PV MODULE LIFE TIME FORECAST AND EVALUATION

PV Performance Model Applied to PV Module Ageing

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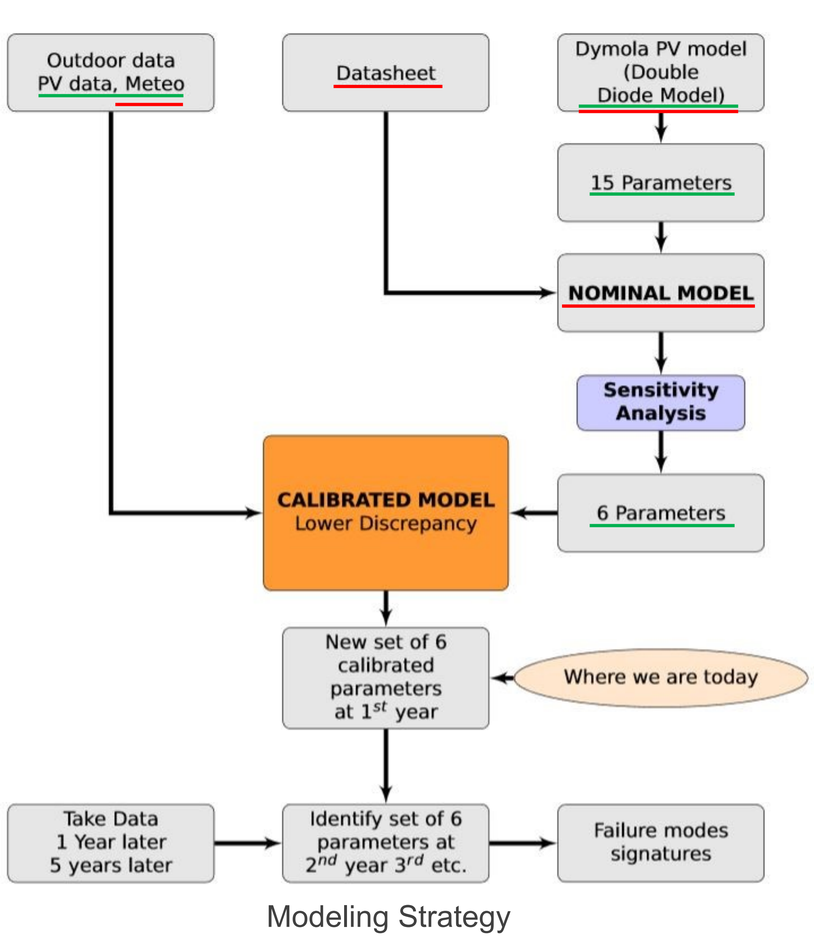
CHALLENGE

Find a suitable method for analyzing the root causes of PV degradation using outdoor PV and weather measurement data to identify the temporal evolution of double diode model parameters.
Assumption: Degradation of the PV power is closely related to the internal variation of double diode model parameters.

Outdoor performance measurements can be used to estimate important device parameters and evaluate the health state of the system. Understanding the parameter evolution could help develop degradation models that allow a prediction of the service lifetime of PV modules.

MODELING STRATEGY

EDF's existing PV performance model written with the Dymola Modelica® (B., Braisaz, 2013) software allows to model the performance and electrical behavior of any PV device under given meteorological conditions based on the double diode model.



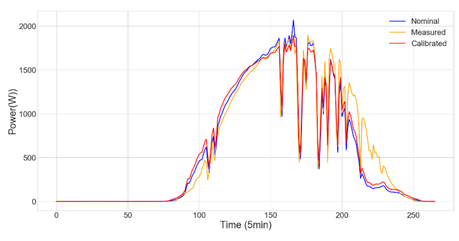
Modeling Strategy

PV Data: IV curves, P_{mpp}, P_{mpp}+ I_{mpp}

CALIBRATION ON REAL DATA

Behaviour of physical systems can be approximated using the PV performance model where degradation modes can be related to the parameter variation of the physical model.

