Dynamic Line Rating without field devices

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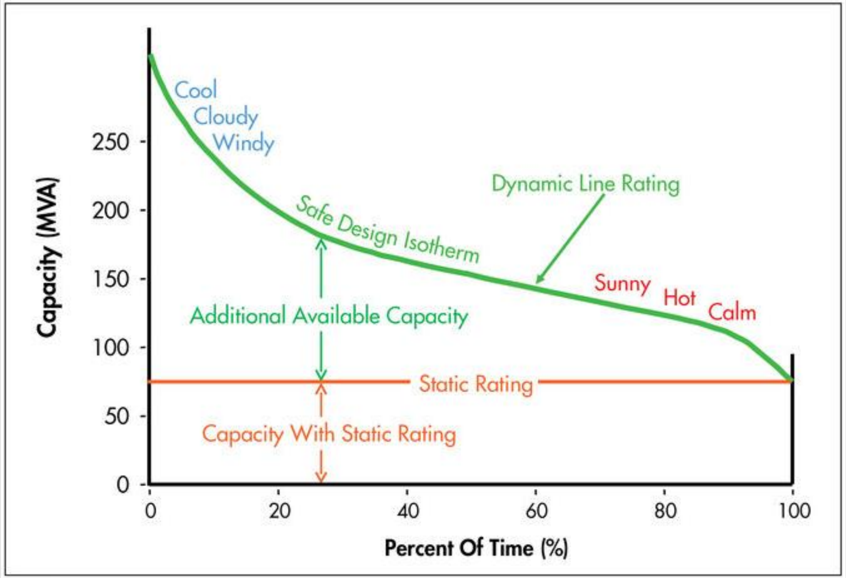
Static Line Rating

- Fixed Current Limit
- Calculated with Limit Conditions
- Summer and Winter Limit

Dynamic Line Rating

- Variable Current Limit
- Calculated with Real Time Conditions
- It depends on weather

Figure 1: Tapping into existing capacity above the static rating



Source: Valley Group

Dynamic Line Rating

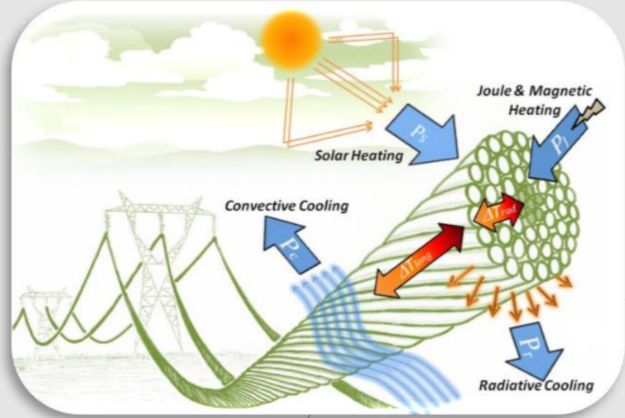
1. CIGRE Technical Brochures: Guide for thermal rating calculations of overhead lines

2. IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors

$$Pj + Ps = Pc + Pr$$

$$I^2 \cdot R + ☀ = 💨 + 🌡$$

$$I = \sqrt{\frac{P_s - P_c - P_r}{R(T_{MAX})}}$$



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Motivation

Current State

- High Cost
- Slow and Complex Instalaton
- Unusable for the Operator
- Conexión Lost

Thesis Approach

- Third Parties Weather Data
- No Equipmanet Needed
- Suitable For The Operator

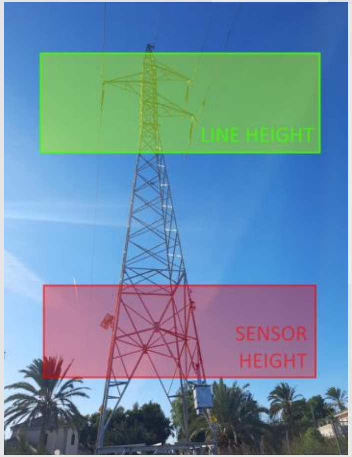
Objectives

Weather Measurement Accurracy

DLR Equations Inputs

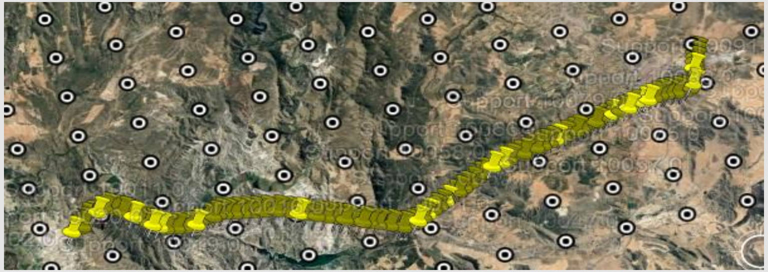
Results for Grid Operation

Weather Measurement Accurracy



Objectives

- Field Devices Height Influence
- Weather Parameters Extrapolation
  - Orography
  - Annual Season
  - Vegetation



