The Rebirth of the Greek Sail Windmill for RES

- traditional appearance of the rotor, but modern mechatronics and advanced controls -

Sad witnesses of broken sail windmills on Santorini, Greece

Megalochori and Emporio, Santorini, Greece

Ideal Conditions for SAILWIND

- Thousands of sail windmills throughout the Mediterranean, Portugal and even southern France
- In most of these countries there is a great need for RES to catch up the EU's energy and climate targets
- Mills are cultural heritage of these countries, therefore well accepted – Growing resistance against big bladed wind turbines especially in tourist regions
- Mills ran slowly and quietly, often in the middle of villages or very close to houses.
- Low speeds help to preserve birds and bats
- The market for small wind turbines is booming!

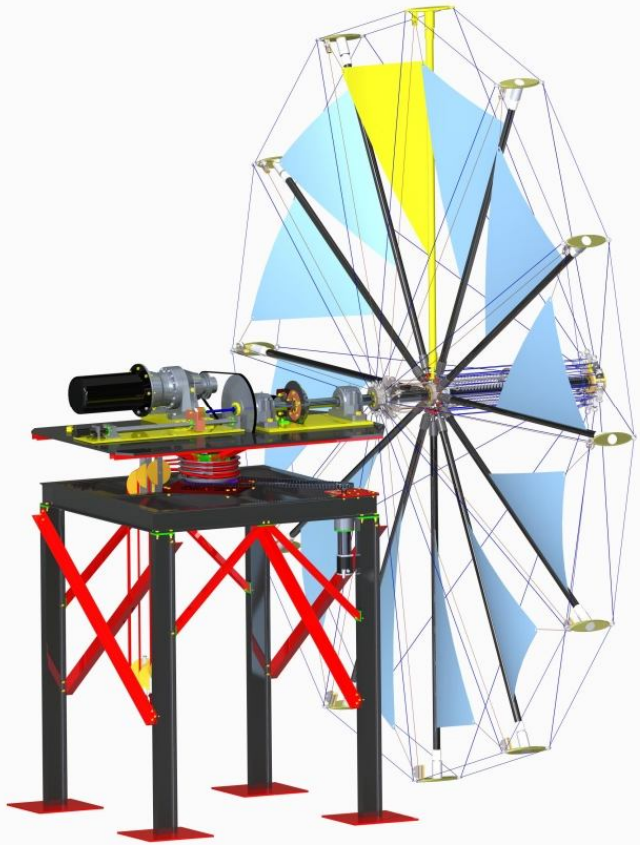
Many sail windmills in touristic areas, villages and beautiful spots

Port of Hydra Island, Greece

General Goals of the SAILWIND Project

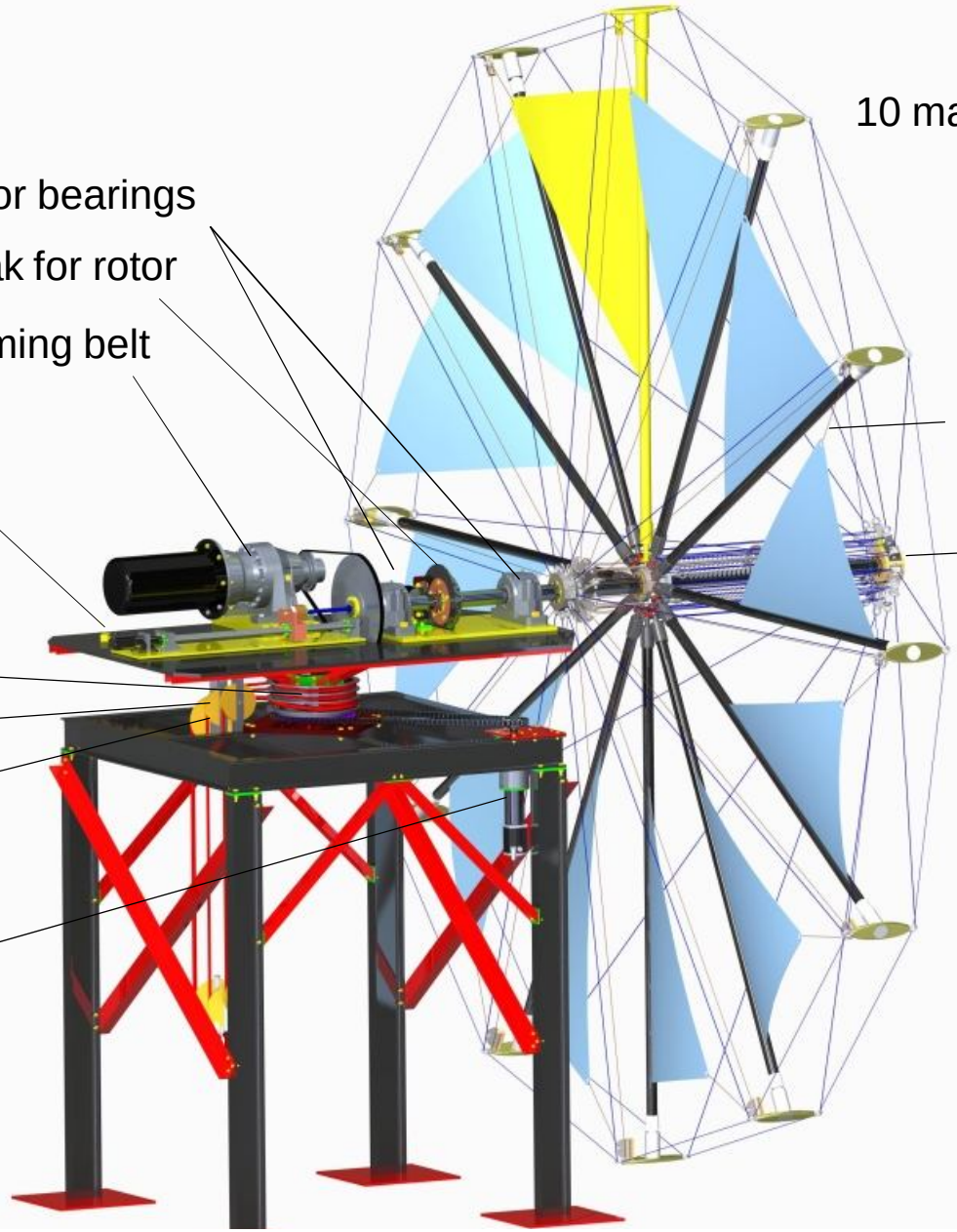
- Reconstruction of historical windmills (with reinforced towers) for local power production
- Erection of turbines on new towers and steel masts
- Fully automated rotor mechanics with sail rolling (storm and dead calm) and sail trimming (low winds)
- Low maintanance and rubust rotor mechanics for hot, dusty sea climate
- Long lifetime of 20 years minimum
- Operation data monitoring and web-based data acquisition, remote operation and diagnostics, predictive maintenance, safety monitoring
- Maximum power point MPP control algorithm
- SAILWINDs in local clusters and windfarms – algorithms for increased cluster efficiency

