Active damage mitigation of the blade leading edge erosion for a wind turbine during rainfall events

Álvaro Úbeda Ripoll

Zhiyu Jiang

Amrit Verma

Jing Zhou

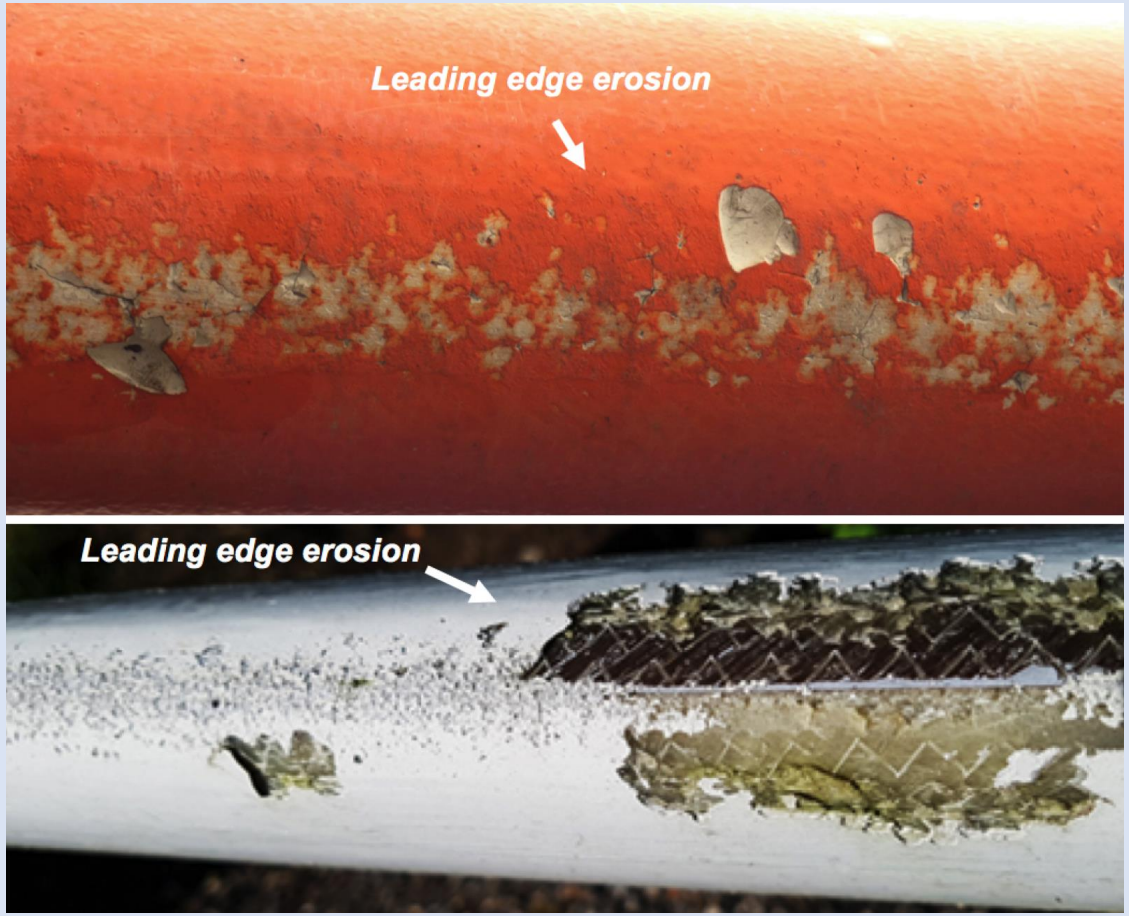
UiA

Leading Edge Erosion

- Reduction in **aerodynamic efficiency**
  - 6% reduction in lift
  - 86% increase in drag

- **Repair** intervention required
  - Up to 30.000,00€ per repair job
  - Up to 3 days of downtime per repair job

- **Existing research** include
  - Accelerated coating material tests
  - Computational frameworks for rainfall erosion
  - Cost analysis of LEE