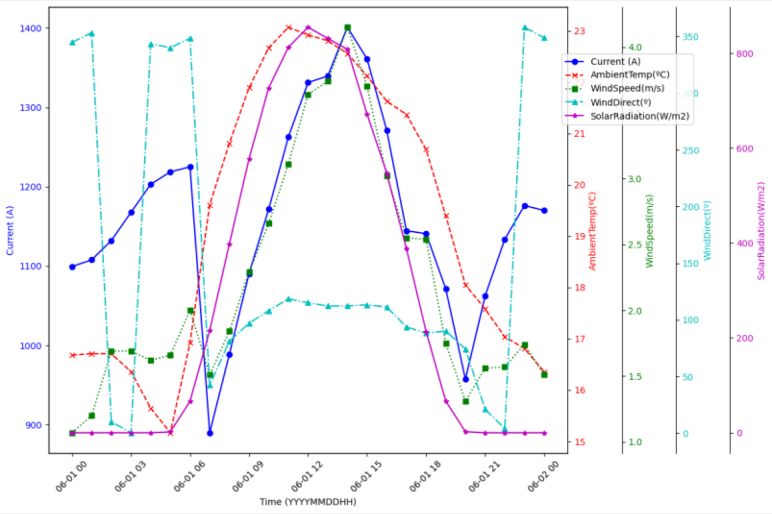
DLR Equations Inputs

Input

Conductor characteristics
Conductor outside diameter (mm)
Core diameter (mm)
Outer strand diameter (mm)
Maximum allowable conductor temp. (°C)
Emissivity
Solar absorptivity
Conductor ac resistance at 25°C (Ω/m)
Conductor ac resistance at 75°C (Ω/m)
Ambient conditions
Ambient air temperature (°C)
Wind speed (m/s)
Wind angle of attack (°)
Inclination β to the horizontal (°)
Height above sea level y (m)
Solar conditions
Azimuth of line (°)
Latitude (°)
Clearness of Atmosphere
Date
Reflectance of the ground (albedo)