CAD modell of the prototype SAILWIND 4 (without cladding)



- 4 m rotor diameter, 5 kWp Generator, variable hight
- Modular design
- Rolling and trimming of sails
- Smart electronics (safety, maintenance, web-based data acquisition, remote controls, MPP)
- All parts corrosion protected

Design features of SAILWIND 4



10 masts for rolling the 10 sails

rotor bearings

pneumatical disk break for rotor

generator 5 kWp with gearbox and timing belt

10 sheets for sail trimming

sliding guide and servomotor with pushrod for sail mechanics (rolling and trimming)

antenna with motion sleeves to operate the sails

azimuth slewing ring bearing

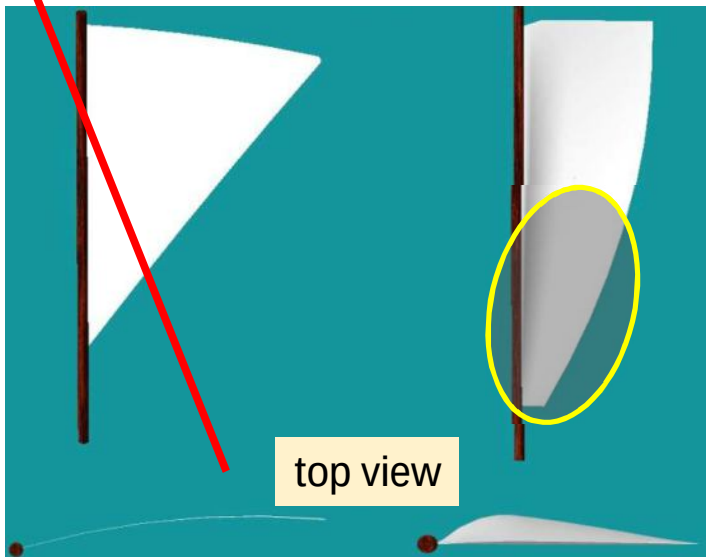
cable rolling in twister chain

azimuth break

servomotor for yaw control (Azimuth) with chain drive

Optimizations for SAILWIND 4

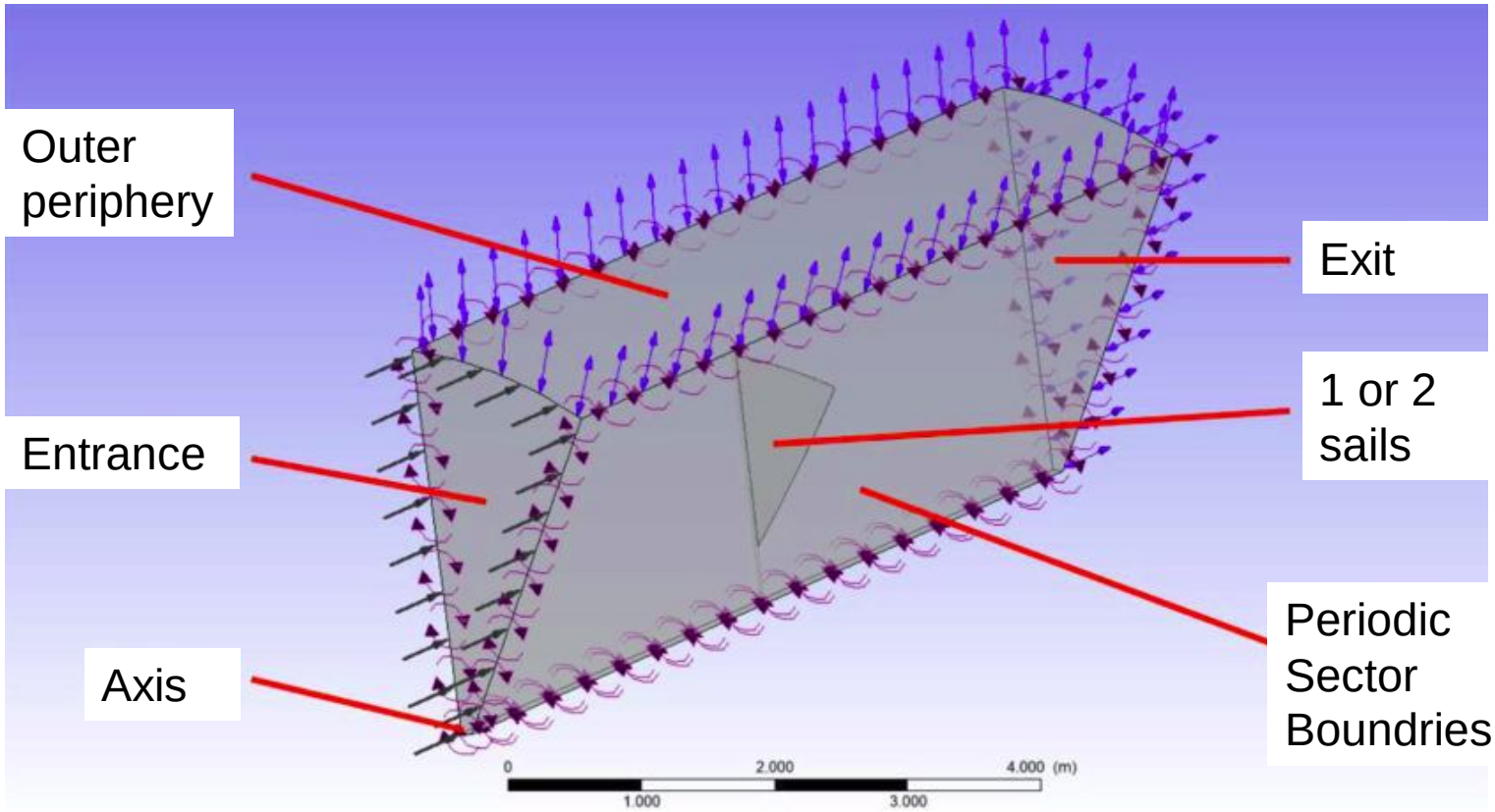
plane sheet sail bulbous sail cut from boats?