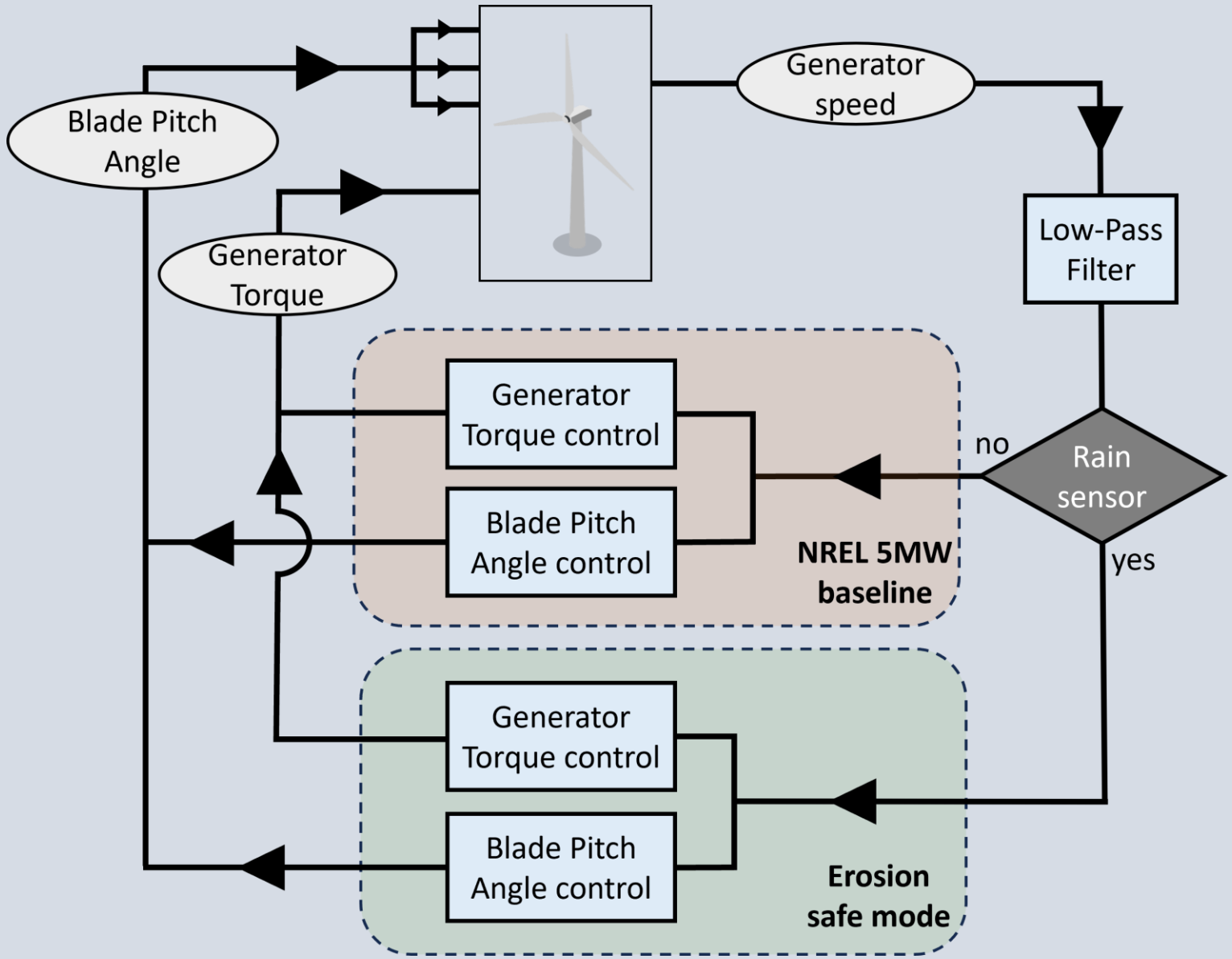


Methods

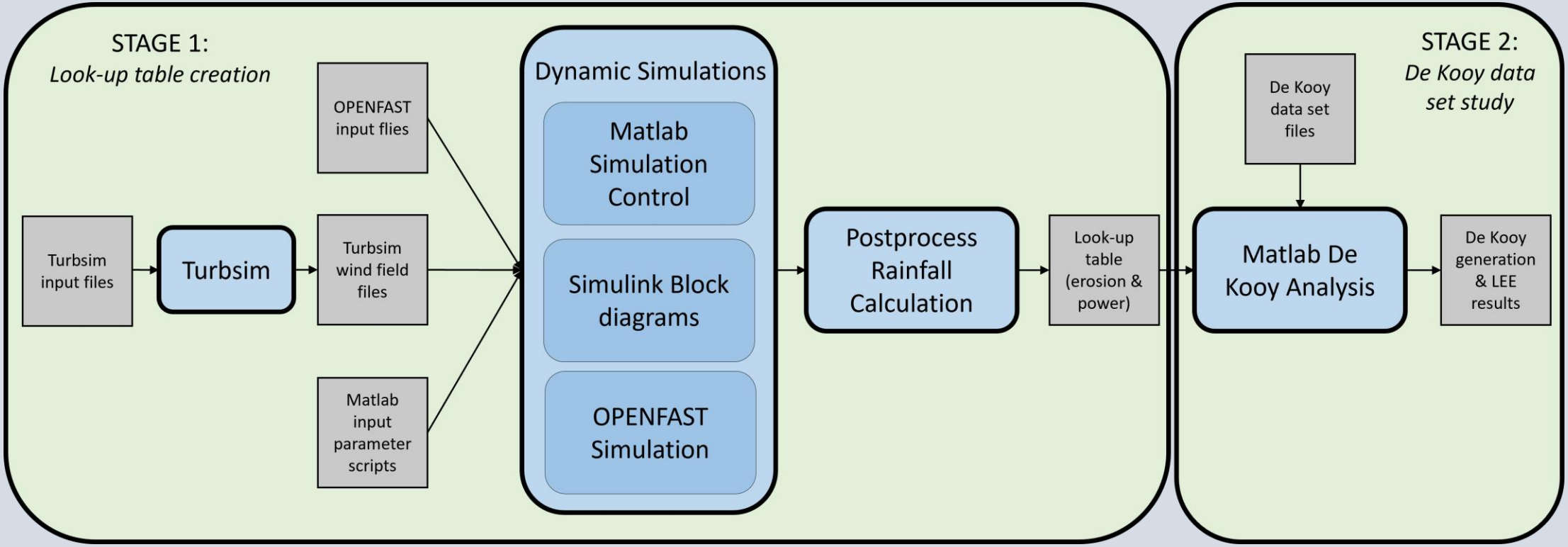
Stronger coatings

Prediction and repair

Erosion safe control



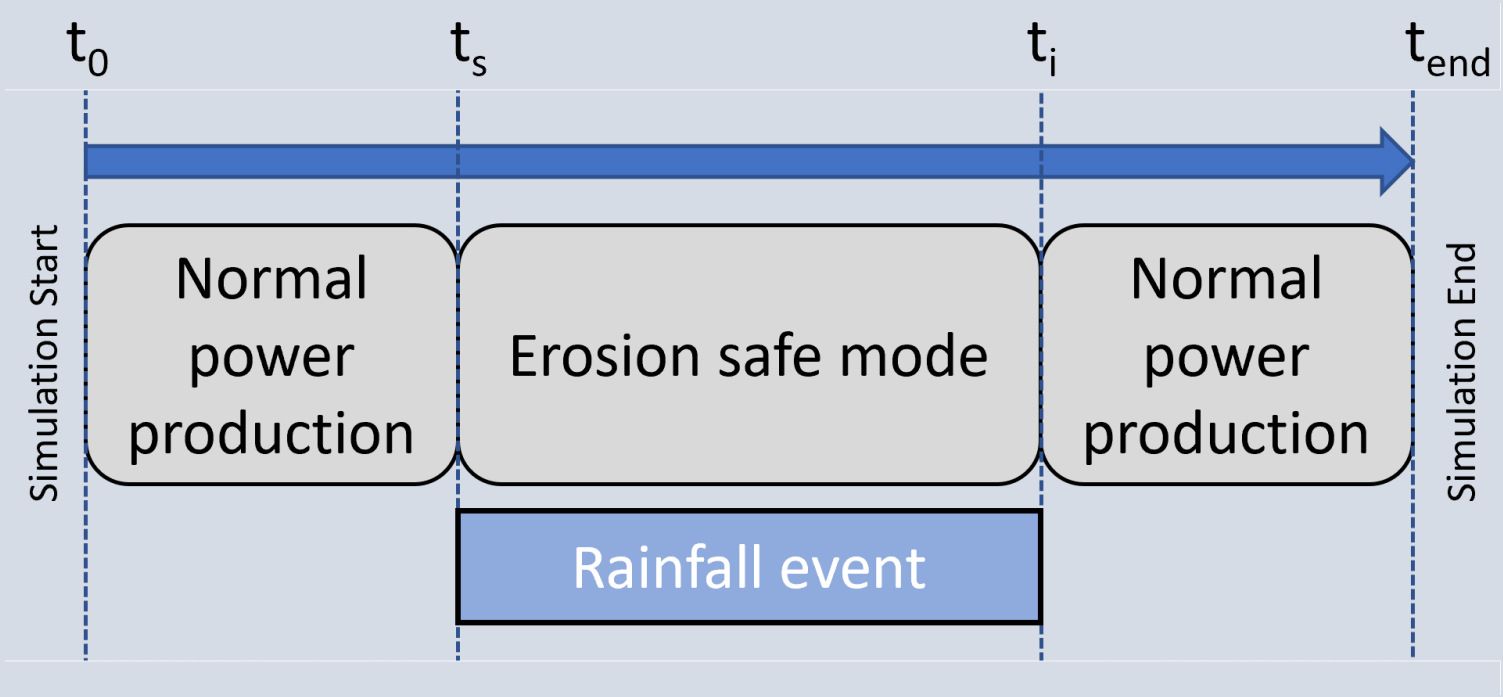
Methods


STAGE 1:
Look-up table creation
Turbsim input files
Turbsim
OPENFAST input flies
Turbsim wind field files
Matlab input parameter scripts
Dynamic Simulations
Matlab Simulation Control
Simulink Block diagrams
OPENFAST Simulation
Postprocess Rainfall Calculation
Look-up table (erosion & power)
STAGE 2:
De Kooy data set study
De Kooy data set files
Matlab De Kooy Analysis
De Kooy generation & LEE results

Methods

Overview of a generalized simulation

- 10-minute simulation
- 5MW NREL Baseline wind turbine model
- **New control** tested for rainfall events
- **Reference case** without the alternative control also simulated.

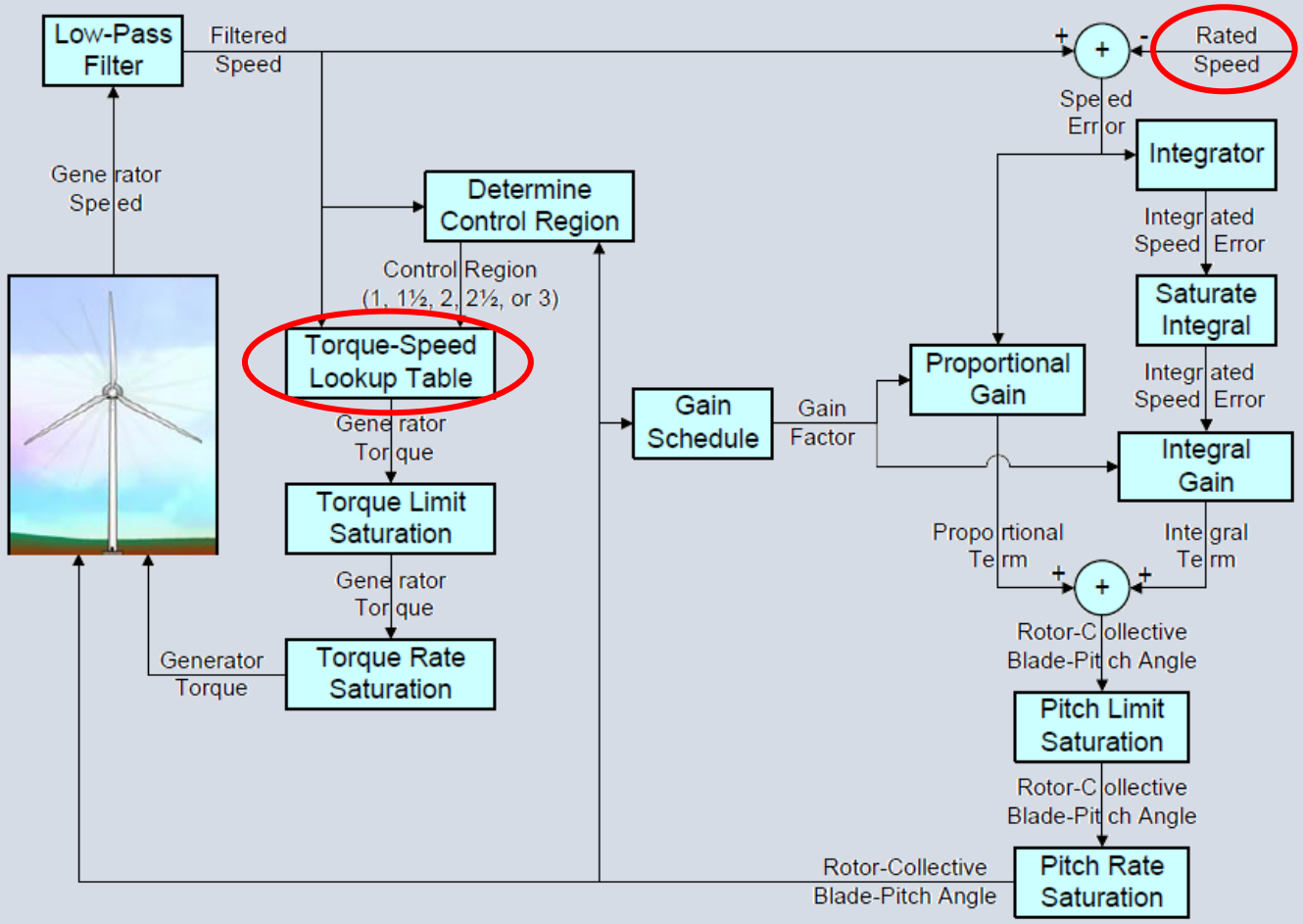


Methods

Alternative control system modifications

Variation in reference values for each control system

- Reference **rotational speed** for the HSS (high speed shaft)
- Electrical **power output** of the generator