Influence

- Conductor Aging
- Ambient Pollution
- Operation History



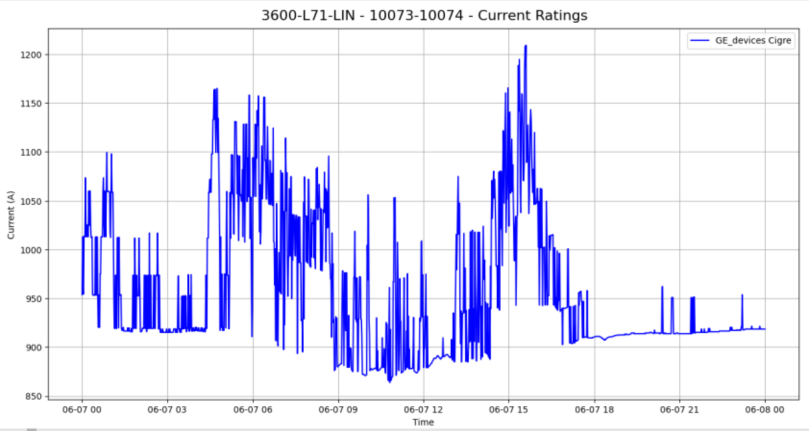
Results for Grid Operation

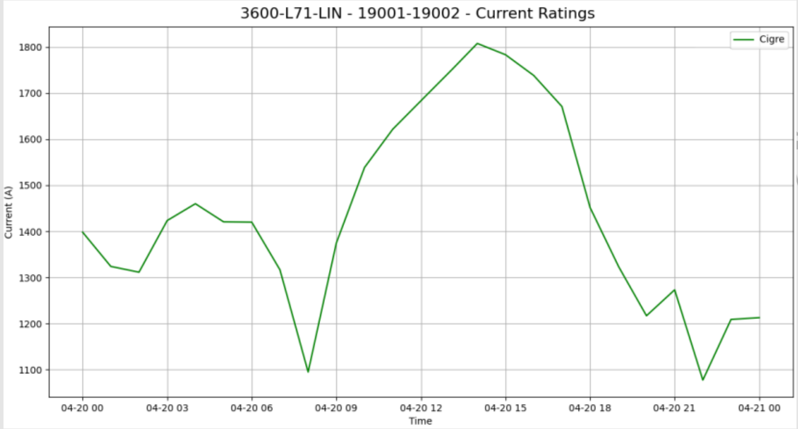
Actual DLR Output

Unstable Current Rating
Not Used

Thesis DLR Output

Stable Current Rating
Weather Forecasting
Forecasting Time Accurracy





Project Plan

01 Parametrize All Lines

02 Provider Weather Data

03 Import Standard Formulas

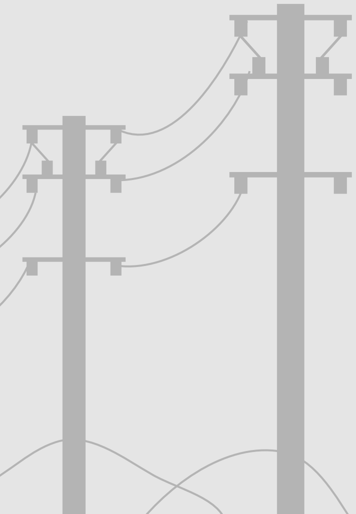
04 Weather and Results Comparison

05 Stabilize DLR Output

CURRENT PROGRESS

Parametrize All Lines

- Line ID
- Span ID
- Coordinates
- Conductor Type

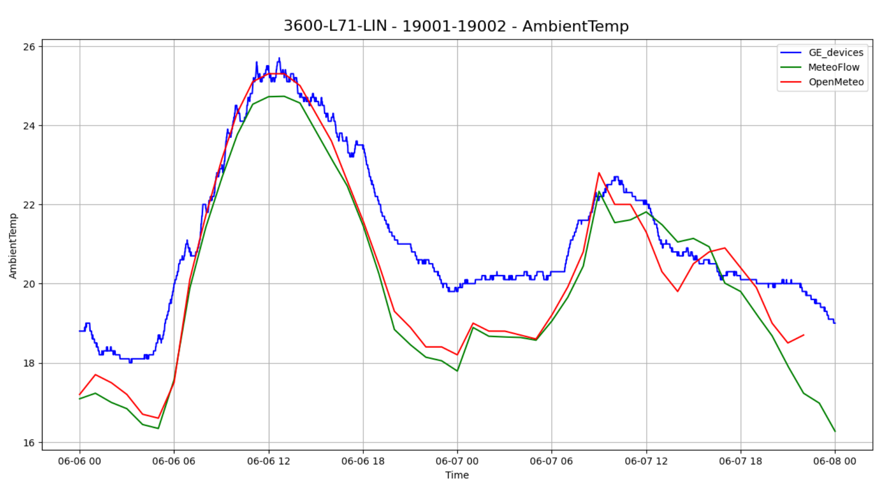


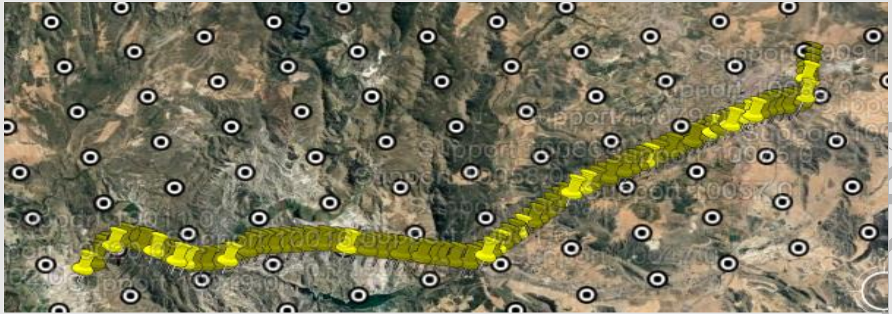
CODE	Conductor Diameter (mm)	Outer Wire Diameter (mm)	DC Resistance at 20ºC (ohm/km)	DC Resistance at 75ºC (ohm/km)
LA 175 OSTRICH	17.28	2.73	0.185	0.226
LA 180	17.5	2.5	0.1962	0.199
LA 280 HAWK	21.79	3.44	0.117	0.142
LA 300 HEN	22.42	3.2	0.116	0.142

```
Span,Latitude,Longitude,Angle,Elevation,SupportHeight,ConductorType,DeviceGE
18067-10068,38.28067228313209,-0.7168867426924255,-125.86191453581152,136.0,21,LA 280 HAWK,no
10068-10069,38.27913500356807,-0.7196091537613991,-125.58991971892864,132.0,21,LA 280 HAWK,no
10069-10070,38.27737316169882,-0.7227450609474958,-125.5901502434150 8,134.0,21,LA 280 HAWK,no
10070-10071,38.27501153839174,-0.72694804602588 8,-125.59335795634874,115.0,21,LA 280 HAWK,no
10071-10072,38.27291721210064,-0.7306750076279667,-125.59432742888876,126.0,21,LA 280 HAWK,no