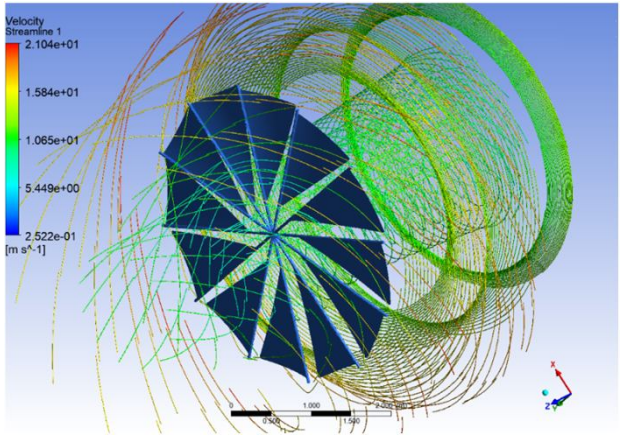


Main Questions:

- Optimum sail cut and profile?
- How many sails and masts?
- Area of the sails? Overlapping?
- Triangular sails?
- Best angle of attack (AoA) for maximum power?

Aerodynamic studies with CFD (in rotating system)

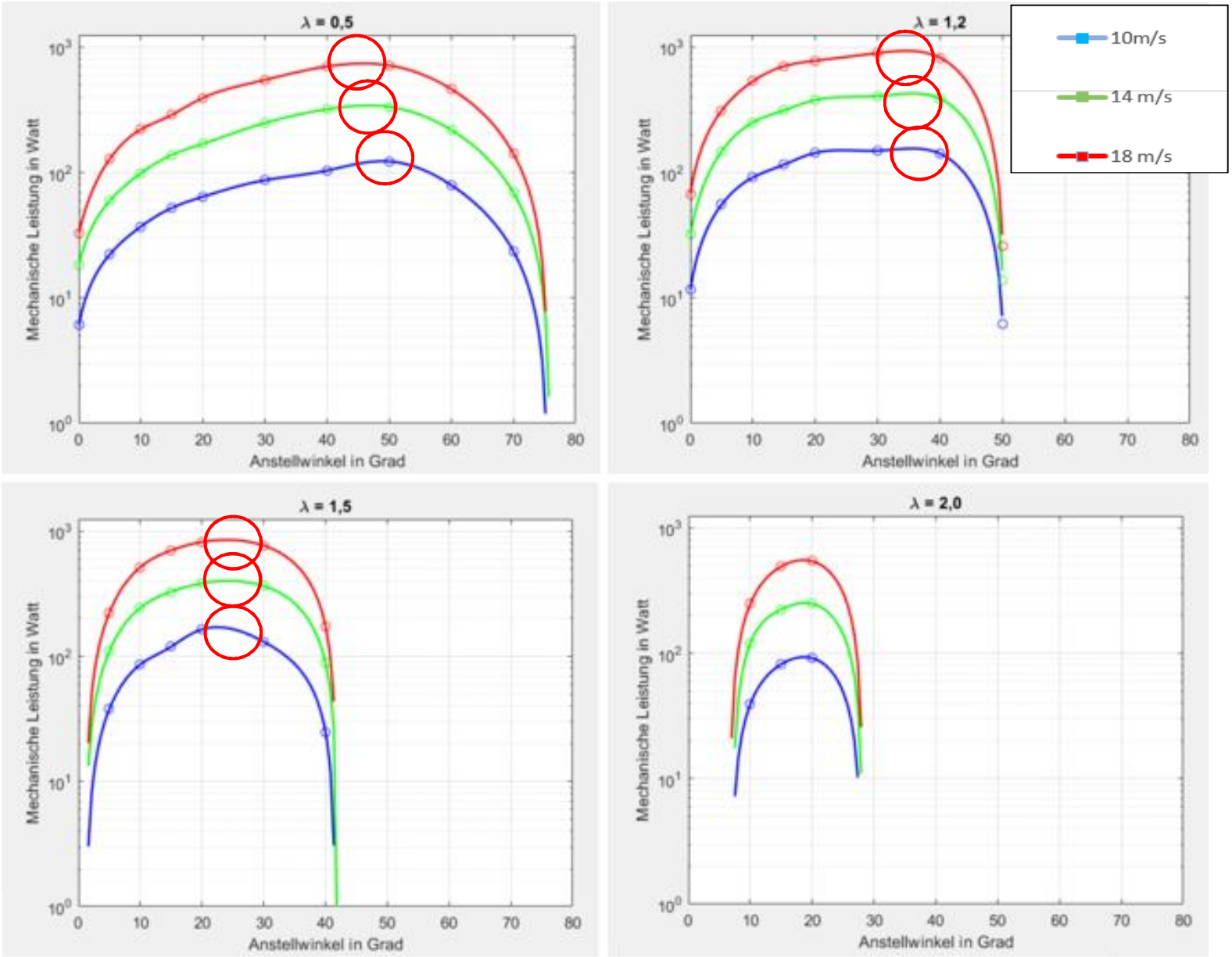




Results from CFD (1)