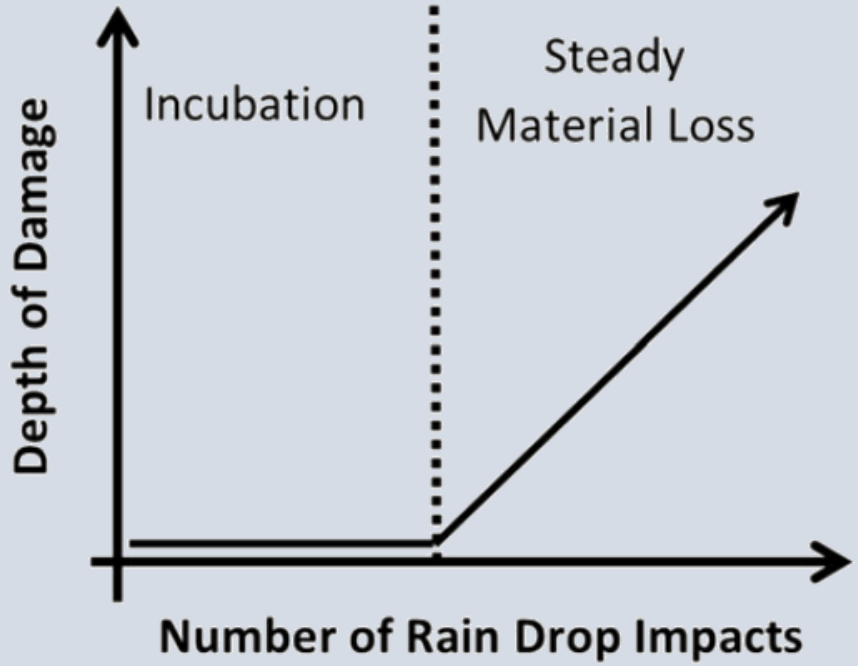
Methods

Rainfall data LEE post process

Springer model rainfall

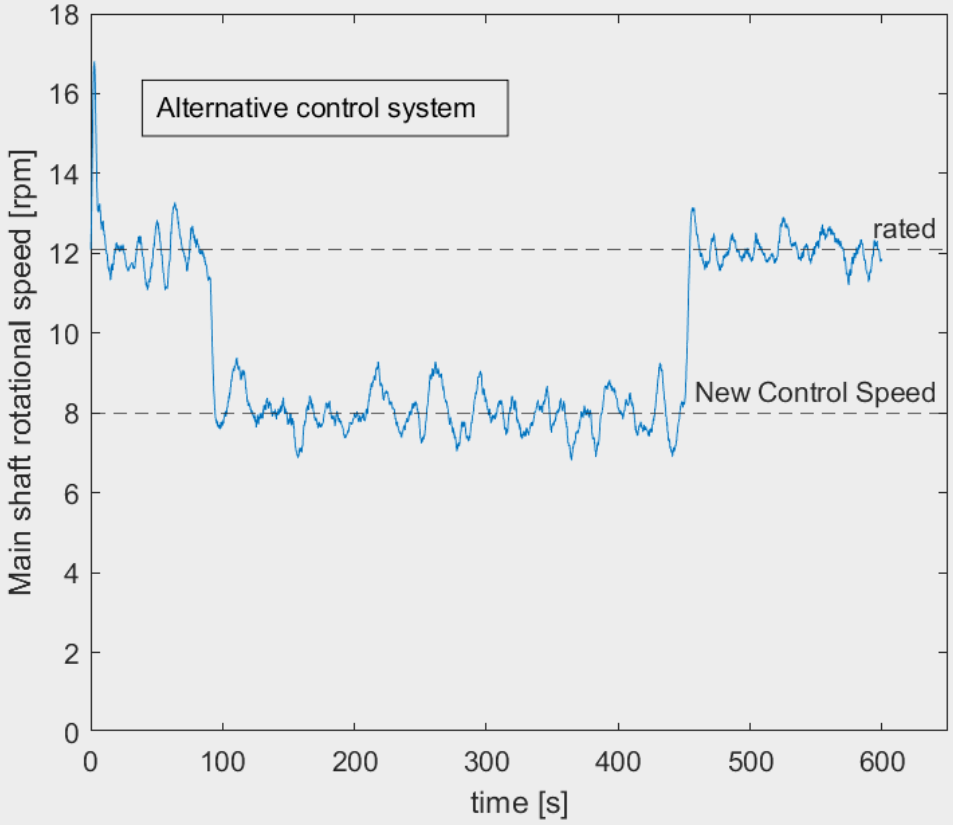
- Material properties
- Rainfall characteristics (DSD)
- Droplet impact velocity (Dynamic simulations)

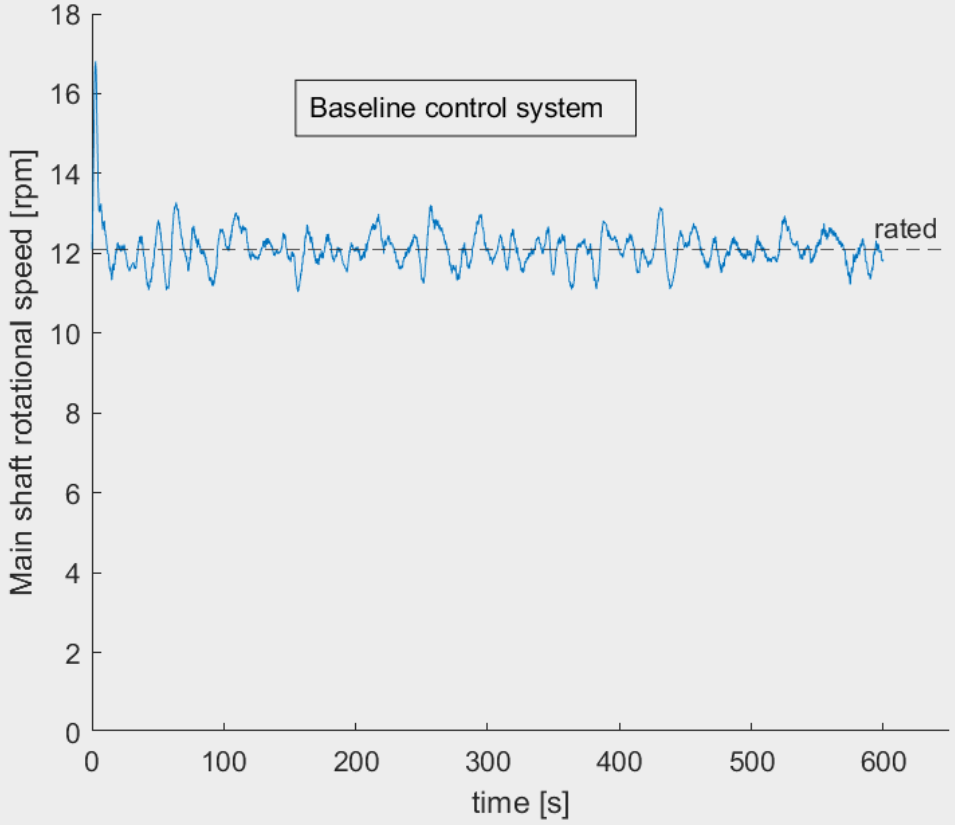
Parameter	Value
ρ_s	$1020kg/m^3$
C_s	$2480m/s$
σ_u	$37MPa$
m	6.1
ν	0.42



Dynamic Results

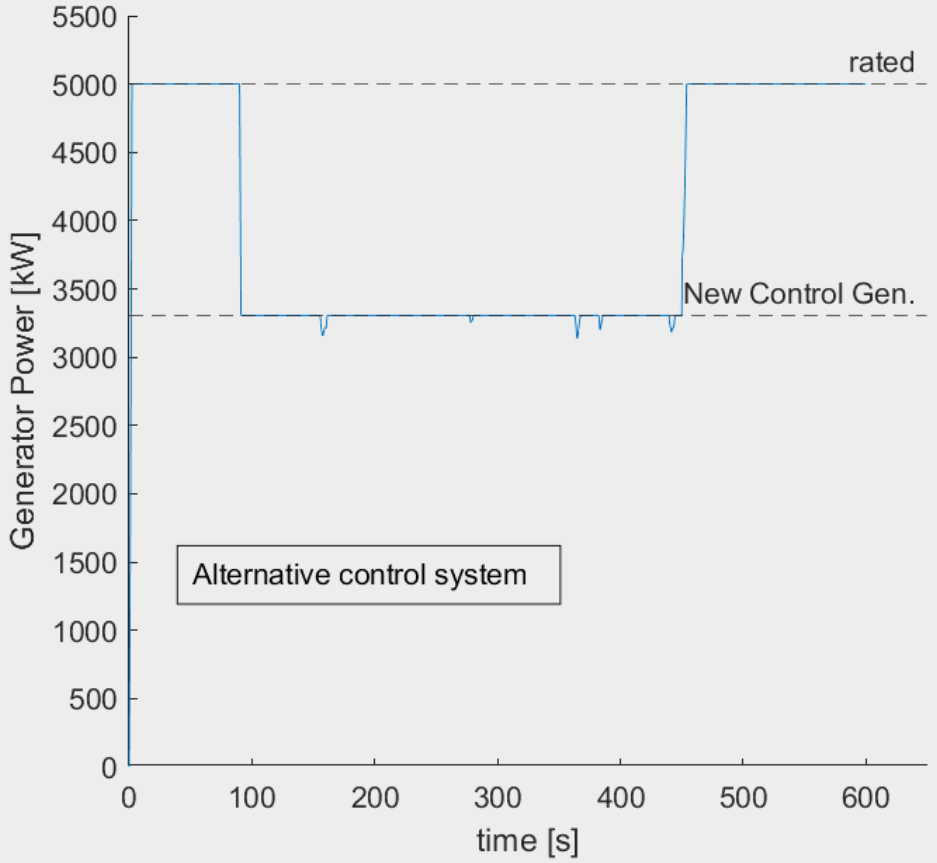
Simulation set-up parameter	Value
Wind mean speed	21 m/s
Turbulence intensity	0.1423
Reduced main shaft speed	8 rpm
Rainfall intensity	50 mm/h
Median droplet size	1.4643 mm