10072-10073,38.271238913070206,-0.733661300553164,-125.59754904203258,116.0,21,LA 280 HAWK,no
10073-10074,38.26960936583586,-0.7365626914224481,-125.552388293997,117.0,21,LA 300 HEN,yes
10074-10075,38.26822462336136,-0.7390304188410167,-125.55488279842046,120.0,21,LA 280 HAWK,no
10075-10076,38.26653754651623,-0.7420366283623947,-125.55600514842604,118.0,21,LA 280 HAWK,no
10076-10077,38.26469796568913,-0.7453143306043013,-125.5582045634629,114.0,21,LA 280 HAWK,no
10077-10078,38.26308873966309,-0.7481812905915681,-125.560649837833,113.0,21,LA 280 HAWK,no
10078-10079,38.26113672985558,-0.7516585683026649,-125.56174242627462,97.0,21,LA 280 HAWK,no
```

CURRENT PROGRESS

Get Weather Data from Providers





opernicus
Europe's eyes on Earth

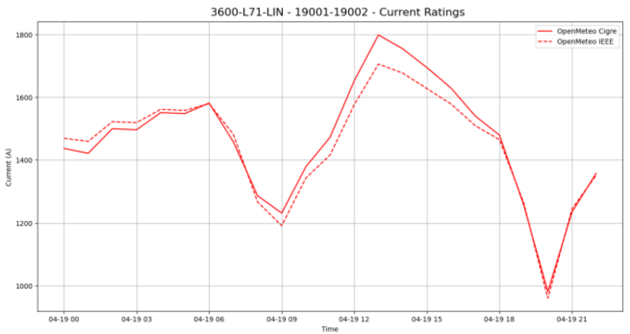
Open-Meteo

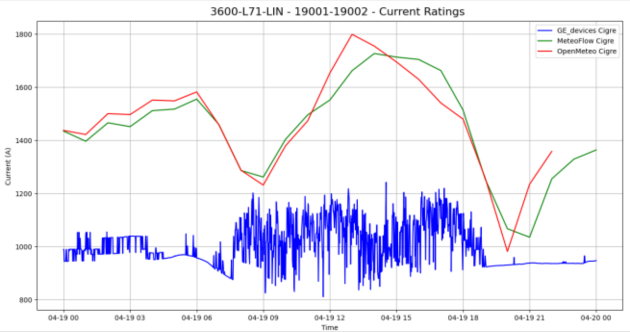
meteogrid

AEMet
Agencia Estatal de Meteorología

CURRENT PROGRESS

Import Standard Equations





Convective heat loss

$$T_f = 0.5 \cdot (T_s + T_a)$$

$$\lambda_f = 2.368 \cdot 10^{-2} + 7.23 \cdot 10^{-5} \cdot T_f - 2.763 \cdot 10^{-8} \cdot T_f^2$$

γ_0 (density of the air at sea level)

$$\gamma = \frac{1.293 - 1.525 \cdot 10^{-4} \cdot y + 6.379 \cdot 10^{-9} \cdot y^2}{1 + 0.00367 \cdot T_f}$$

$$\mu_f = \left(17.239 + 4.635 \cdot 10^{-2} \cdot T_f - 2.03 \cdot 10^{-5} \cdot T_f^2\right) \cdot 10^{-6}$$

$$v_f = \mu_f / \gamma$$

$$R_s = d/2 \cdot (D - d)$$

$$Re = V \cdot D / v_f$$

B; n (Table 4)