Log Power per Sail /W

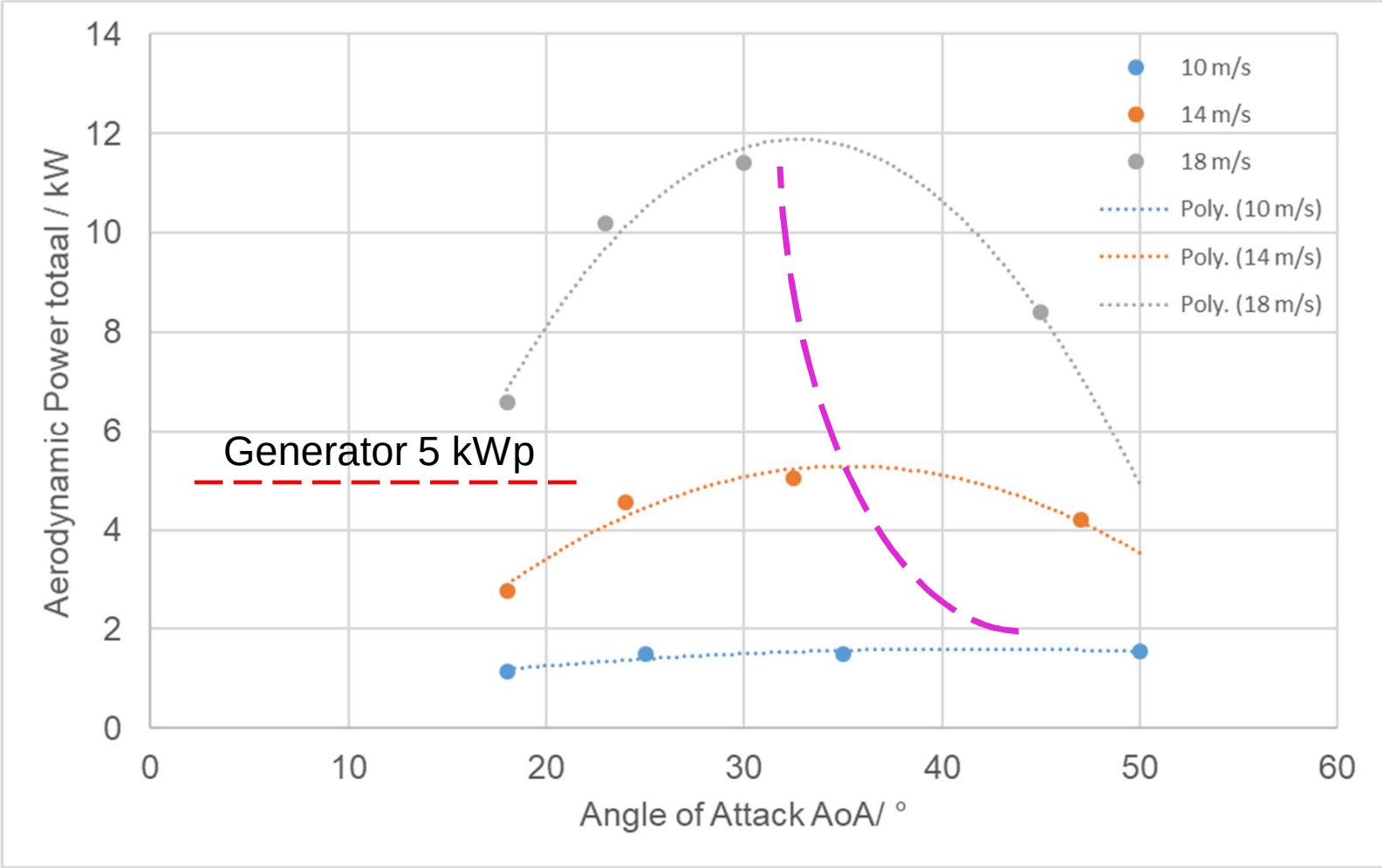
AoA/ Degree



Speed ratio λ
12 sails of 0.65 m²

Sail Trimming

10 m/s	36.0 km/h	5…6 Bft.
14 m/s	50.4 km/h	6…7 Bft.
18 m/s	64.8 km/h	8 Bft.