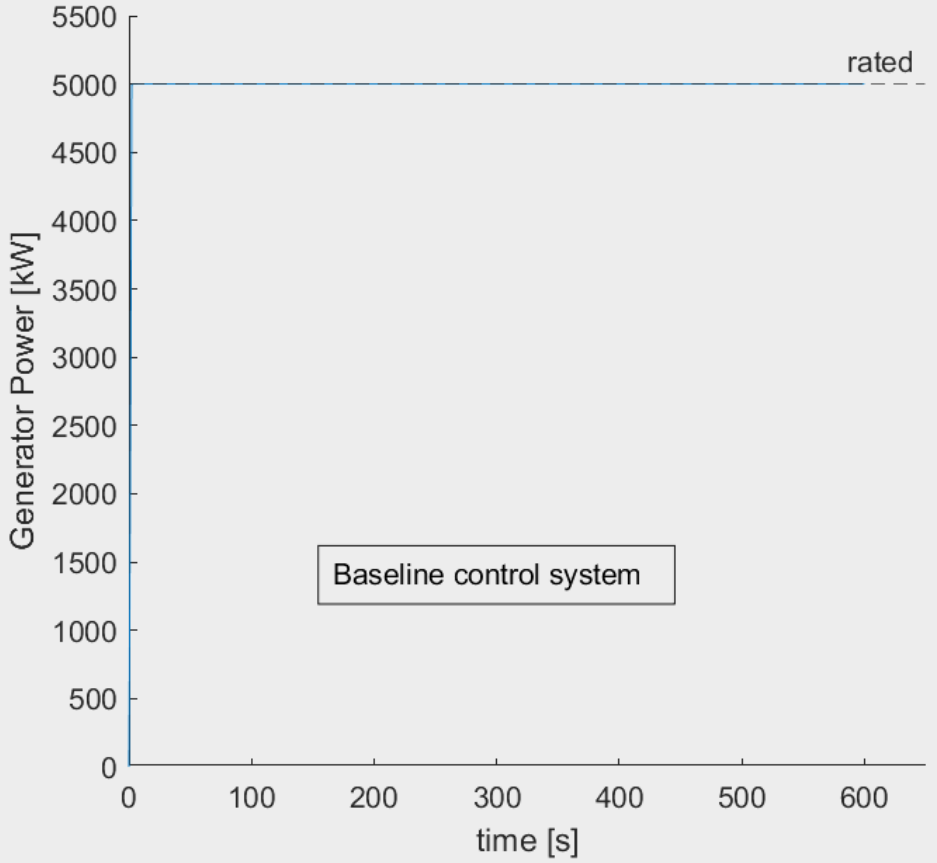




Dynamic Results

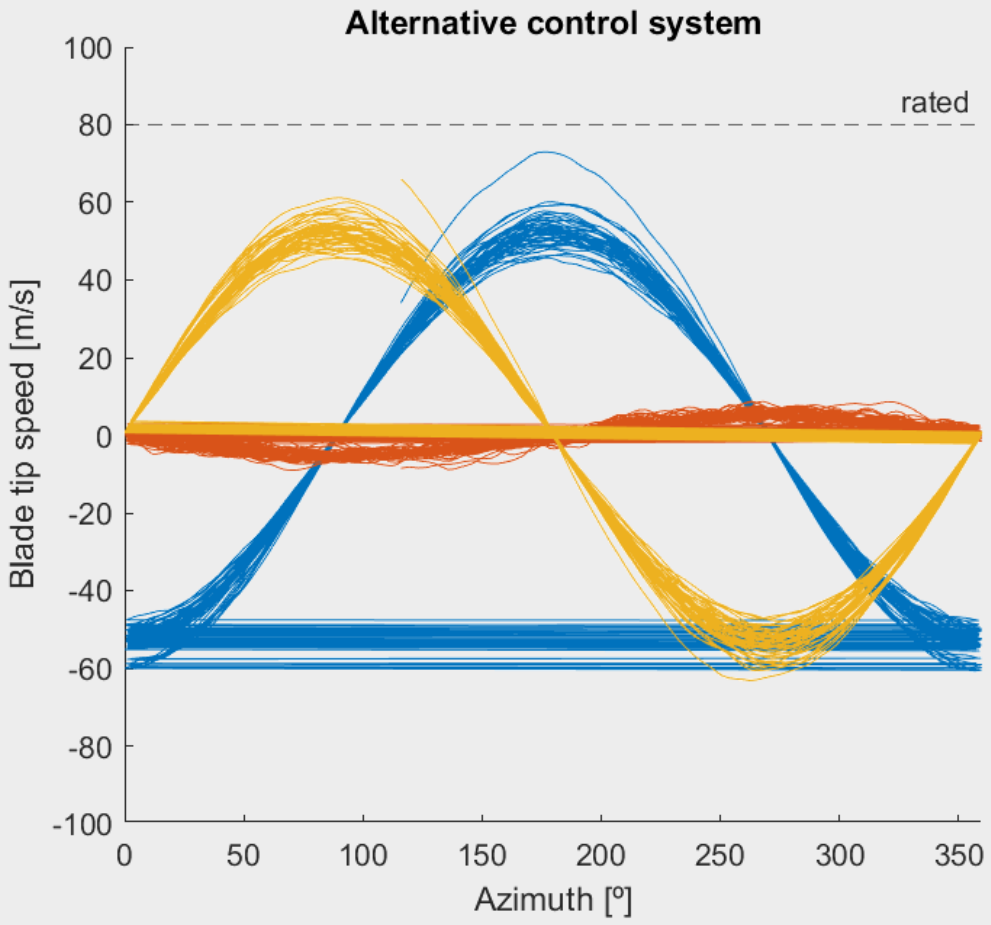
Simulation set-up parameter	Value
Wind mean speed	21 m/s
Turbulence intensity	0.1423
Reduced main shaft speed	8 rpm
Rainfall intensity	50 mm/h
Median droplet size	1.4643 mm

