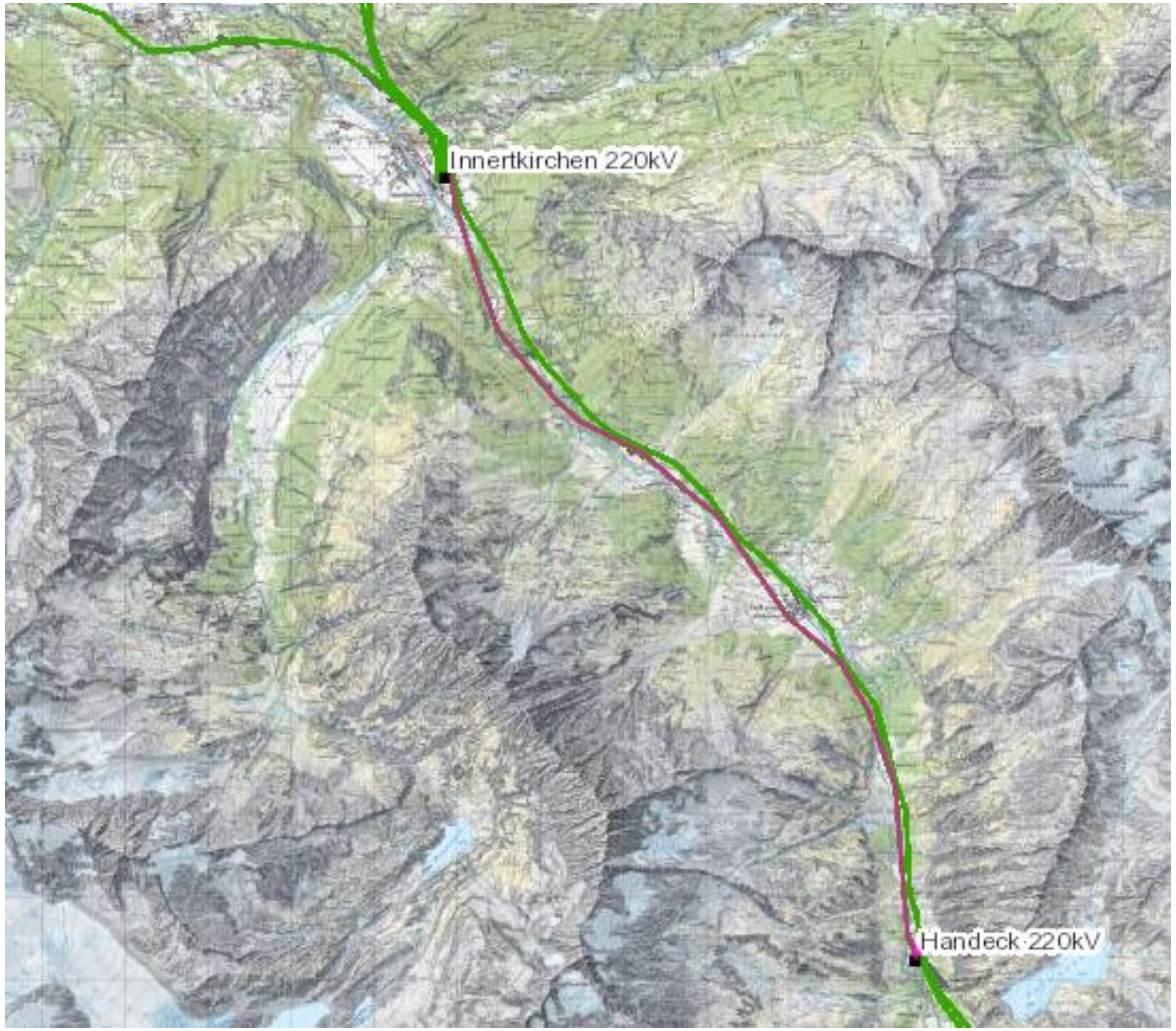
Handeck - Innertkirchen 1&2 - Lines for PoC





2 Parallel Lines in a valley in the Swiss Alps

Innertkirchen: 633 masl, Handeck 1300 masl

Each line ~12 km, ~ 35 pylons

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Handeck - Innertkirchen 1&2 - Lines for PoC

Why those lines?

- High hydro power plant production in the Grimsel Region (Handeck)
- Different seasonal load flow patterns on the lines
- One of the two lines had a planned outage in 2020
  - Caused N-1 violations
- Minimal ground clearance is very tight in some spots

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Handeck - Innertkirchen 1&2 - PoC Installation

- **8 IoT sensors** were installed on the conductor of L2
  - Split of 5 / 3 between both lines due to topography and exposure
- Sensors measure **conductor current**, conductor **surface temperature**, angle of **inclination** and 3-axis conductor **acceleration** without external power supply. Data is transmitted over public LTE (4G) to a cloud based application.
- Validation completed, operational rules defined, N-1 rolling FC data from SCADA is provided to DLR cloud application.
- Sensor data and application allows to focus on nowcasting **1-4h** (real time systems operation) and **24h-forecasting** (IDCF) of the ampacity on the two lines.
- **Ampacity forecast** is provided as IEEE, CIGRE and vendor specific models.
- **Alarms** for sag clearance, conductor temperature and N-1 violations are implemented.