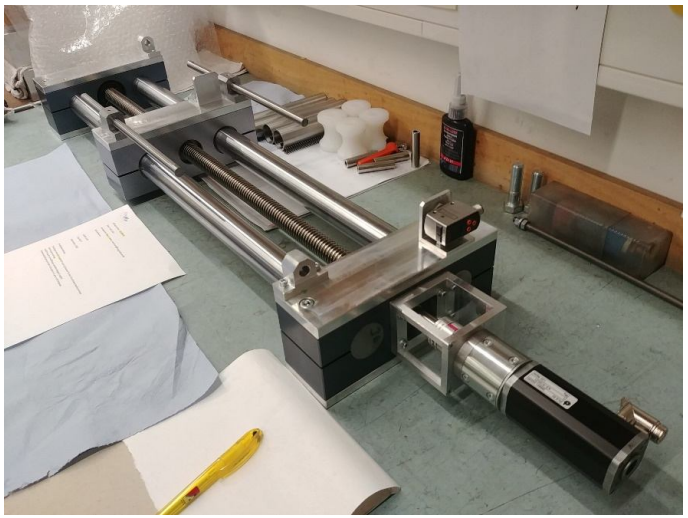


Results from CFD

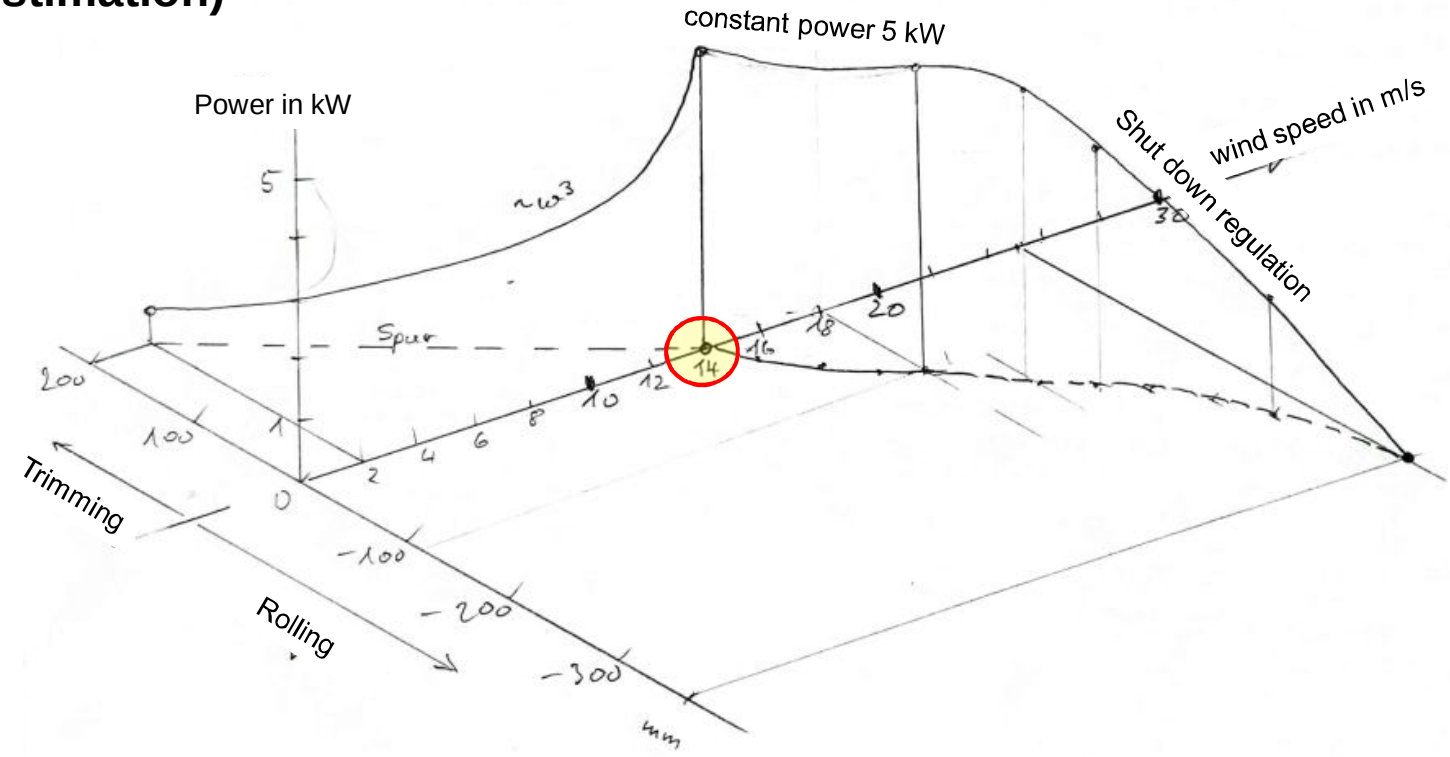
- ✓ 10 sails of 0.96 m² each is better than 12 sails of 0.65 m²
- ✓ No overlapping of sails
- ✓ 5 kWp at 14 m/s was a perfect first estimation
- ✓ So far: $C_{p,max}$ = 0.26 at λ=1.2
- ✓ Angle of attack between 50° and 30° (20° to 25 ° rolling)

Still open questions !

Sail control and power curve (estimation)



Sliding guide with servo motor drive



Further Activities and Outlook

- Continue with CFD + FEM (Coupling of flow with sail deformation)
- Completion of smart controls and PLC/ µC programming
- Concept design for SAILWIND 12 in CAD
- Optimized operation of SAILWINDs in clusters - based on AI
- Start of construction of SAILWIND 4 with donated money and funding (≈ 50.000 € for hardware)

➢ **Search for long-term cooperation partner company (shared know-how, start-up)**

Conclusions

- SAILWIND will be a new, innovative and unique type of wind turbine with big potential

- People acceptance, cultural heritage in southern Europe
- Traditional or modern design towers
- Low noise, running slowly at $\lambda \approx 1.2$
- Complies with nature conservation demands
- Smart electronics (web controls, safety, maintenance, wind farms)
- Long-lasting design, corrosion proof construction (sustainablity)

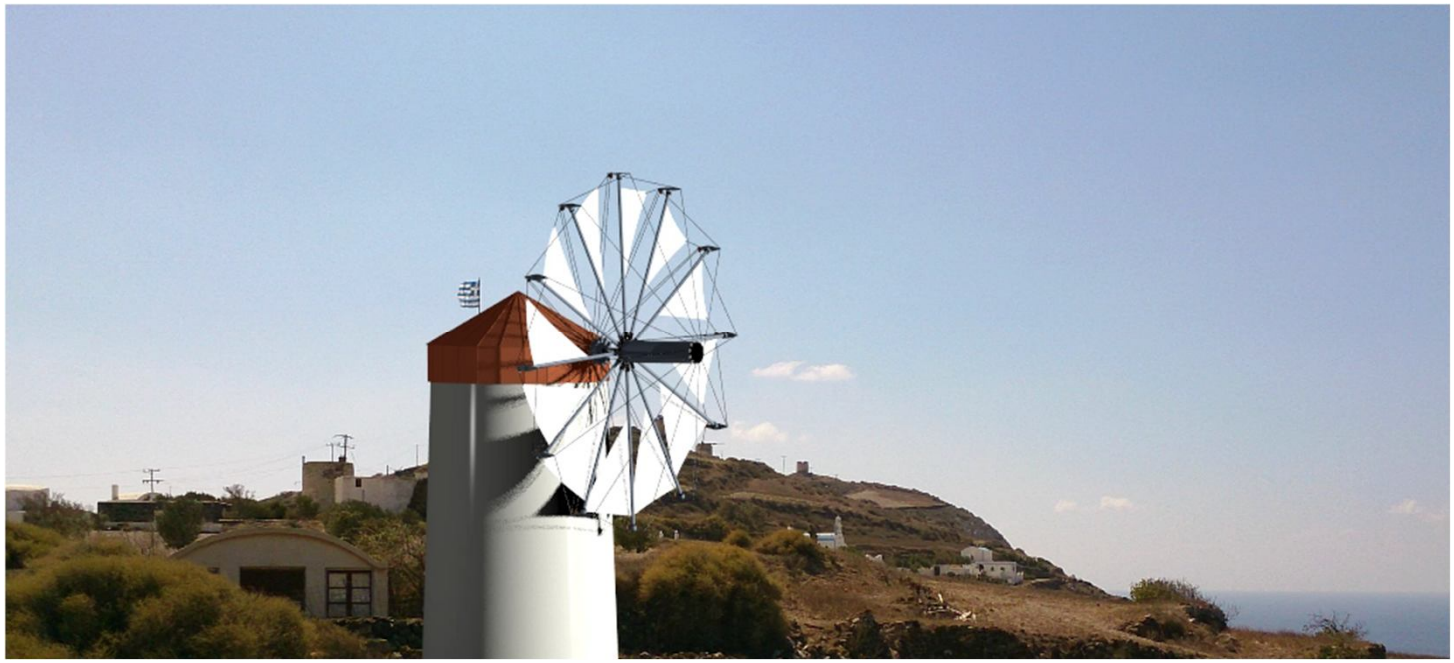
- Rolling and trimming of sails is essential for safety and power optimization