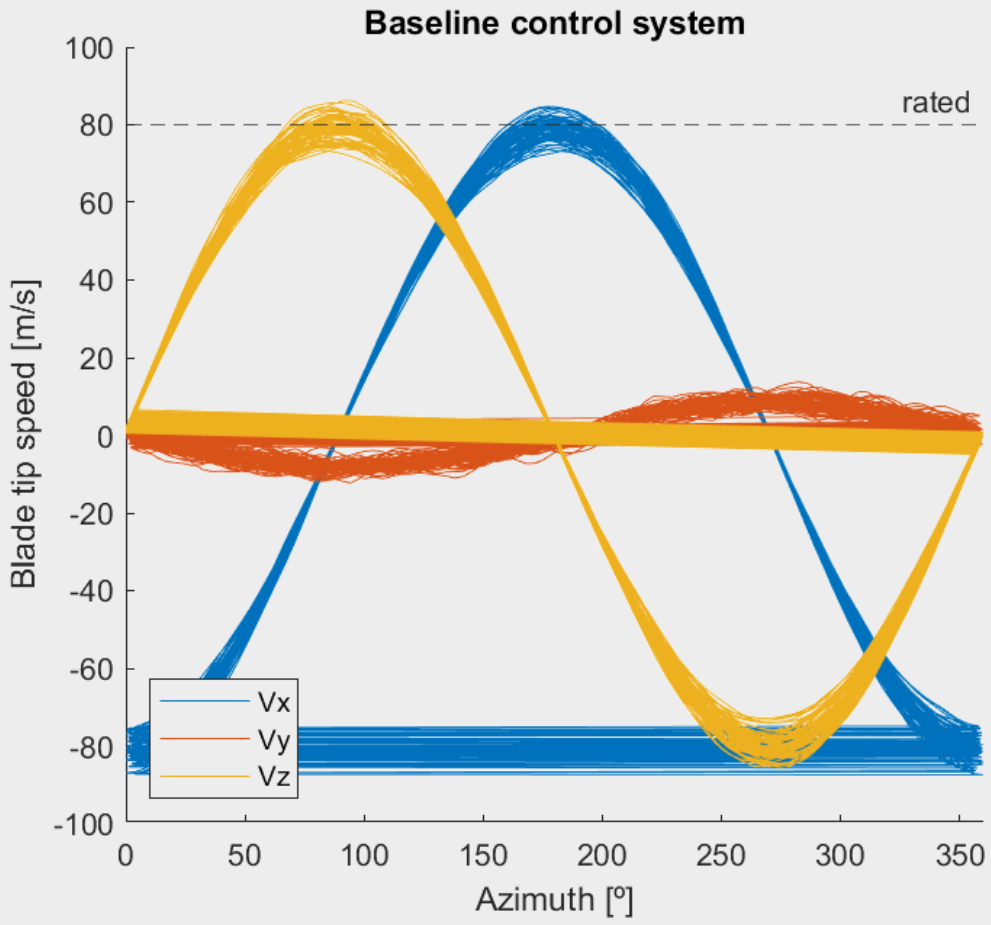




Dynamic Results

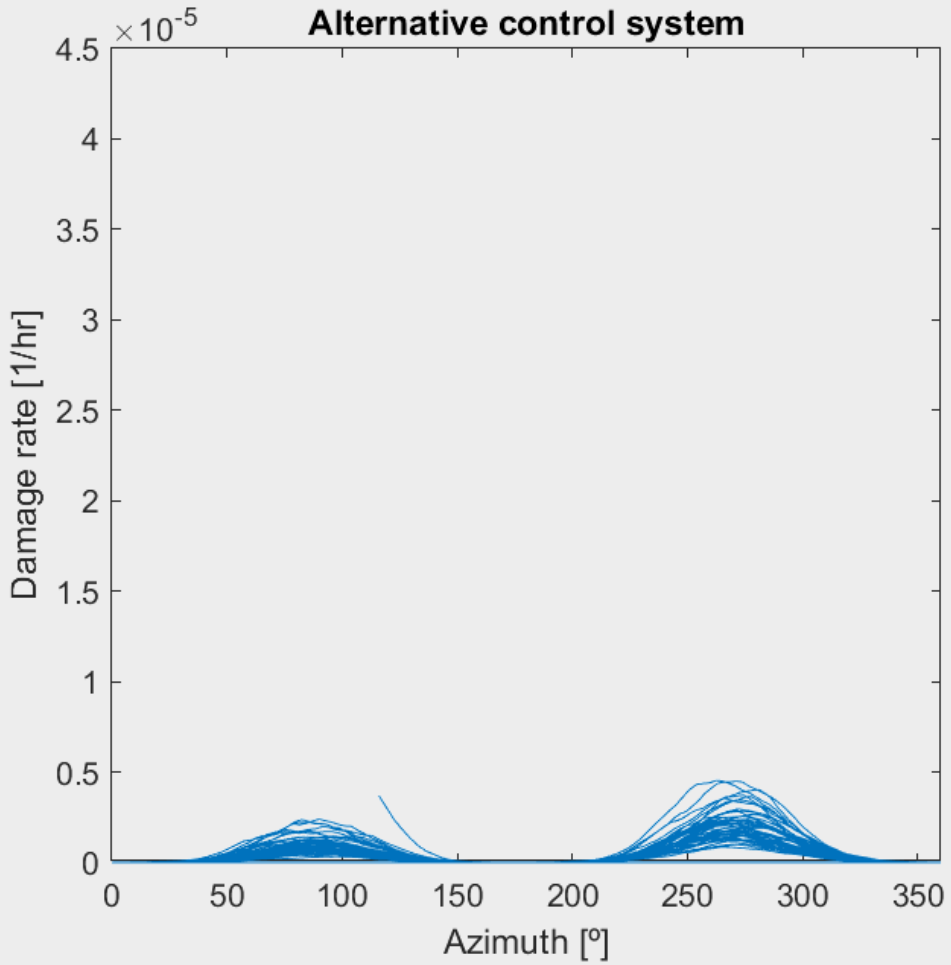
Simulation set-up parameter	Value
Wind mean speed	21 m/s
Turbulence intensity	0.1423
Reduced main shaft speed	8 rpm
Rainfall intensity	50 mm/h
Median droplet size	1.4643 mm

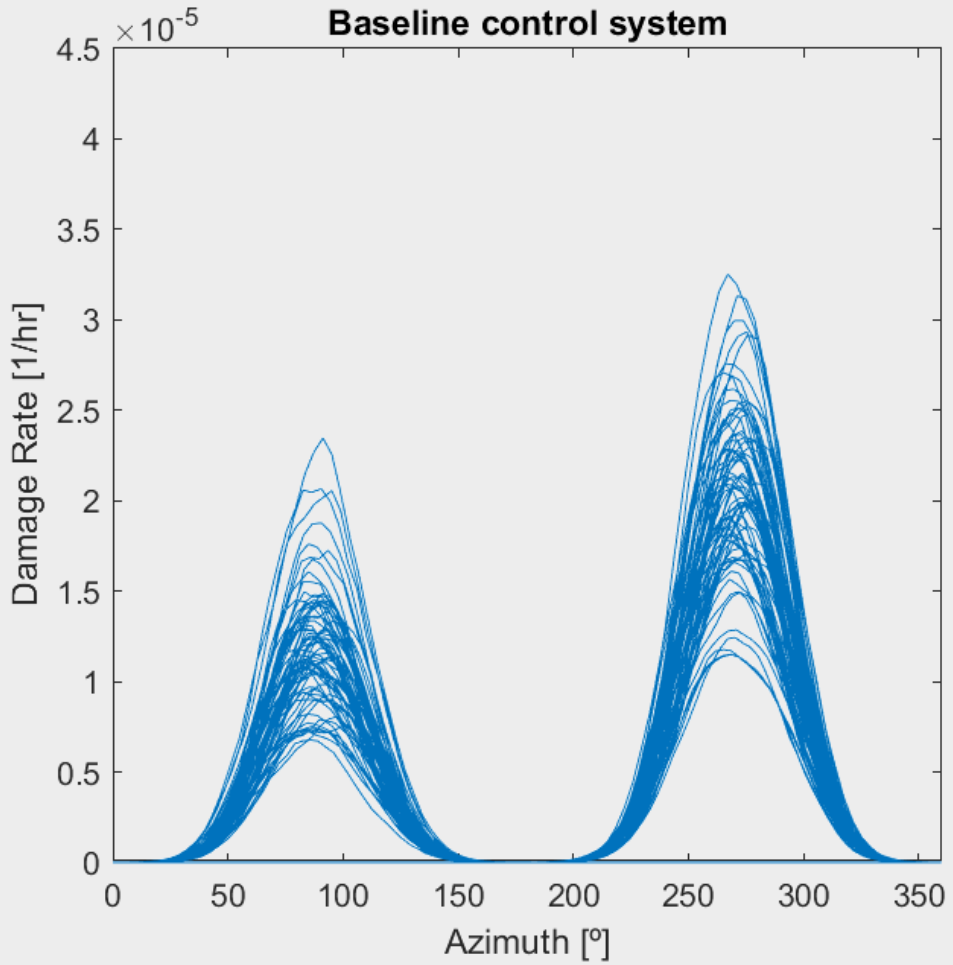




Dynamic Results

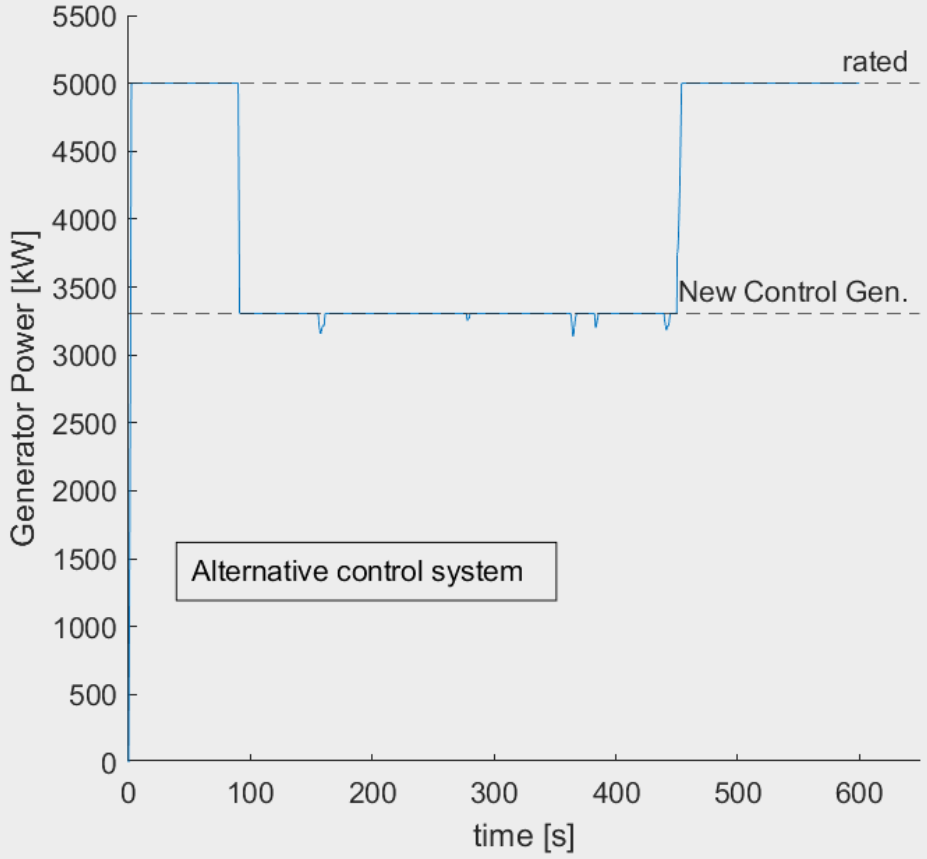
Simulation set-up parameter	Value
Wind mean speed	21 m/s
Turbulence intensity	0.1423
Reduced main shaft speed	8 rpm
Rainfall intensity	50 mm/h
Median droplet size	1.4643 mm