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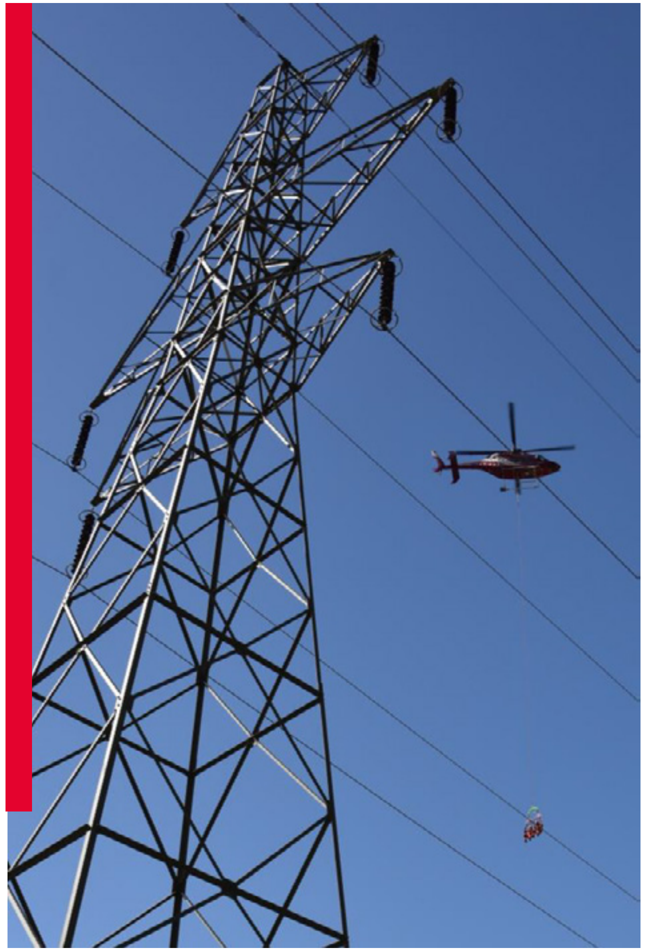

