This work was partly funded by national funds through the FCT – Fundação para a Ciência e a Tecnologia, I.P., under the grant PTDC/EEI-EEE/31711/2017

Dynamic Line Rating - an overview and presentation of the models implemented

Final Workshop

20th September 2022

Disclaimer: The statements and opinions expressed in this presentation do not bind the organizations participating in the study: LNEG, R&D NESTER.

Overhead Power Lines; General facts

Given the electric and mechanical characteristics of the power line cables, engineers design the power lines considering:

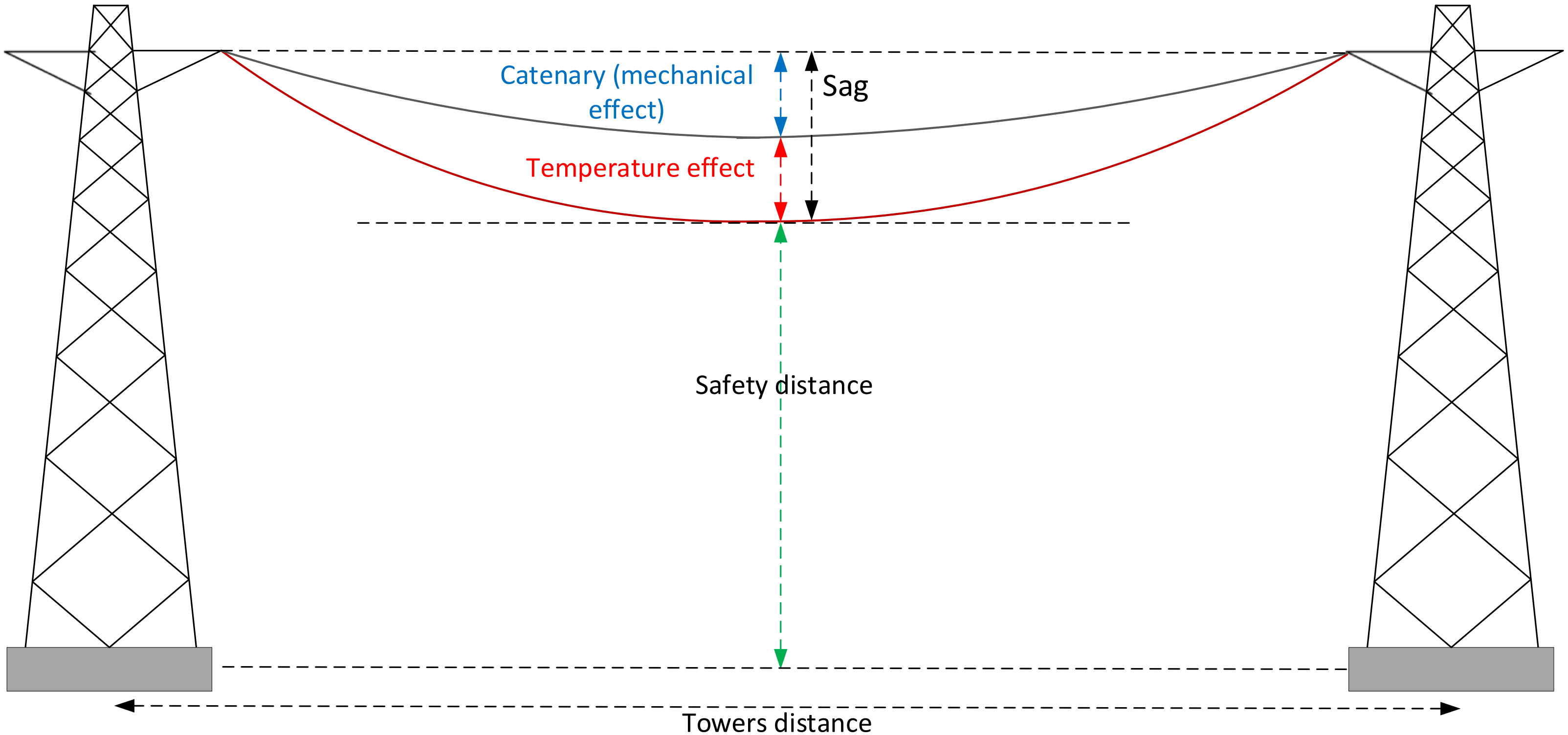
- **The orography along the future line path, between the endpoints,** along with other technical and economical factors leads to the location of the line's support towers.