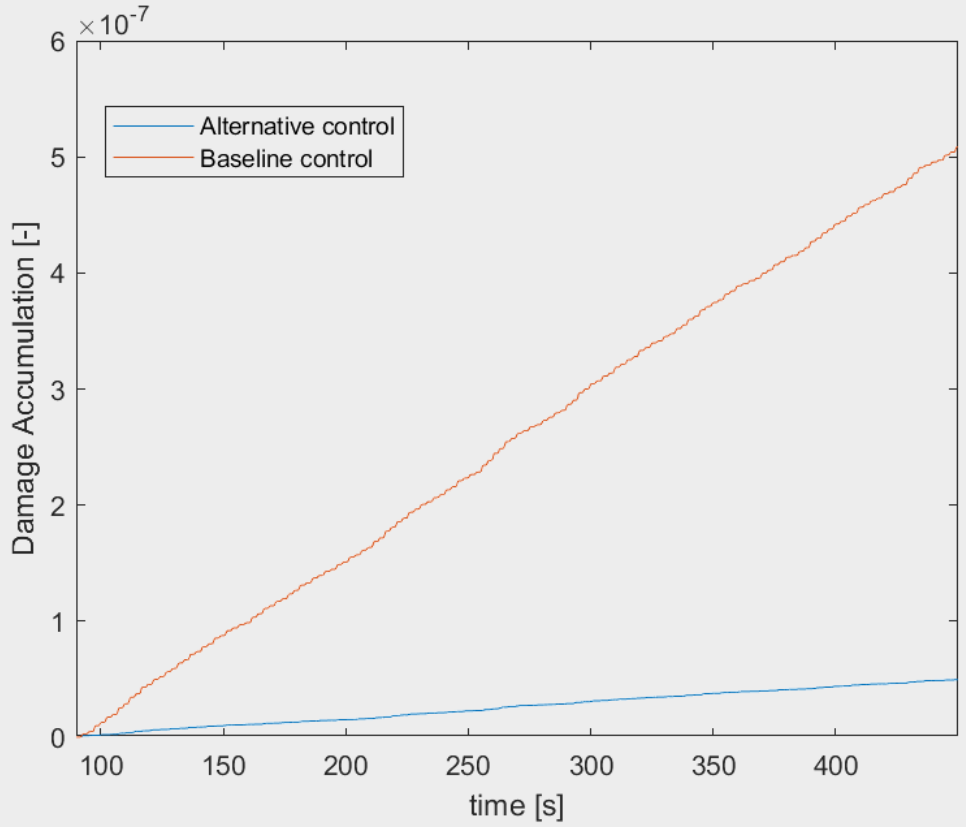




Dynamic Results

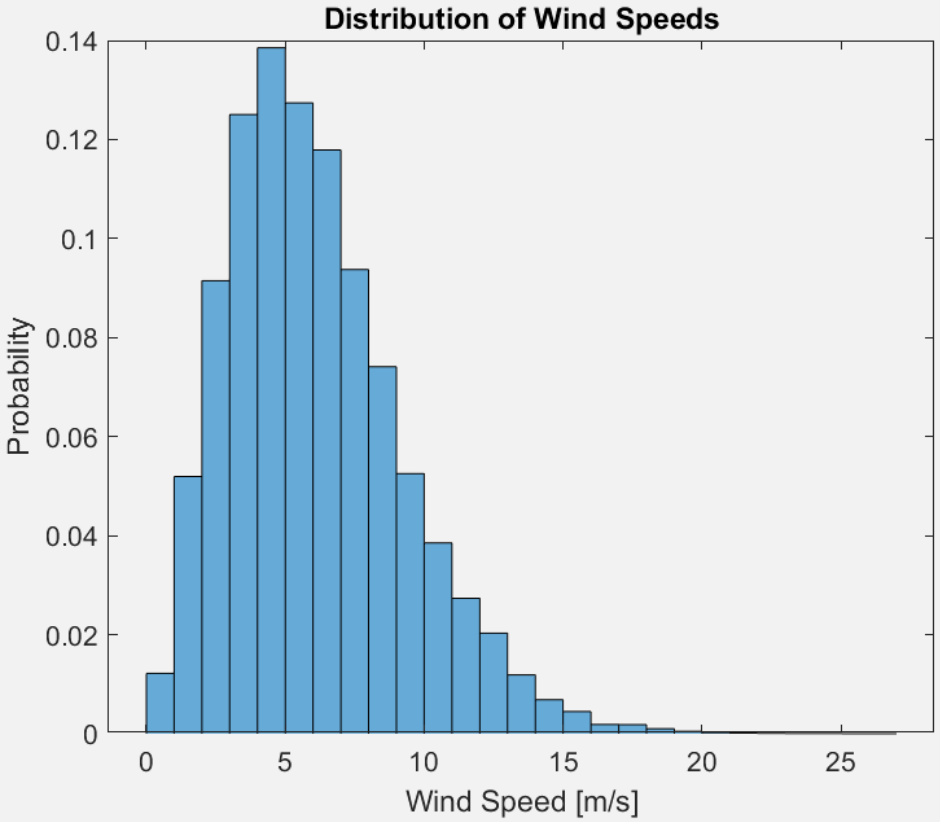
Simulation set-up parameter	Value
Wind mean speed	21 m/s
Turbulence intensity	0.1423
Reduced main shaft speed	8 rpm
Rainfall intensity	50 mm/h
Median droplet size	1.4643 mm