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Experiences from the PoC

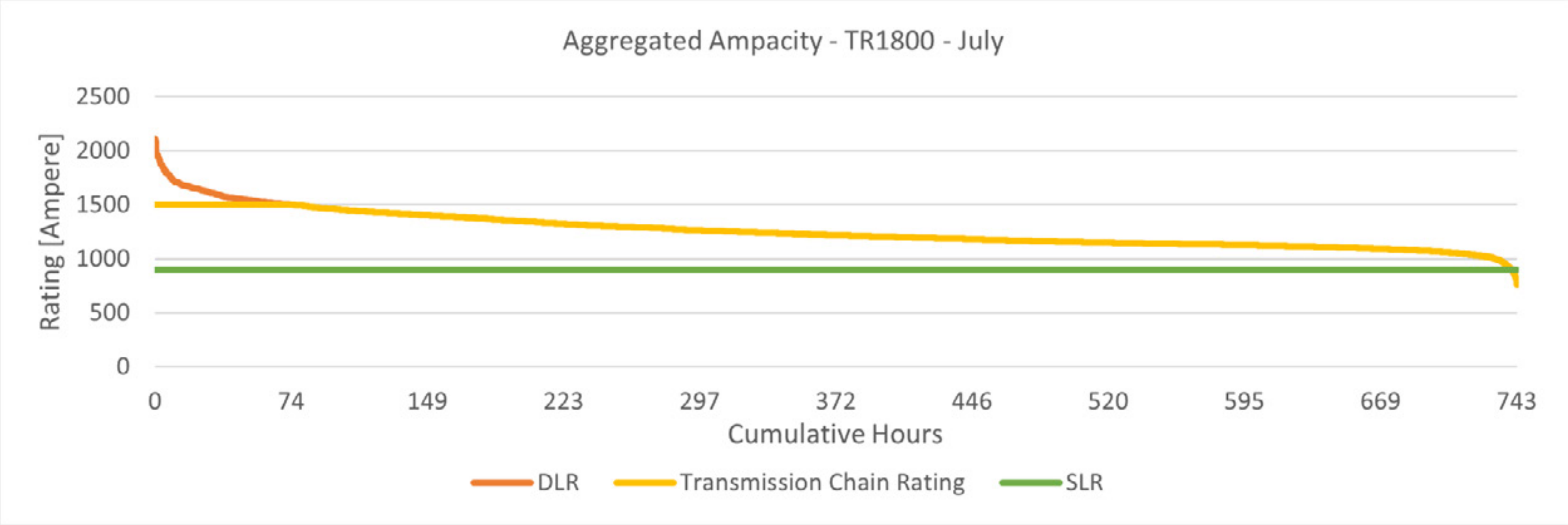
Opportunities

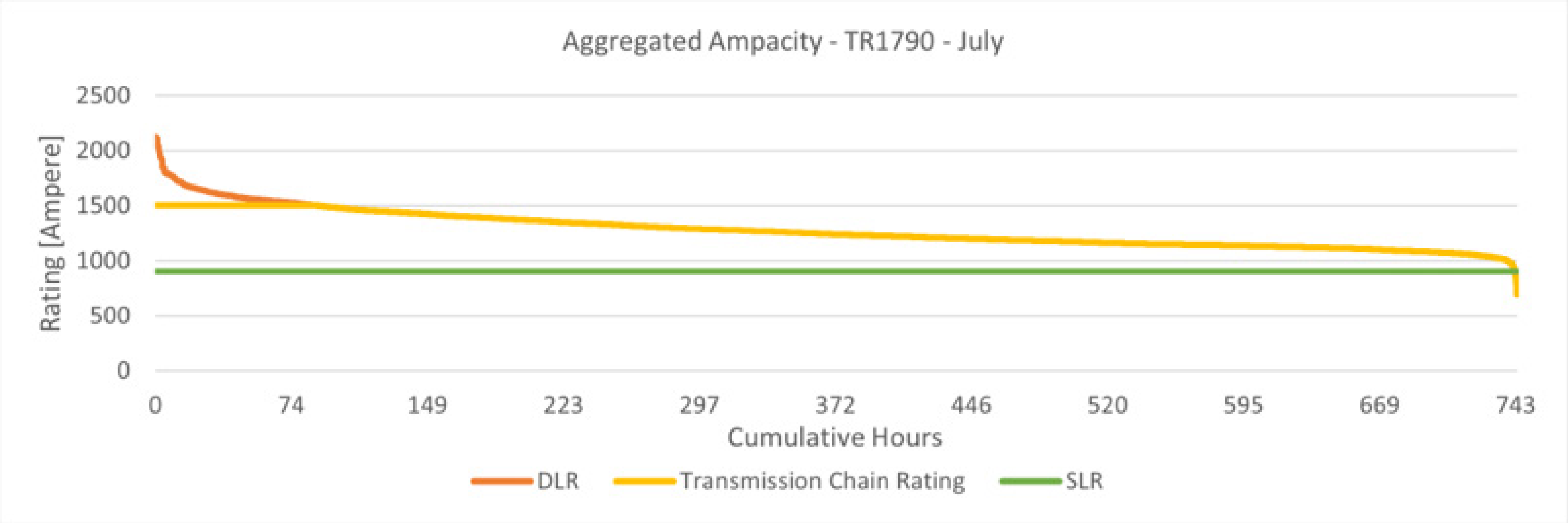
- Higher Ampacity compared to SLR
- Installation effort can be quantified
- Awareness within Swissgrid – from theory to running PoC within 6 months
- Building know-how

Challenges

- Definition of spans to cover with se
- Installation effort (e.g. outage plann helicopter)
- Sensor failures (reboot of sensor re to switch off one line *)
- Integration of Dynamic Ampacity in current SCADA would require huge

Capacity increase most of the time, max. ampacity limited by downstream components





- **Substantial capacity increase** over the whole month of July*. Only during **some hours DLR was below SLR**.
- Seasonal SLR values of the two lines proved to be very conservative.
- Max Ampacity value depends on limiting downstream components, potential hotspots on conductors, unequal phase current distribution and safety margins.
- When installing DLR, **the whole** transmission **chain** from substation1-busbar to substation2-busbar **must be considered.**