- The **maximal power** to be transmitted, **is set by the line's operating voltage**.

- **The manufacturer's** specifications give among others, the maximal operating temperature to avoid significant cables damage**;**

Overhead Power Lines; General facts (Cont.)

The maximal cable temperature along with the operating voltage, defines a minimal height of the support towers to maintain a line's safe distance to the ground.



Project engineers use all the previous considerations to set a limit value for the lines' operating temperature.

Overhead Power Lines; General facts (Cont.)

The cable temperature is the leading effect of the sag variation (the mechanical effects present little or no variation to the sag value)**:**

Cable temperature depends on the endured conditions in diverse magnitude levels**.**

It raises with :

- **the current** passing through,
- **the solar irradiation** hitting it

And decreases by the effect of:

- **the wind** passing by,
- **The radiation** it emits
- **The evaporation** of the water accumulated from rain or mist

Example of a multilayer braided power cable for overhead power lines. Al onducters and a steel core for strenght

Cable temperature evaluation thus requires a thermal balance, and a suitable methodology to assess it.

Power upper limit assessment (SAR)

There are two main well-established methodologies to perform the thermal balance of the overhead power lines: **CIGRÉ** and **IEEE.**

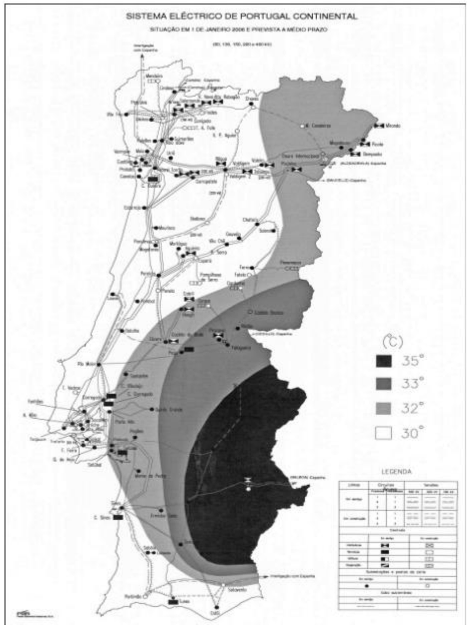
CIGRÉ methodology was used within the scope of this project.

Most TSOs normally use simplified versions of these methodologies to assess the capacity of the lines

Power upper limit assessment (SAR)

Seasonal Adjusted line Rating (SAR)

SAR is a type of line rating methodology used by power system operators, to assess the maximal seasonal capacity of the lines, using the line max temperature values along with a set of seasonal extreme meteorological conditions to establish the seasonal set of maximal safe capacity values to operate the lines in safe conditions.



The Portuguese TSO uses a SAR methodology derived from IEEE to assess the maximal seasonal capacity of the lines, using the lines' max. operating temperature and adequate but fixed seasonal weather condition values for wind speed, solar irradiation, and air temperatures.

Power Cables Thermal Balance (DLR)

The cable's thermal balance may consider two cable states:

- **Steady-State,** the cable is considered to be in thermal equilibrium,
- **Dynamic-State,** the cable thermal balance is evolving over time

Important Note: The methodologies are designed as dynamic simply because they compute the thermal equilibrium using diverse sets of imposed variables, namely meteorological values.

In fact: the cable's thermal inertia does not allow it to instantaneously adapt to the changes in electrical or meteorological conditions. Instead, it "slowly" evolves (asymptotically) to the new resulting equilibrium in less than an hour.

So: The thermal balance may, for an hourly set of imposed conditions values, use the steady-state approach in most cases to avoid accrued and unnecessary complexity.

Steady-State Dynamic Line Rating:

The steady-state thermal balance involves matching the cable thermal gains to its losses.

