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RICE

Statistical Calibration of Dynamic Ampacity Model

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Outline

Motivation

- Dynamic Ampacity
- Mathematical model

Problem definition

Proposed model

- Validation: real data

Ampacity = Ampere capacity of a conductor

Limited by:

1. Conductor thermal limit
2. Minimal clearance of the ground

Why it is important (VARLEY, J. 2009):

1. Demands for power transmission are unstable due to renewable sources,
2. Large safety margin on ampacity remains unused,
3. Too conservative limits on ampacity may yields energy money loss or stability problems.

CIGRE model of ampacity

Model:

$$P_J + P_s + P_c = m_c c_c \frac{dT_c}{dt} + P_r + P_k + P_w$$

where:

- P_J are Joule conductive losses, $P_J = RkI_{ef}^2[1 + b(T_c - 273)]$,
- P_s is solar heating, $P_s = \epsilon\sigma S(T_c^4 - T_{amb}^4)$
- P_r is radiative cooling
- P_c is convective cooling
- P_k is corona heating
- P_w is water cooling

Properties

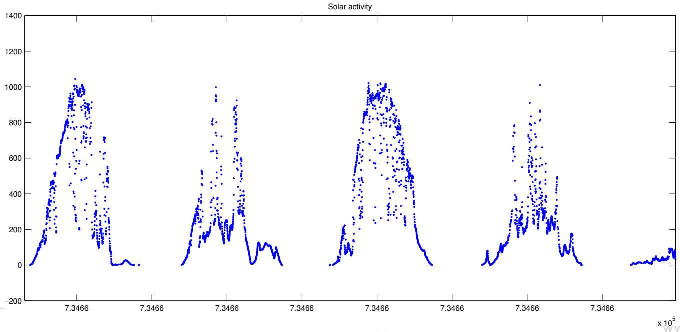
- complex non-linear model,
- **uncertain inputs** – weather conditions: solar, wind, rain

Experimental line

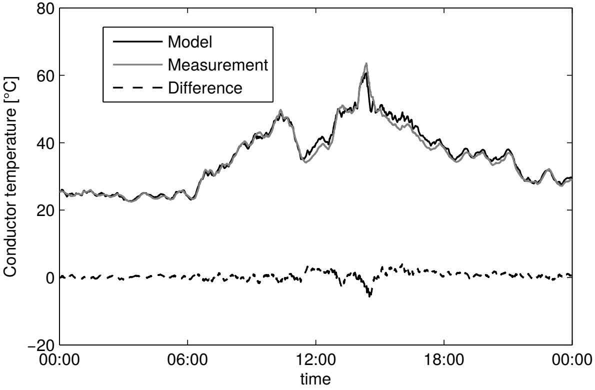
Data from a line equipped by meteostations are available from ČEPS.

Measurements (irregular sampling):

- solar radiation intensity,
- wind velocity and angle
- ambient and surface conductor temperature



Deterministic approach



1. The goal is to reach temperatures under a certain limit,
   - errors can be used as safety margin
2. Errors are not constant, they are state dependent

Statistical approach

Goals

1. Estimate not only the temperature but also the error bound.
2. Calibrate the error bound for reliability

Challenges

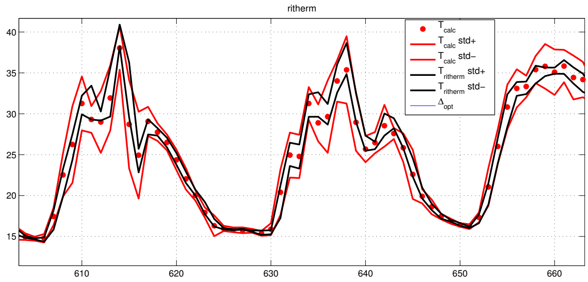
1. quantify uncertainty of the inputs (how can we trust the sensors, potentially predictions)
2. transform the uncertainty through the non-linear model,
3. design model of corrections (callibration)

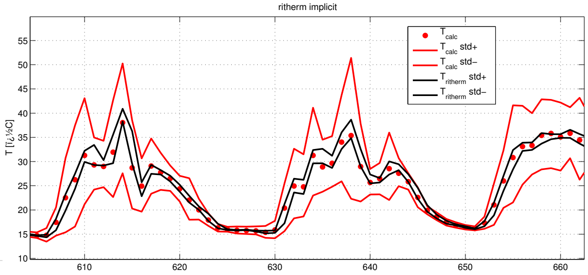
Proposed model

1. uncertainty of the inputs
   - we operate on one hour window. Uncertainty is modeled by mean and variance of the values.
2. transform the uncertainty through the non-linear model,
   - using sigma point transform on deterministic samples from the distribution of the inputs
3. design model of corrections (callibration)
   - we estimate unknown multiplier, γ, of computed correlation

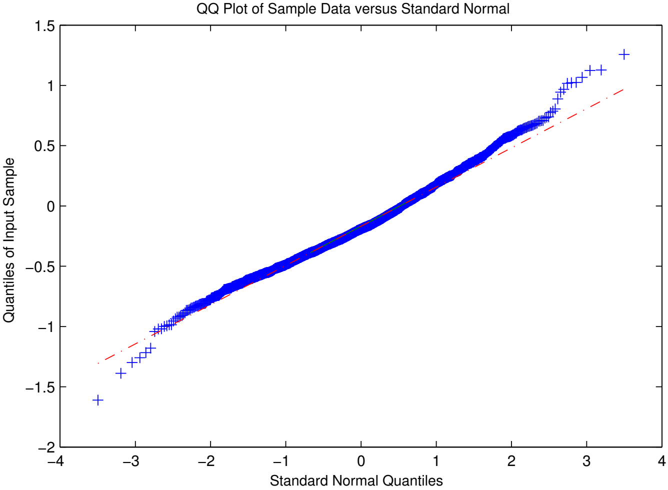
$$\text{cov}(T_c) = \gamma \text{cov}(T_{c,model}),$$

Validation: real data





Quantile-Quantile plot



Conclusion

1. Maximum current through a transmission line is restricted by thermal limit,
2. Temperature of the conductor depends on weather conditions, which are uncertain,
3. Statistical models calibration aims to provide **reliable** uncertainty bound
4. Future work:
   4.1 design of model for predicted weather,
   4.2 model local corrections,