*) Data from 2021, it was a very rainy / cold summer in CH

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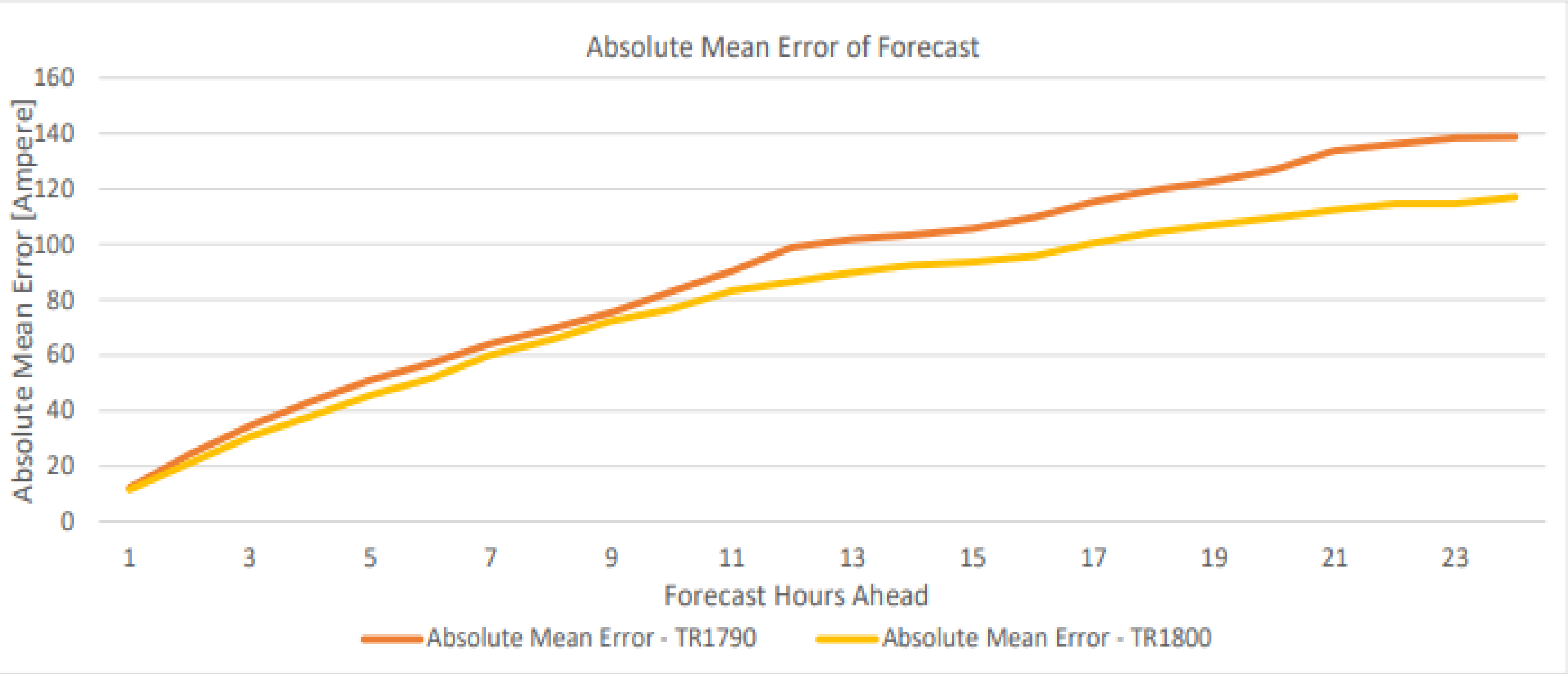
Ampacity 24h-forecast quality.
Absolute Mean Error of Forecast mainly caused by uncertainty of weather forecasts.



- Forecast modelling is based on CIGRE / IEEE models.
- Meteo data from a Swiss service provider is used (microscale) – but prediction of wind vector in mountain valleys is very demanding.
- Benchmarks between meteo forecasts and measured values were conducted
- Meteo station data close to the lines may be used for meteo forecast model calibration and for improving the ampacity forecasts.
- Using acceleration data from sensors may contribute to better estimation of wind vectors.

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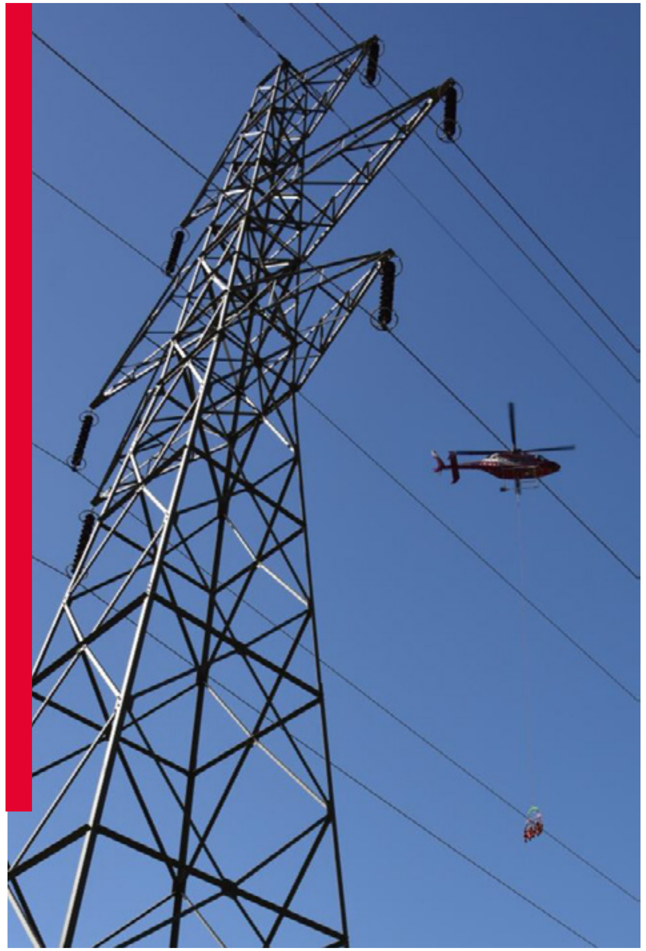