Heat Gain = Heat Loss

$$P_J + P_S + P_M + P_i = P_C + P_r + P_W$$

NOTE:
Since P_i and P_W contributions are typically at a comparatively lower level, by an order of magnitude**, they are not usually considered** for the thermal balance analysis**.**

Where:

- P_J - Joule Heating
- P_S - Solar heating
- P_M - Magnetic heating
- P_i - Corona heating
- P_C - Convective cooling
- P_r - Radiative cooling
- P_W - Evaporative cooling

Steady-State Dynamic Line Rating

Factor on the Equation		Effect of
ID	Meaning	
P_J	Joule Heating	the **current** flowing on the cable
P_S	Solar heating	the **solar irradiance** on the cable surface
P_M	Magnetic heating	the current induced on the cable
P_i	Corona heating	the **ionization** of the air
P_C	Convective cooling	the heating up of nearby or passing through air
P_r	Radiative cooling	thermal radiation emission of the cable
P_W	Evaporative cooling	the heat needed to dry its surface

The **thermal balance** uses a unitary length (1 m) and a unitary period (1 s).
Joules heating is then given by a product of current squared (I^2), and cable's resistivity (ρ).
But **cable resistivity varies** with the temperature of the cable surface (T_s)

Standardized thermal balance methodologies ensure using a correct set of factors/constants on all the needed conversions.

Steady-State Dynamic Line Rating

Some Additional Facts

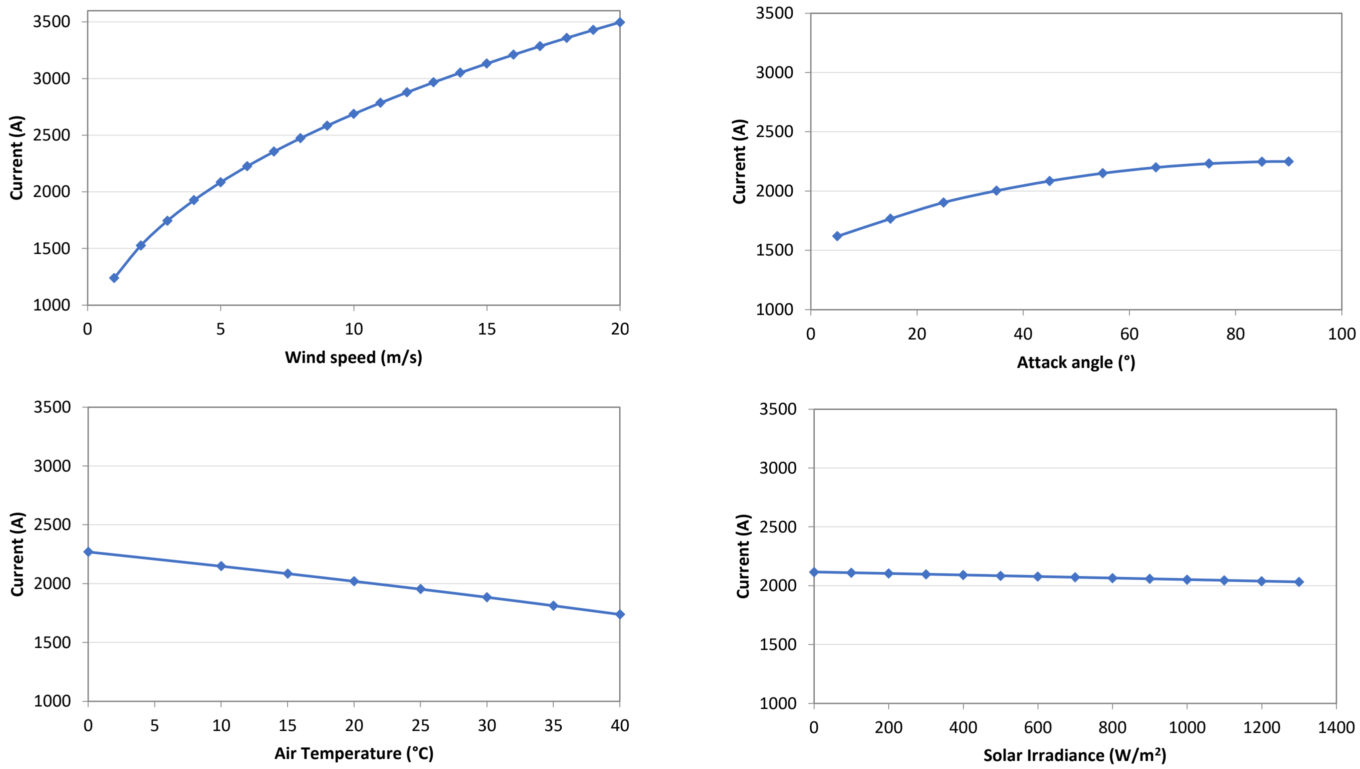
***P_i* and *P_W* contributions are usually not considered for the thermal balance analysis,** they are of comparatively low level, by an order of magnitude**.**