- Further sail optimization (sail cut and area) has the potential to reach cp=0.3 +

- SAILWIND 12 with 50 kWp at 14 m/s is very realistic for windy locations

- SAILWIND will be a smart turbine
  It could become a substantial contribution to RES together with PV and battery storage systems in rural or touristic regions of southern Europe …on-grid or off-grid

Thank you for you attention!



Videomontage, SAILWIND between the 11 old mills of Emporio, Santorini, GR

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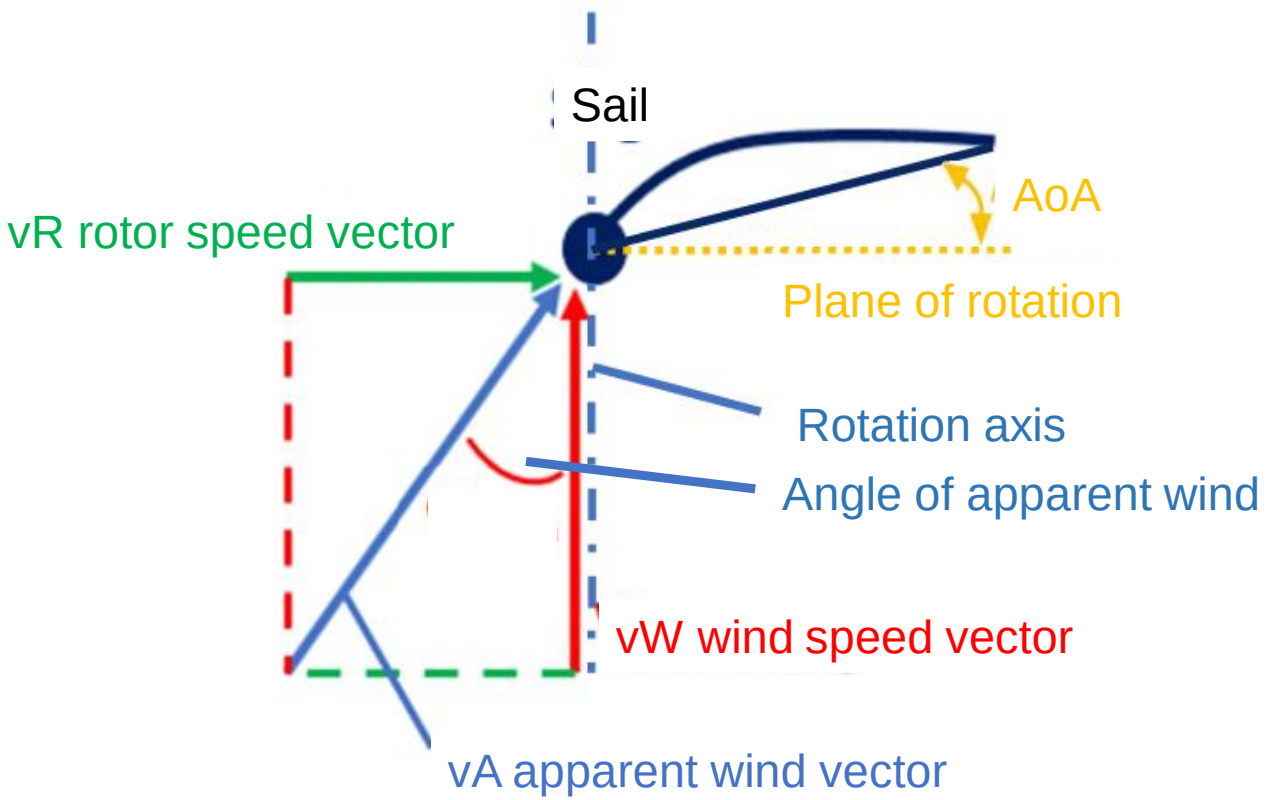
Are you interested in a cooperation?
Your questions are welcome!