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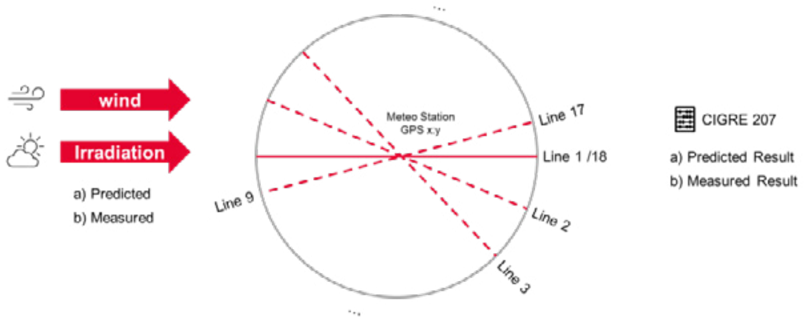
Explanation of Data shown on following slides

- CIGRE 207 Steady State computations are used

- 10 minute Weather predictions for April 2021 on the coordinates of the local Meteo Stations
- Measured values at the meteo stations in Innertkirchen, Gutannen and Handeck
- For each time stamp ampacity is calculated once according to the station data and once according to the predictions.
- For wind angle, simulated lines (each with a 20° offset) are used



- The deviation in percentage is used as a metric:

$$\text{Absolut Percentage Error} = \frac{|Ampacity_{meteostation} - Ampacity_{predicted}|}{Ampacity_{meteostation}} \times 100$$

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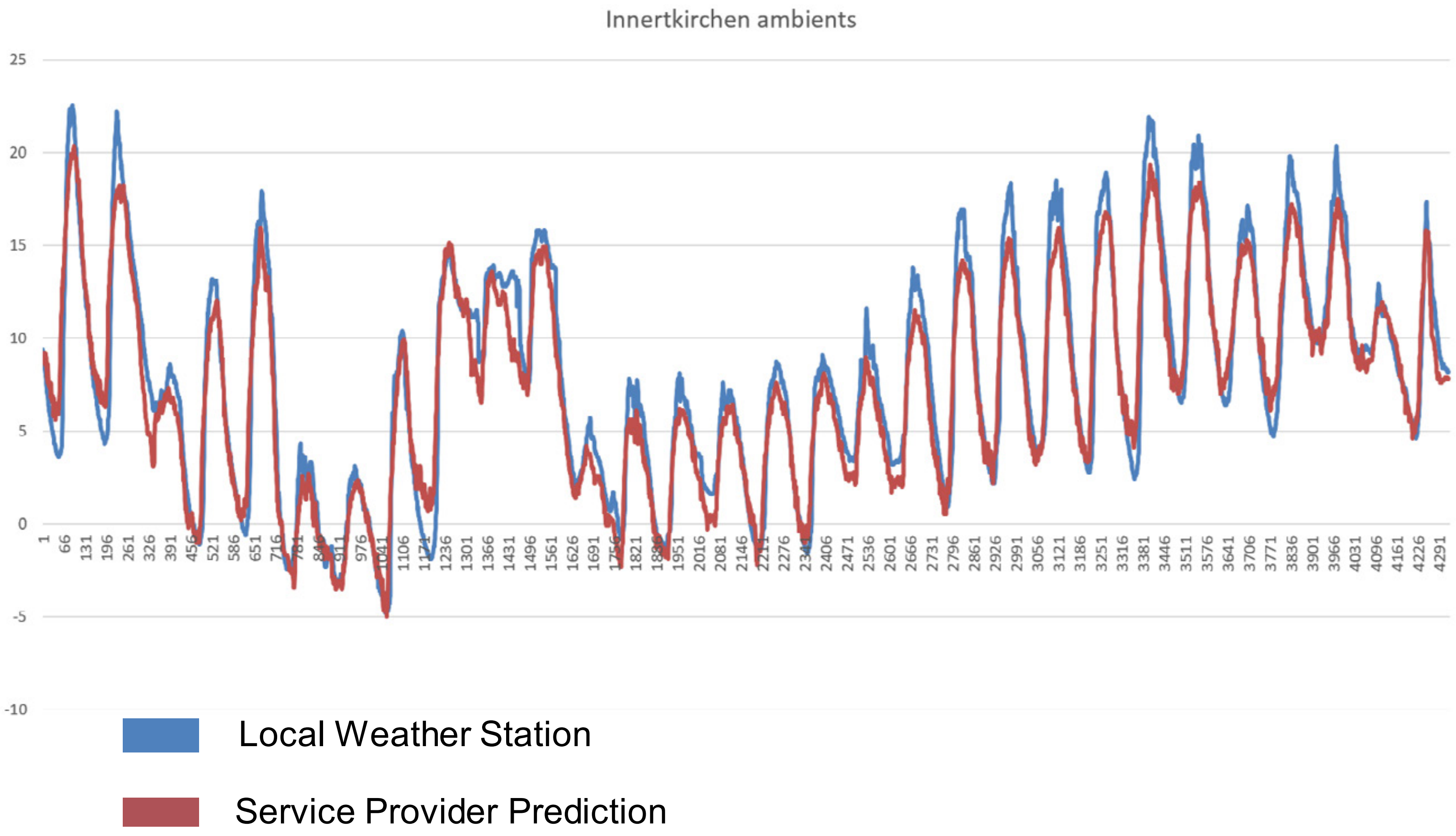
Ambient Temperature Comparison between weather station and prediction