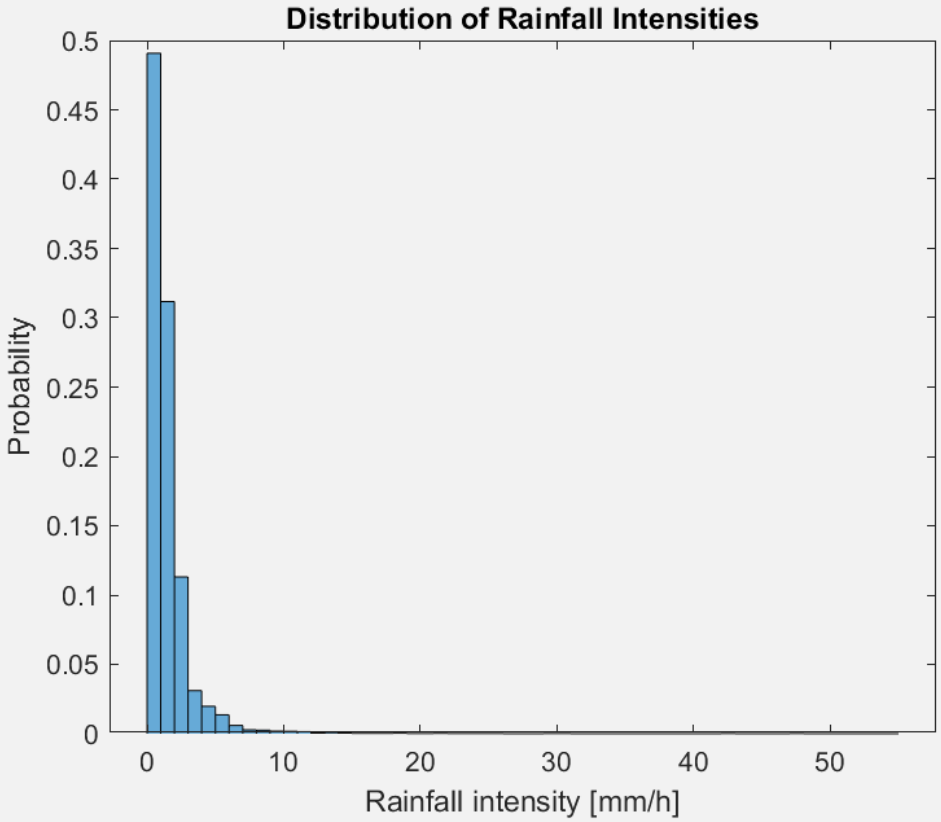




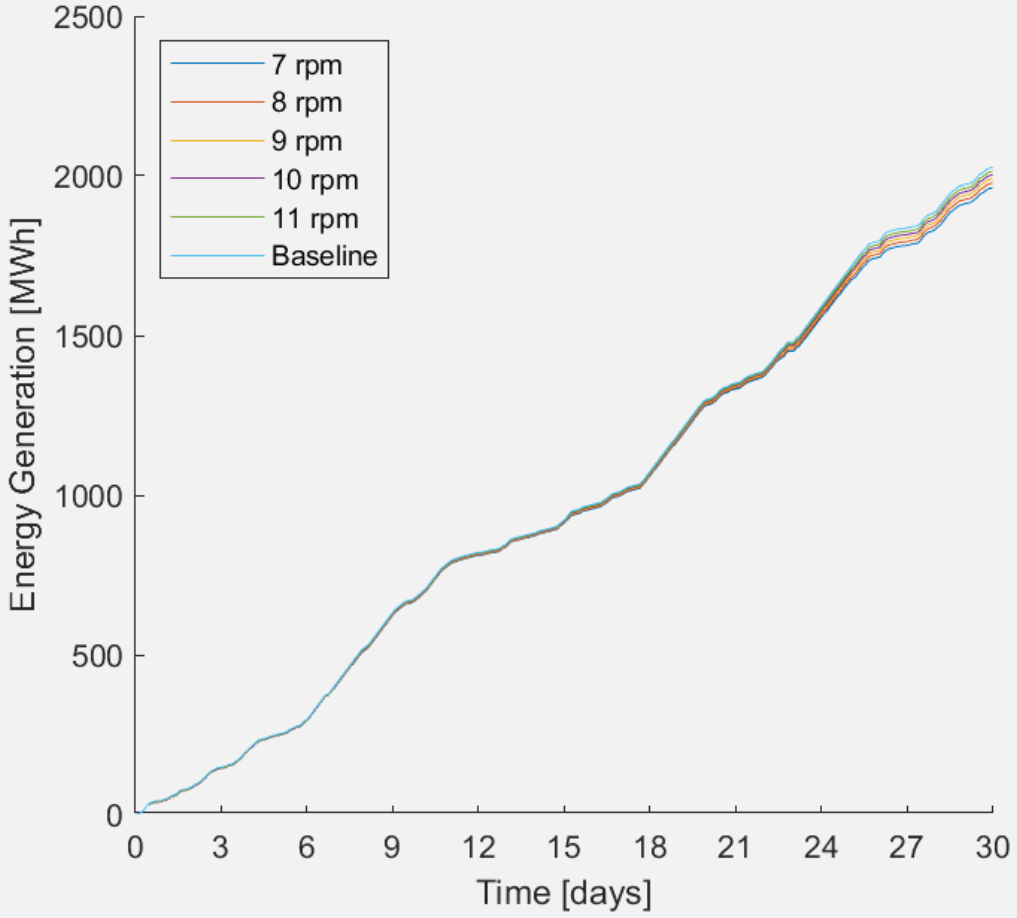

De Kooy

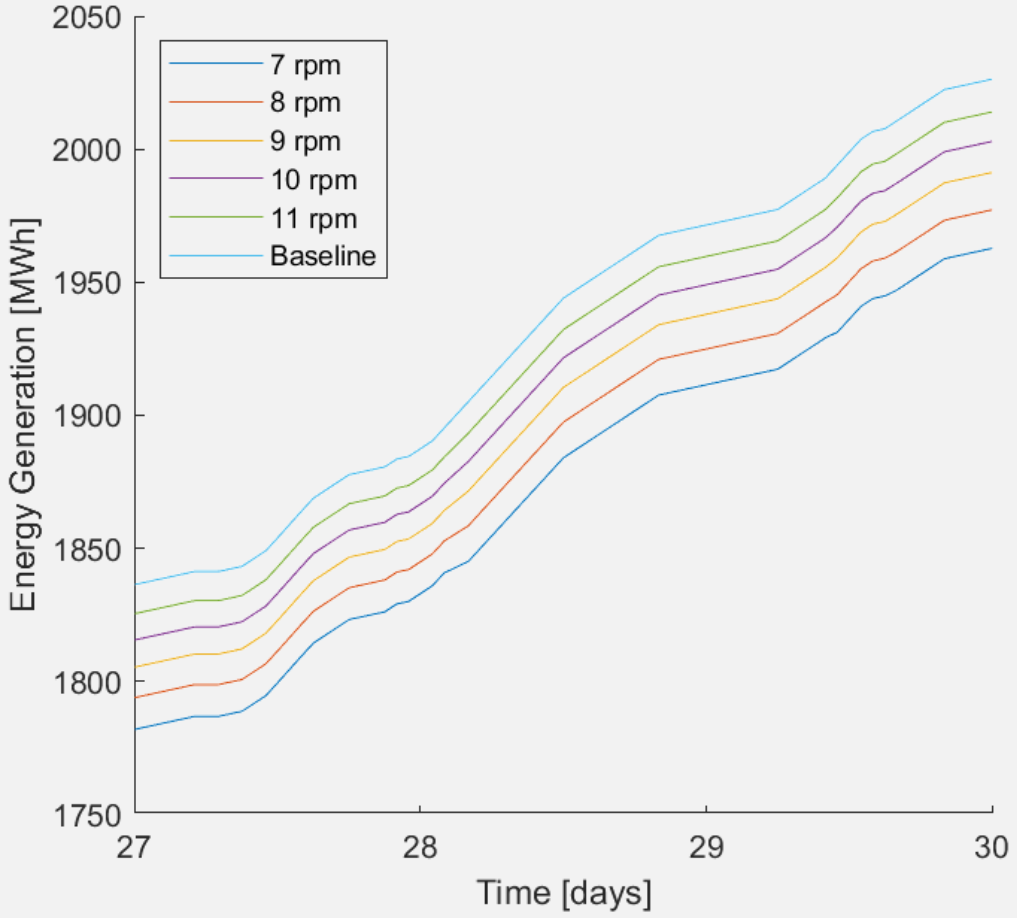
De Kooy Case


Distribution of Wind Speeds
Probability
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
Wind Speed [m/s]

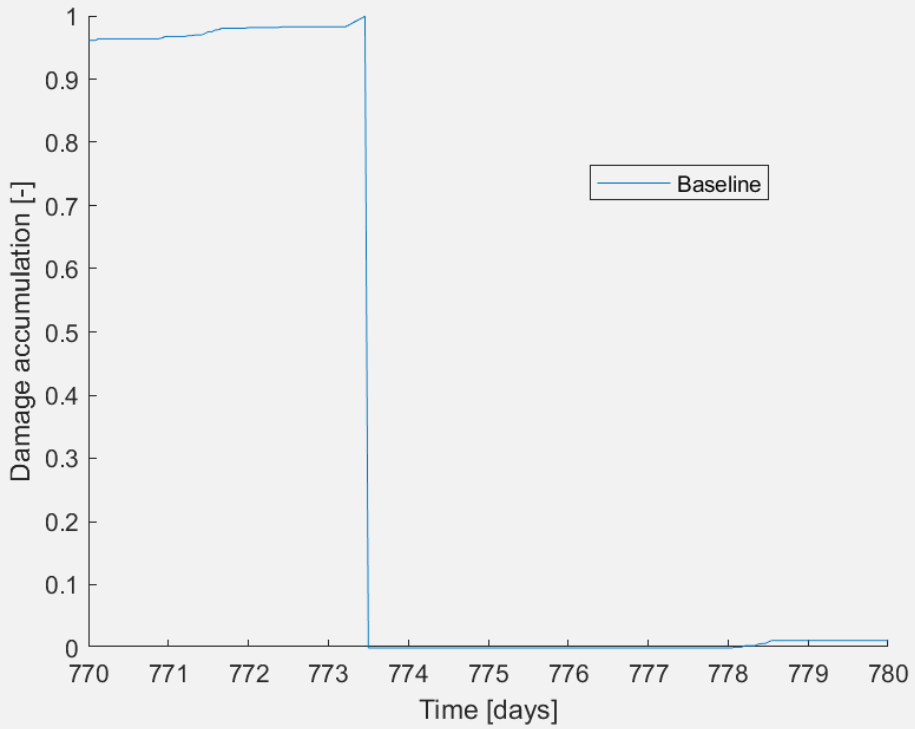

Distribution of Rainfall Intensities
Probability
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
Rainfall intensity [mm/h]