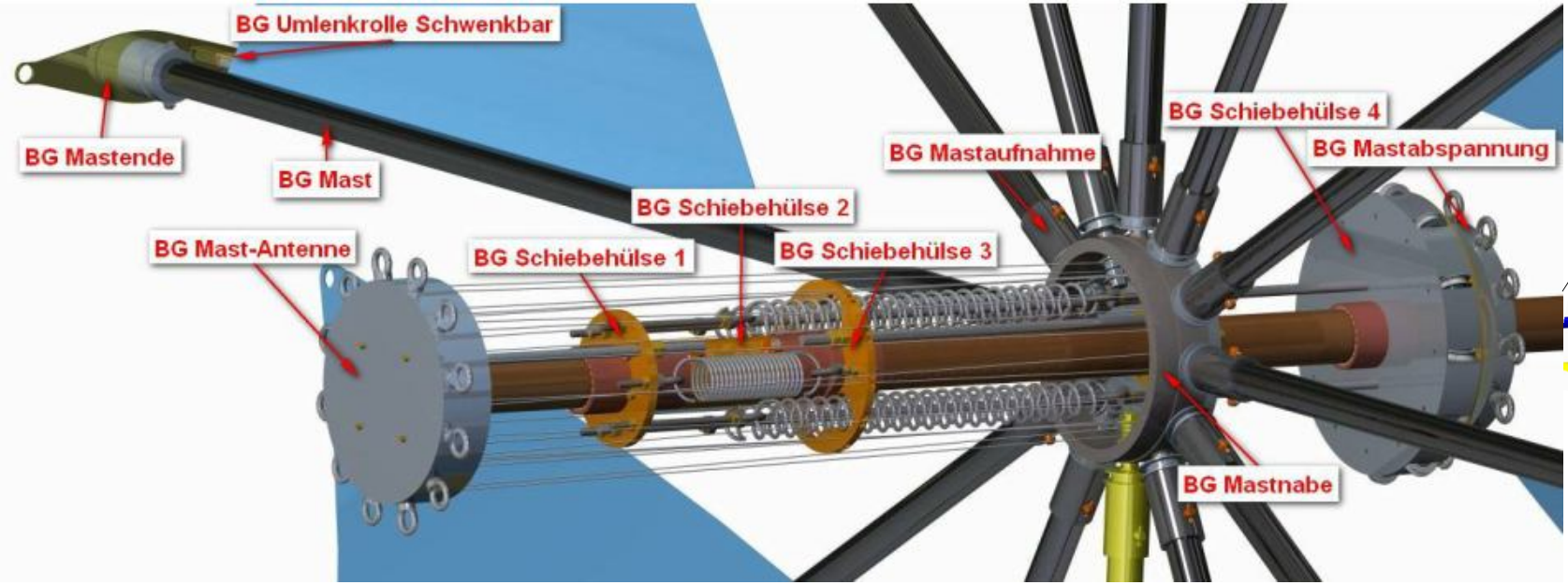
Appendix A

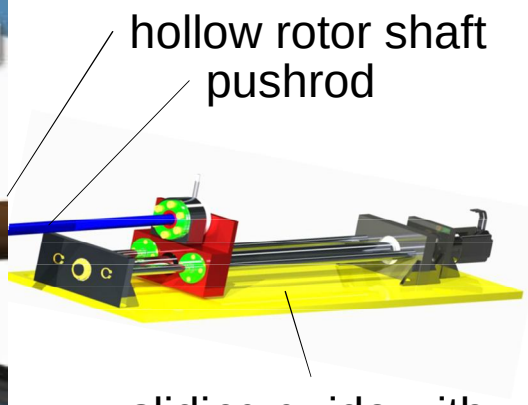
Angle of Attack (AoA) and Speed Vector Triangle



Rolling and trimming of sails with sleeves (wire rope mechanics for SAILWIND 4)

Appendix B





Trimming of sails (control of sail profile, angle of attack AoA)

2 -14 m/s wind speed
pushrod movement +200…0 mm

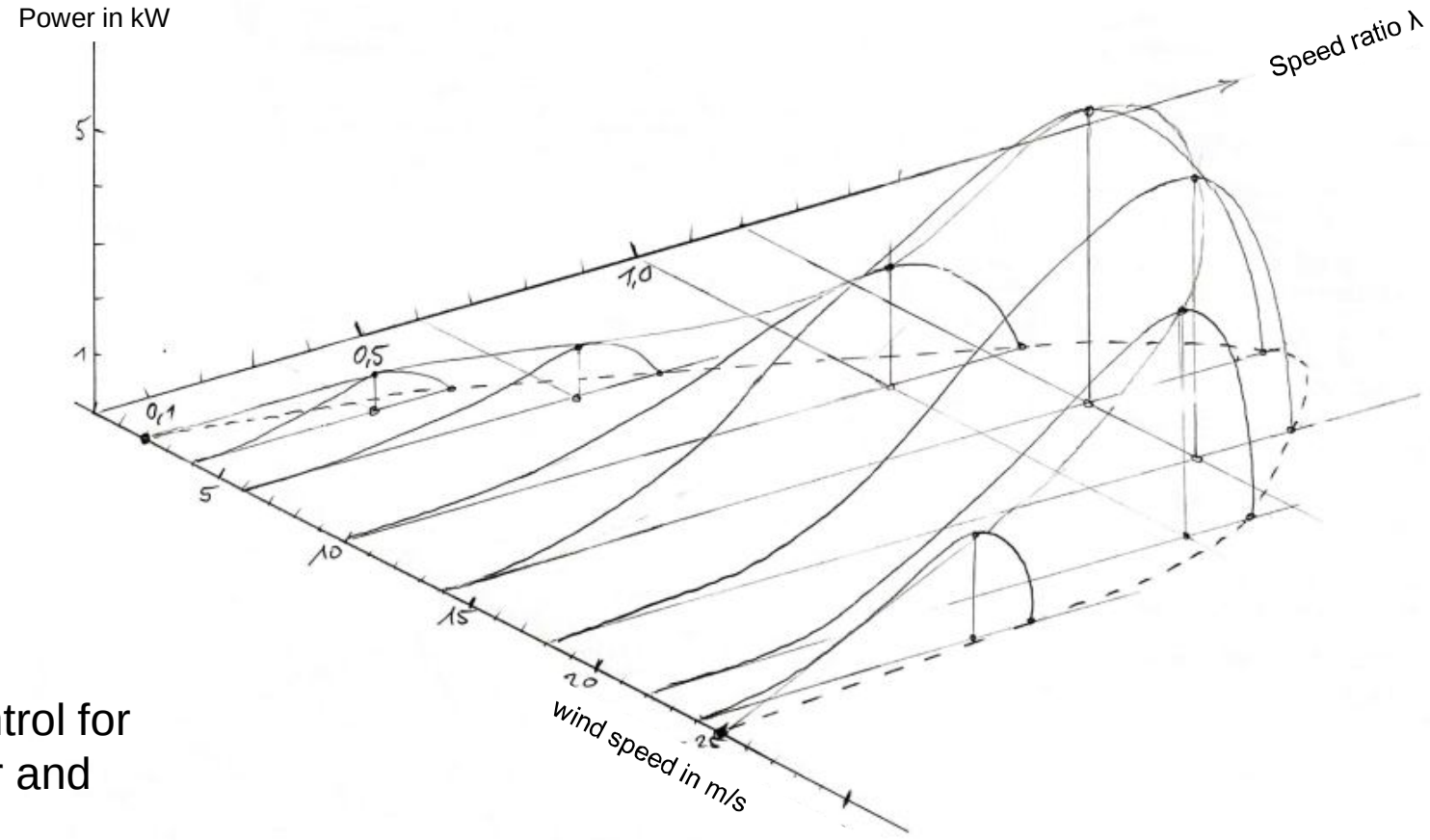
Rolling of sails (rotation of the masts)