Comparison

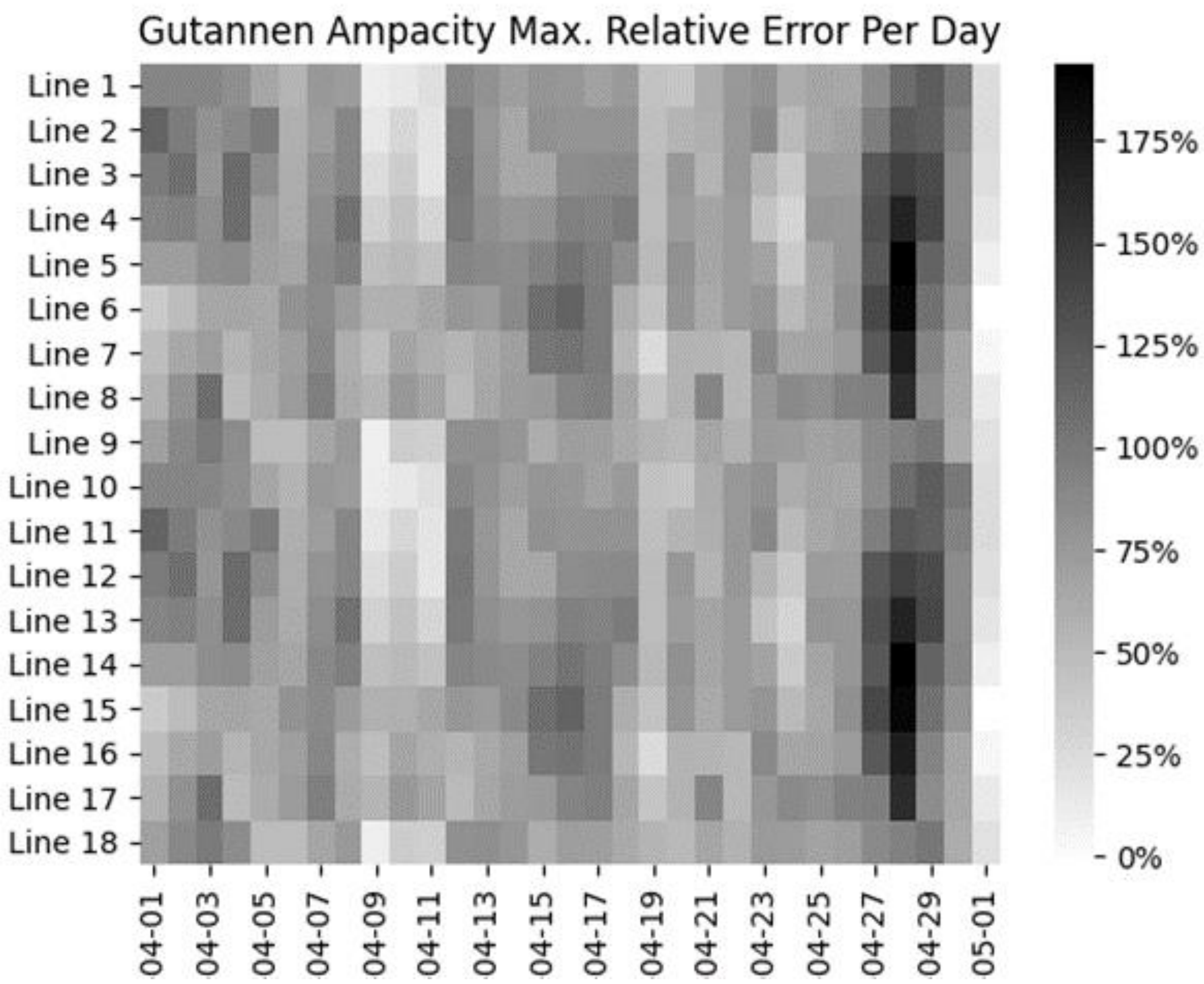
10 min Forecast compared to Data from local Weather station

Conclusion:

Ambient temperature prediction is quite accurate

The deviation of 1.16-1.51 °C results in 4% ampacity error

Sensitivity of DLR to the inaccuracies of the weather predictions



max
180%

Effect of Wind Direction Prediction

Horizontal Axis

Date (April 2021 – May 2021)

Vertical Axis

Imaginary OHL, each with a 20° offset

Greyscale

Error Rate

Conclusion:

The maximum Error is more than 175% (on 04-28)