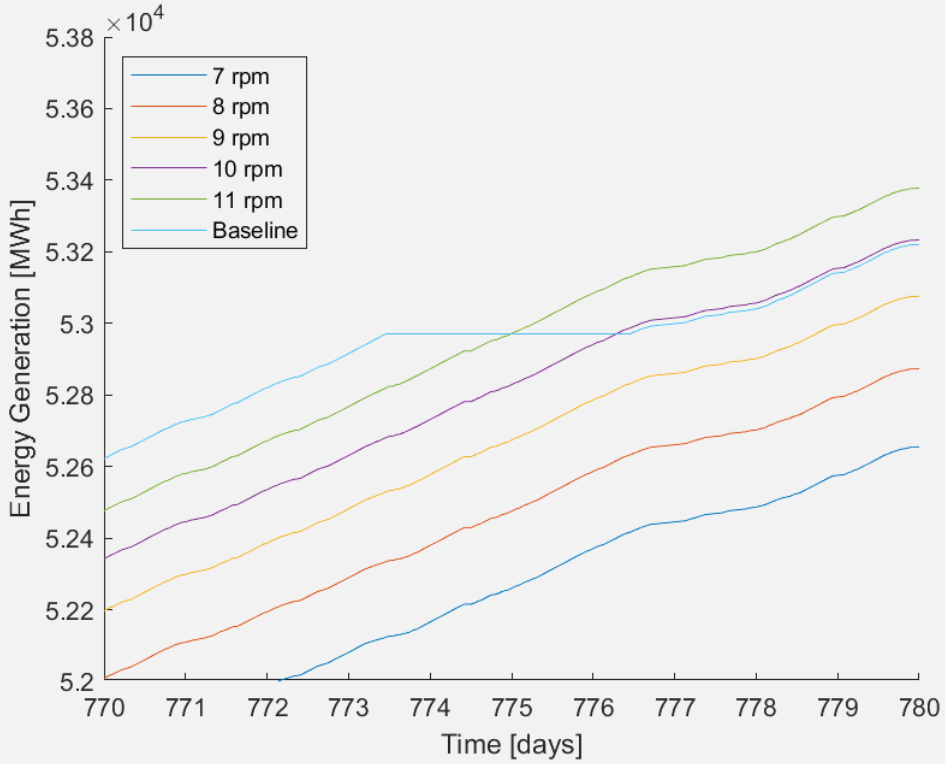
De Kooy Results



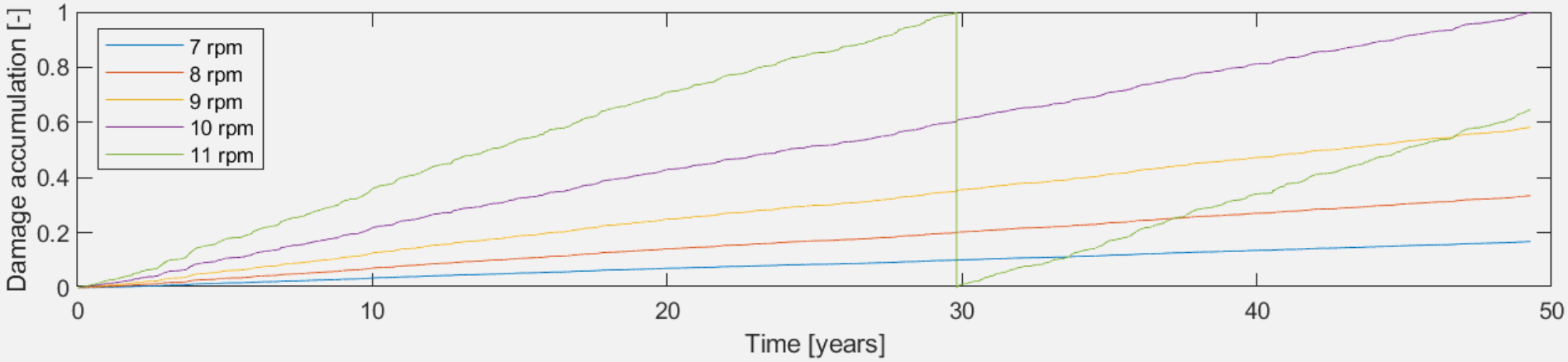


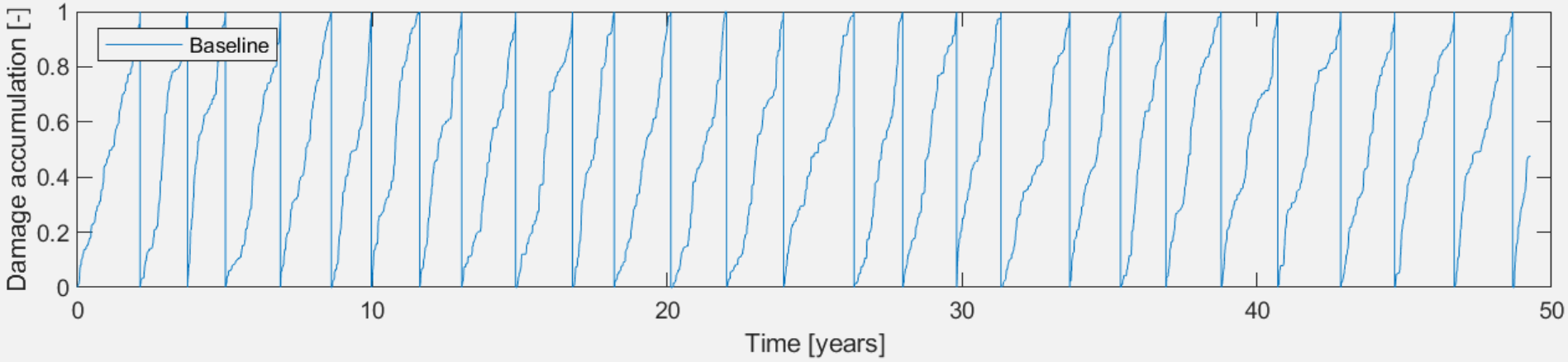
De Kooy Results



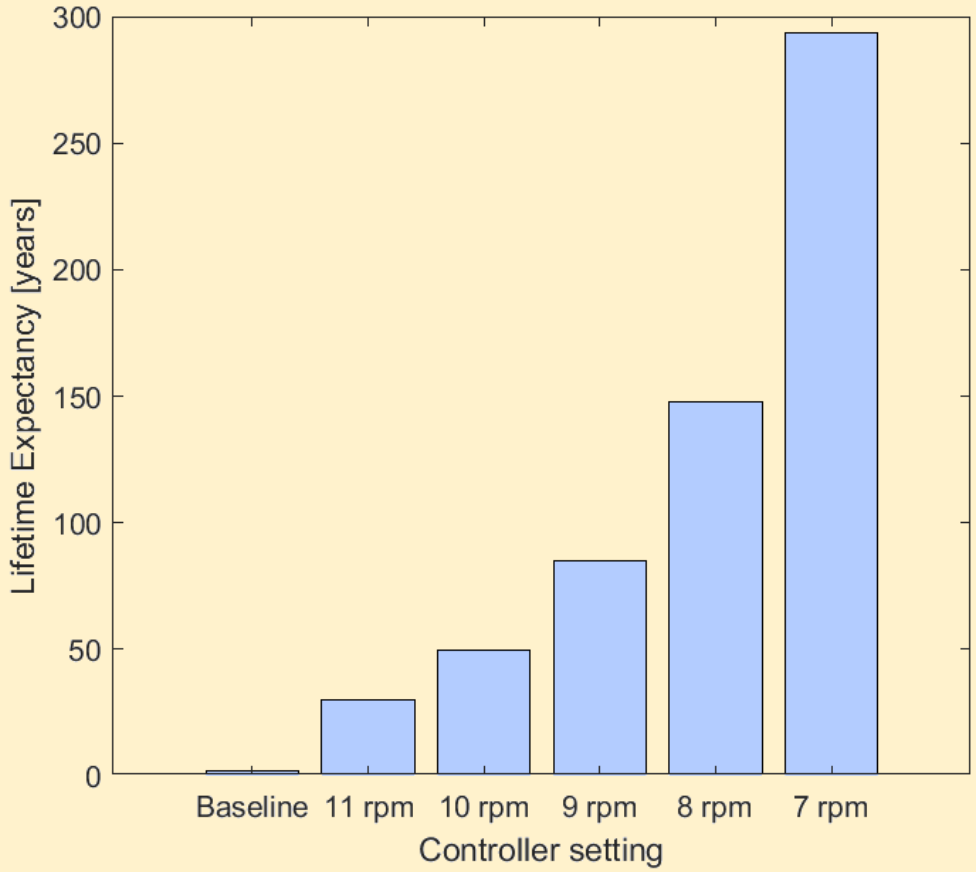


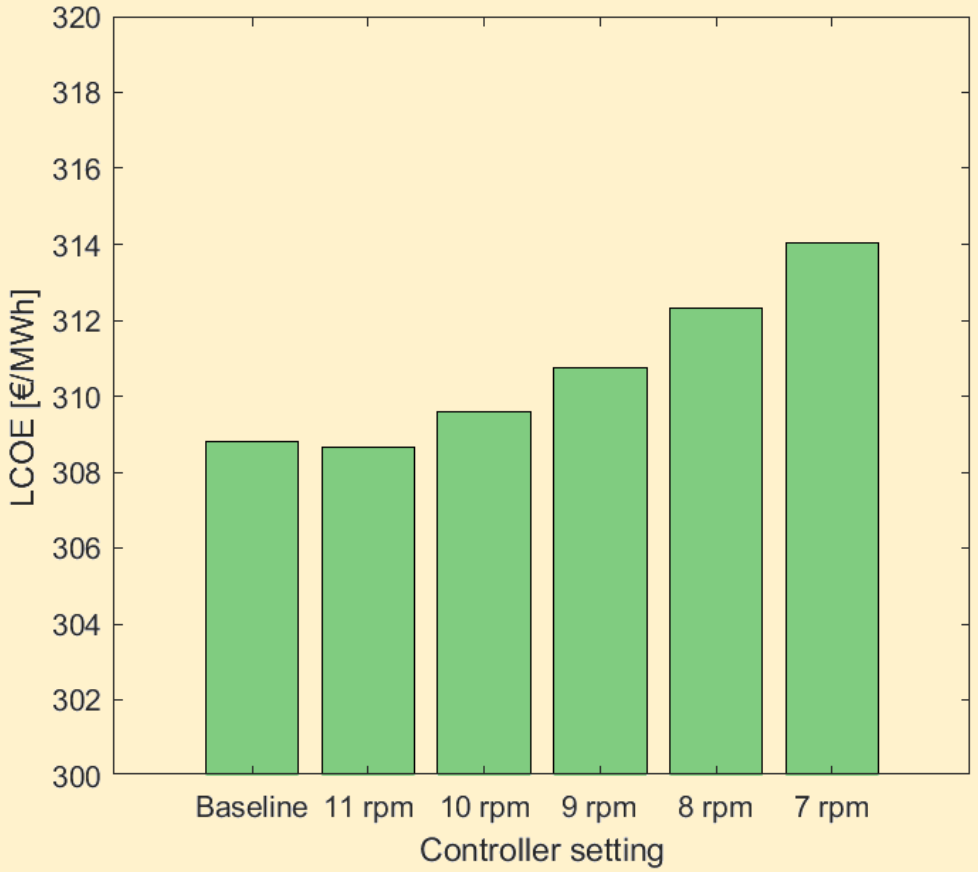
De Kooy Results





Discussion


Lifetime Expectancy [years]
300
250
200
150
100
50
0
Baseline
11 rpm
10 rpm
9 rpm
8 rpm
7 rpm
Controller setting


LCOE [€/MWh]
320
318
316
314
312
310
308
306
304
302
300
Baseline
11 rpm
10 rpm
9 rpm
8 rpm
7 rpm
Controller setting

Discussion

Contributions of the project

- Data set of dynamic wind turbine simulation results.
- Method for analysis of the long-term effects of a given control system.
- Deeper understanding of the long-term consequences of LEE.

Future work improvement

- Highly sensible to set-up parameters
  - Repair costs & times
  - Material properties
  - Wind turbine model
- More and longer simulations. Testing more weather and control conditions.


UiA