$$Nu_{90} = B \cdot Re^n$$

$$Nu_\delta = Nu_{90} \cdot (0.42 + 0.58 \cdot sin(\delta)^{0.90})$$

$$P_{c,forced} = \pi \cdot \lambda_f \cdot (T_s - T_a) \cdot Nu_\delta$$

$$Gr = \frac{D^3 \cdot (T_s - T_a) \cdot g}{(T_f + 273) \cdot v_f^2}$$

$$Pr = c_f \cdot \mu_f / \lambda_f$$

A; m (Table 5)

$$Nu_{nat} = A \cdot (Gr \cdot Pr)^m$$

$$Nu_\beta = Nu_{nat} \cdot (1 - 6.76 \cdot 10^{-6} \cdot \beta^{2.5})$$

$$P_{c,nat} = \pi \cdot \lambda_f \cdot (T_s - T_a) \cdot Nu_\beta$$

$$P_c = max(P_{c,forced};\ P_{c,nat})$$

Radiative heat loss

$$P_r = \pi \cdot D \cdot \sigma_B \cdot \varepsilon_s \cdot [(T_s + 273)^4 - (T_a + 273)^4]$$

Solar heat gain

$$\delta_s = 23.4 \cdot sin[2 \cdot \pi \cdot (284 + N^*)/365]$$

$$H_S = arcsin(sin(\varphi)\, sin(\delta_s) + cos(\varphi)\, cos(\delta_s)\, cos(Z))$$

$$\gamma_S = arcsin(cos(\delta_s) \cdot sin(Z) \,/\, cos(H_S))$$

$$\eta = arccos[cos(H_S) \cdot cos(\gamma_S - \gamma_c)]$$

$$I_{B(0)} = N_S \cdot \frac{1280 \cdot sin(H_S)}{sin(H_S) + 0.314}$$

$$I_{B(y)} = I_{B(0)} \cdot \left[1 + 1.4 \cdot 10^{-4} \cdot y \left(\frac{1367}{I_{B(0)}} - 1\right)\right]$$

$$I_d = \left(430.5 - 0.3288 \cdot I_{B(y)}\right) \cdot sin(H_S)$$

$$I_T = I_{B(y)} \cdot \left(sin(\eta) + \frac{\pi}{2} \cdot F \cdot sin(H_S)\right) + I_d \cdot \left(1 + \frac{\pi}{2} \cdot F\right)$$

$$P_s = \alpha_s \cdot I_T \cdot D$$

Electrical resistance

$$R_{ac}(T) = R_{ac}(T_1) + (T - T_1) \cdot \frac{R_{ac}(T_2) - R_{ac}(T_1)}{T_2 - T_1}$$

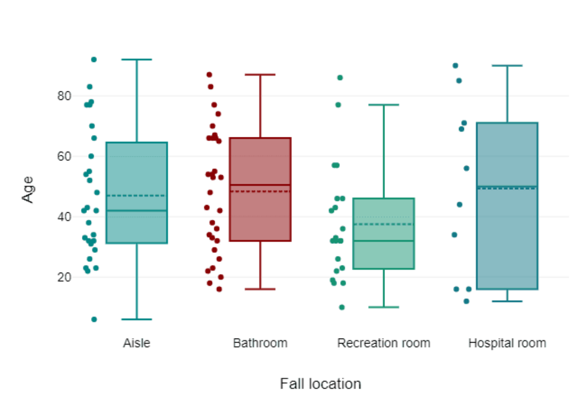
Current calculation

$$I = \sqrt{\frac{P_r + P_c - P_S}{R_{ac}}}$$

NEXT STEPS

Weather and Results Comparison

- Accurracy Comparison
- Comparison with Field Devices
- Comparison between Providers



Stabilize the Output

- Grid Operator Needs
- Thermal Inertia

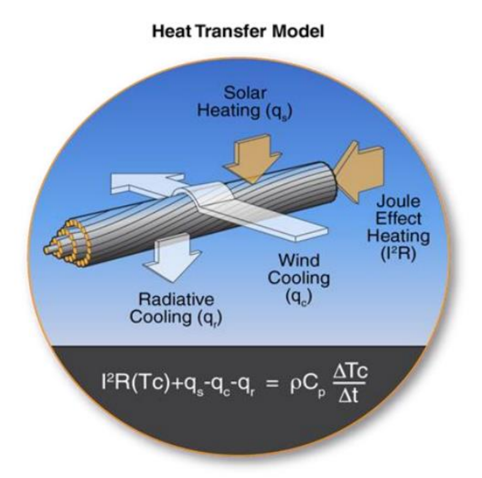


Figure 1: Heat-transfer model for a conductor.

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