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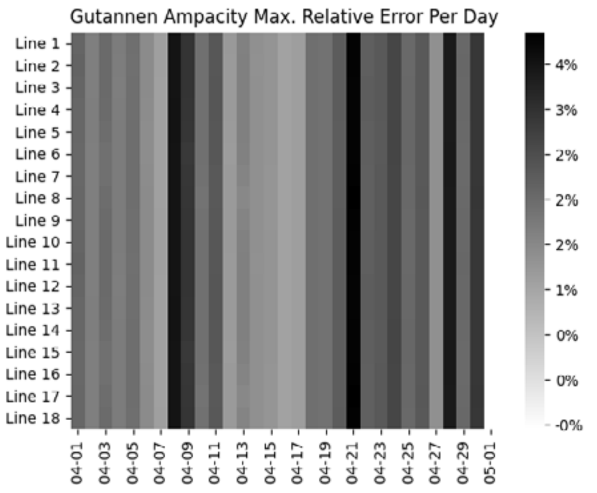
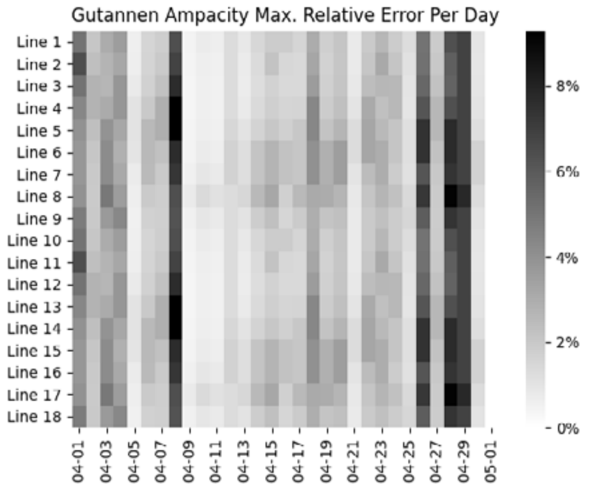
Individual Sensitivity of the Weather prediction parameters

Ambient Temperature



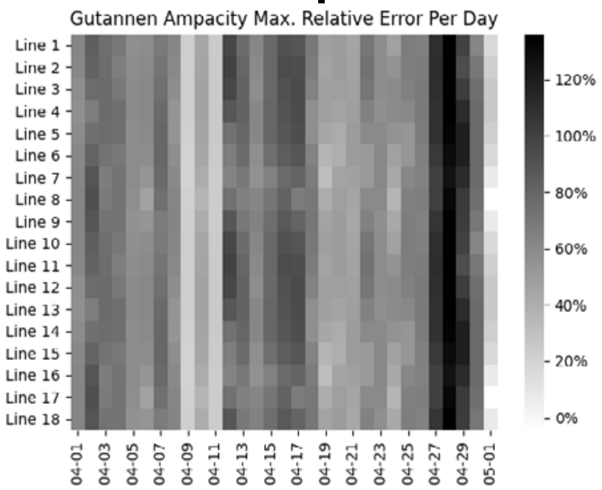
max 4%

Solar Irradiation



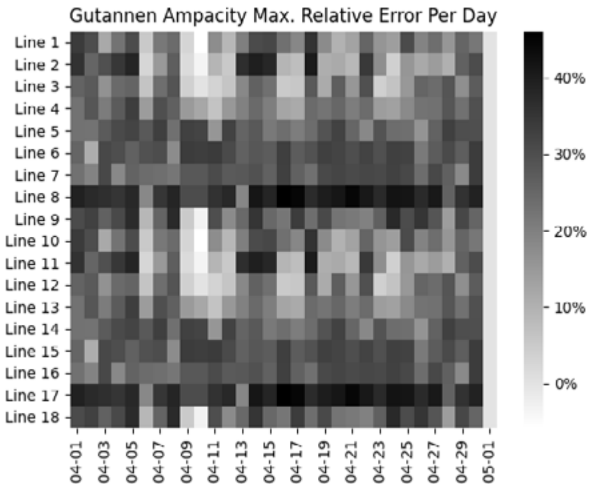
max 8%

Wind Speed



max 120%

Wind Direction



max 40%

Effect of individual Parameters

Horizontal Axis

Date (April 2021 – May 2021)

Vertical Axis

Imaginary OHL, each with a 20° offset

Greyscale

Error Rate

Conclusion:

Ambient Temperature and Solar Irradiation have a small effect of the accuracy.

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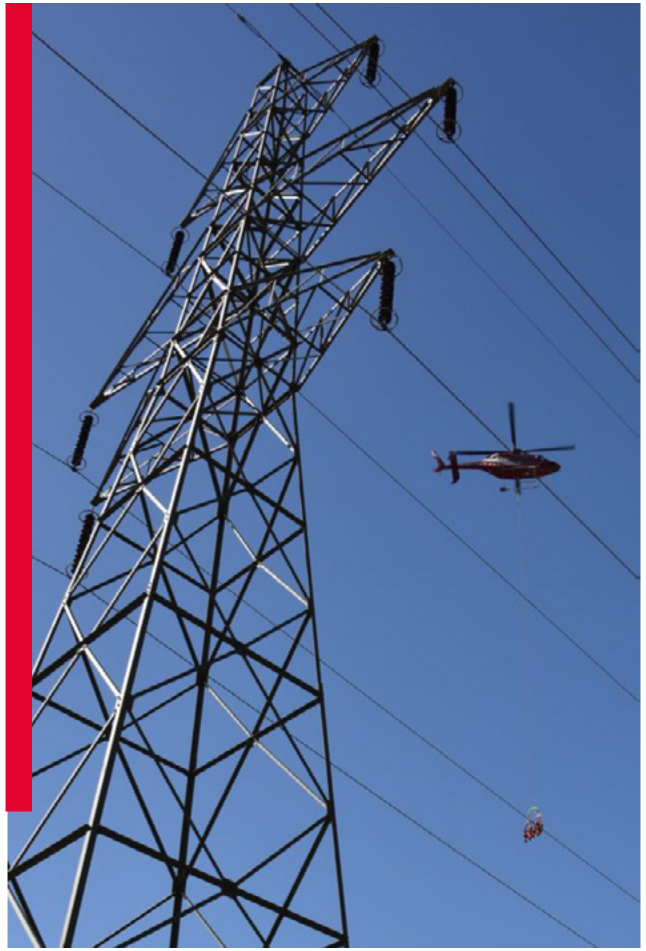