Cable temperature may be measured directly, but they are relatively expensive besides needing a previous analysis to identify the best points of the line to set the transducers.

Meteorological data for the DLR analysis may be obtained by direct measurement or from the computational assessment for specific line segments, for **day-ahead estimation** or for relevant historical periods – the so-called *indirect approach.*

Steady-State Dynamic Line Rating

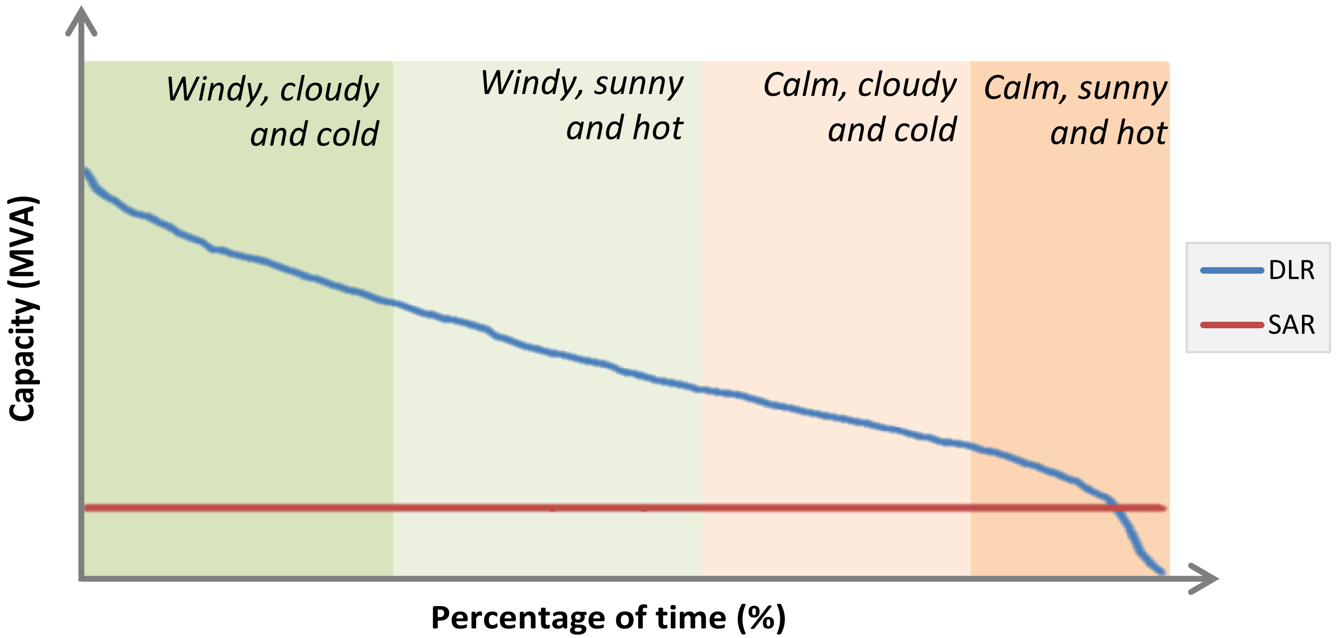
Some Additional Facts



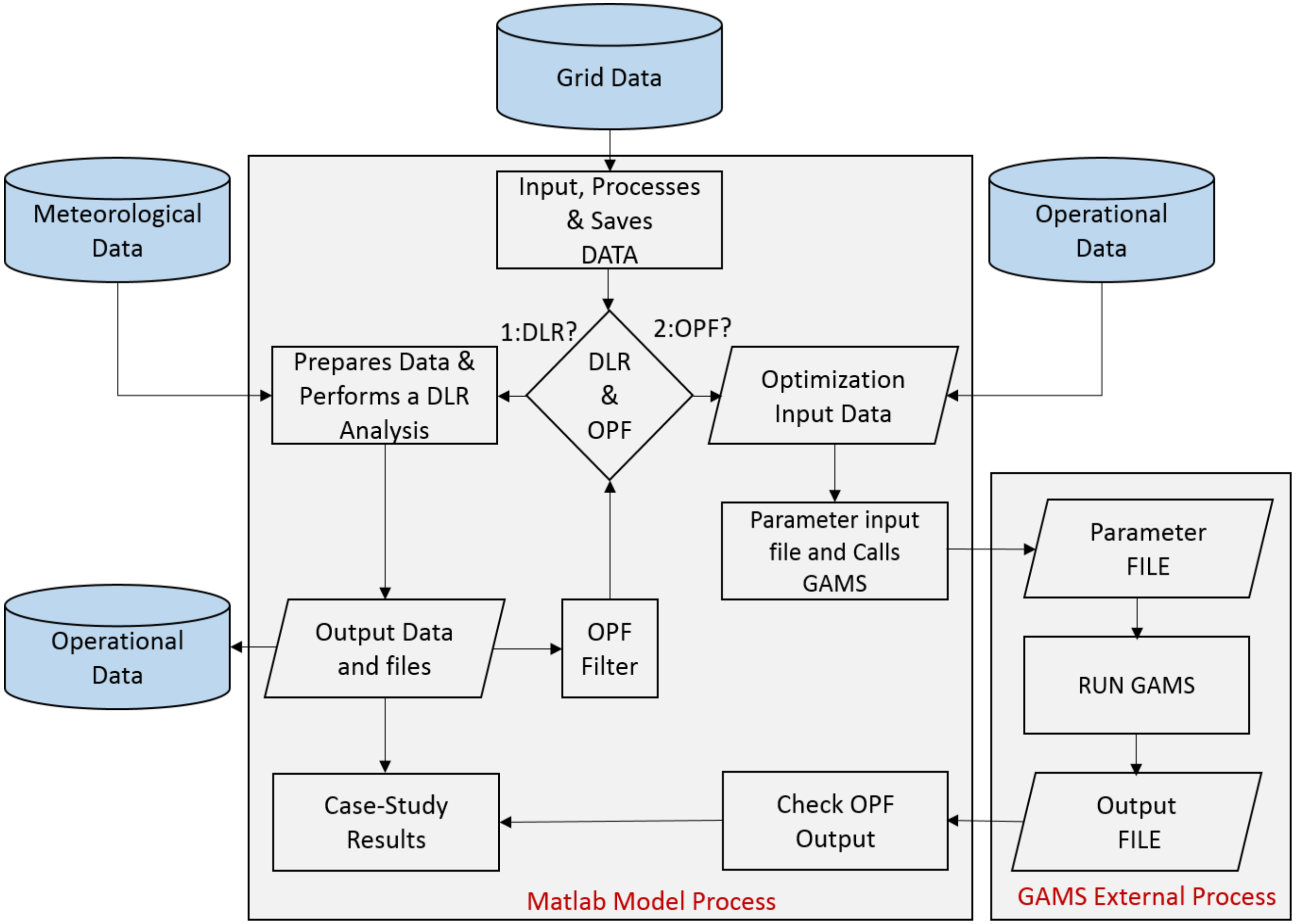
The wind velocity is usually the most important meteorological data for the cable's thermal balance.

Steady-State Dynamic Line Rating

Some Additional Facts



Models implemented



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