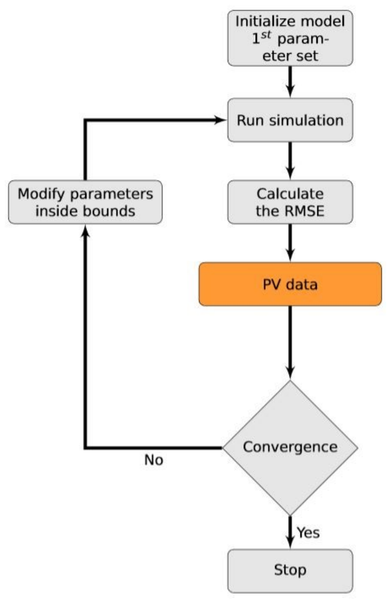
CALIBRATION: Searching for a set of parameter values **θ** such that the computer model ***f(x, θ)*** fits as closely as possible the field data ***R***.

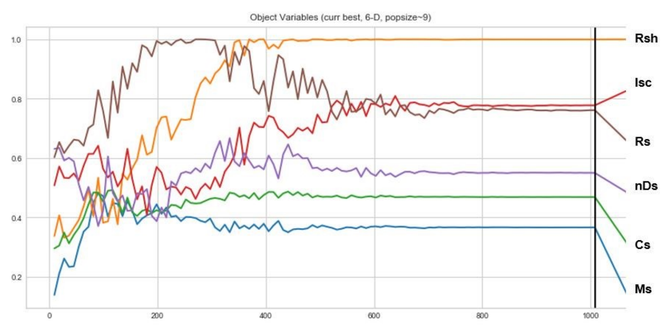


Calibrating a single day of PV production from the EDF's test site PVZEN

Benoit Braisaz et al. *"An advanced model of PV power plants based on Modelica"* European photovoltaic solar energy conference; EU PVSEC 2013

For the calibration the **CMA-ES** (Covariance Matrix Adaptation Evolution Strategy) was used.





Typical evolution of the parameters with the number of function evaluations

	Parameter	Nominal	Boundary	Calibrated
Calibration Loop	Isc (A)	5.44	[4,7]	5.691
	Rsh (Ω)	0.14745	[0.015,0.25]	**0.24999**
	Rs (Ω)	0.00012	[0.0001,0.009]	0.000364
	Ms	3	[2.8,3.2]	2.967
	nDs	1	[0.9,1.1]	0.905
	Cs (A/m^2K^3)	3337.51	[3320,3350]	33341.87
	RMSE	86.0354		78.0156

First analysis on P_{mpp} shows calibration is not converging, the parameter values reached the calibration boundaries.

CALIBRATION ON SIMULATED DATA

The possibility to uniquely estimate the true values of the model input parameter where the data is assumed to be known completely (noise free).

Parameter	Nominal	Calibrated
nDs	1	0.999
Rs (Ω)	0.00012	0.00012
Rsh (Ω)	0.14745	0.14742
RMSE		0.00172

KNOWN PARAMETER VALUES
SIMULATE DATA
CALIBRATE THE MODEL ON THE SIMULATED DATA
SAME PARAMETER VALUES

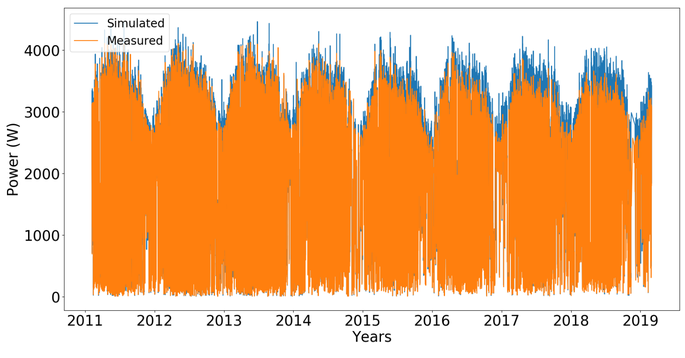
No identifiability issues with reduced number of parameters. The parameters can be estimated with high precision.

CONCLUSION

Multi-objective calibration needs to be applied on both P_{mpp} and I_{mpp} where I_{mpp} is weighted to have comparable sensitivity to obtain meaningful double diode model parameter results.

PERSPECTIVES

Comparing the 8 years of simulated and measured PV production data shows that the difference is increasing over time → DEGRADATION



Simulated vs measured PV production from EURAC test site

The average monthly PV production shows that the Initial difference is around 2.5-5% while after 8 years of outdoor operation the difference is around 10-12%.
Multi-objective calibration of 8 years of PV performance could identify the parameter values and the underlying failure modes.

https://solar-train.eu/ @MSCA_SolarTrain

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 721452.