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Conclusion and Outlook

DLR ampacity is not only limited by the line conductors.

- Reducing calculated Ampacity is necessary due to other limiting elements

DLR increases the quality for systems operation and IDCF / DACF* planning.

DLR probably avoids some of the investments for network capacity increase

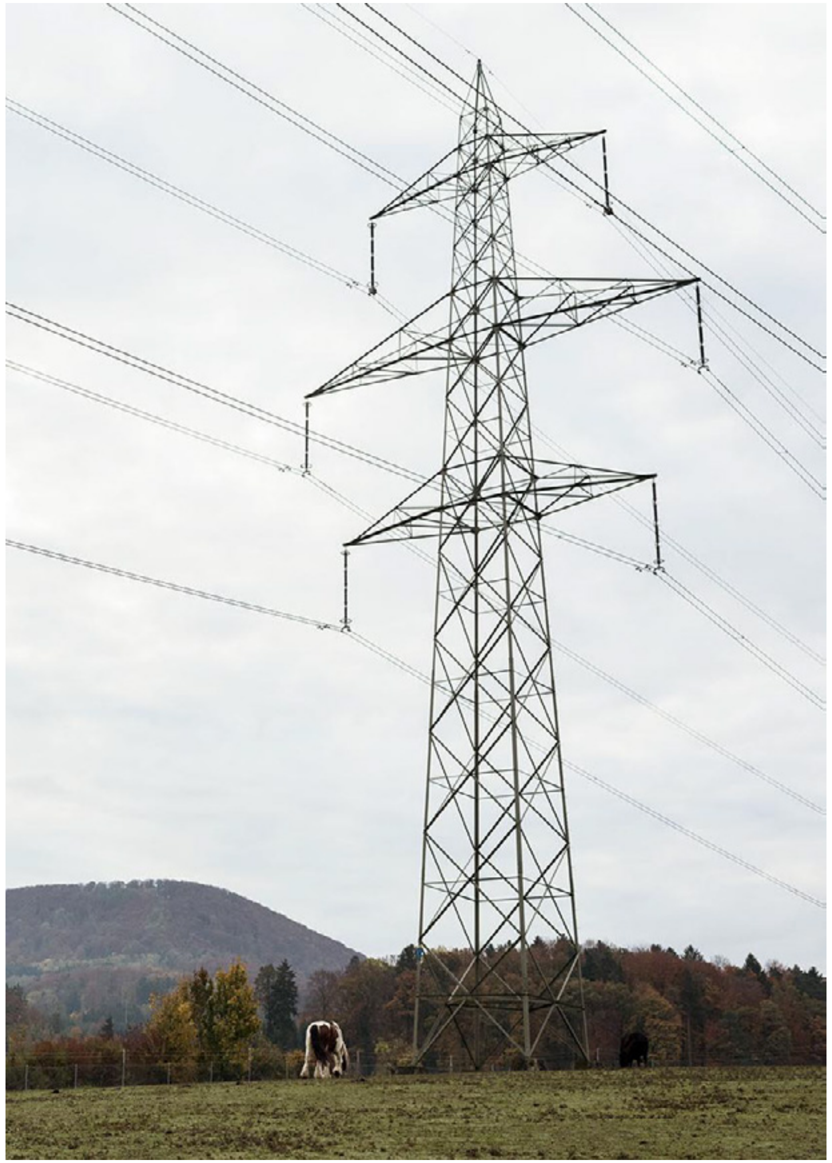
DLR benefits include reduced redispatch costs and increased network security

- Hidden safety margins may no longer be required since line parameters are permanently monitored on the most critical spans.

DLR will demonstrate its biggest value when lines are heavily congested due to construction works on parallel lines.

DLR ampacity values must be integrated into the SCADA System (replacement of SLR values by DLR / SDLR values). On the long term, a stand-alone decision support system cannot be handled by system operators since N-1 calculations have to be harmonized manually with DLR ampacity forecasts.

Swissgrid will start an internal project to plan all aspects for a DLR roll-out



*) IDCF: Intra Day Congestion Forecast, DACF: Day Ahead Congestion Forecast

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