14 – 25 m/s wind speed
pushrod movement 0…-350 mm

→ **Nominal Power of 5 kW**

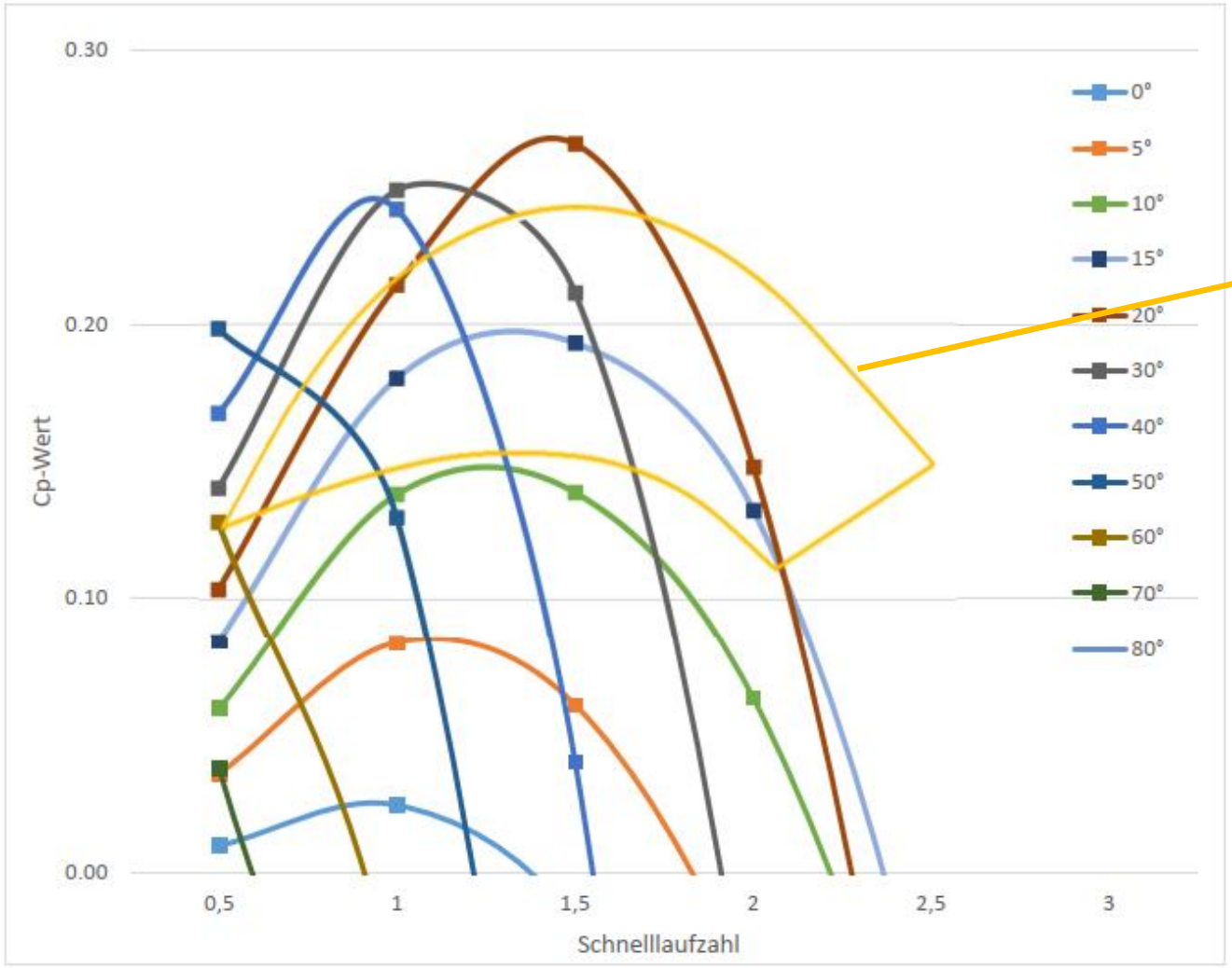
MPP Controls (hypothetical data field)

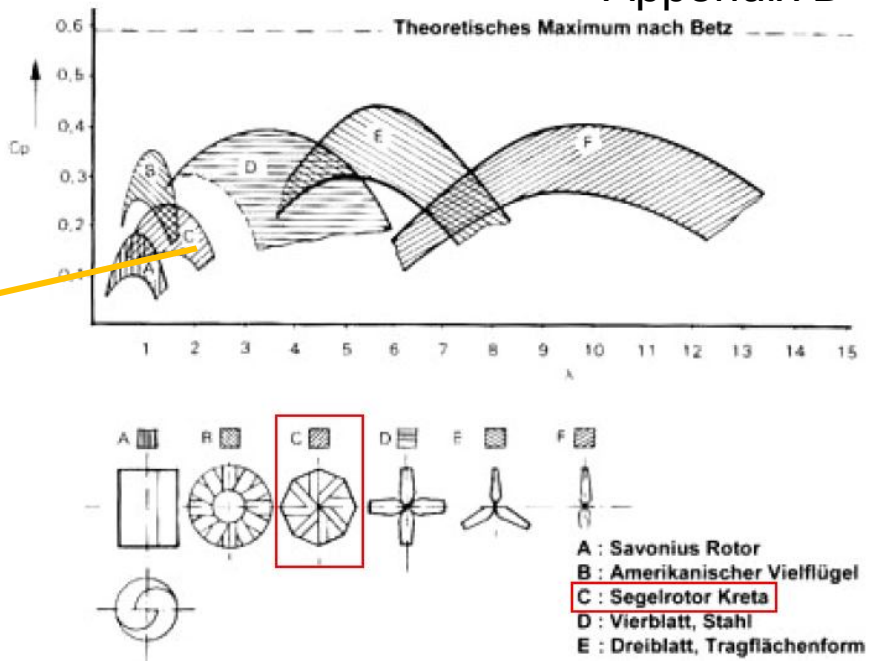
Appendix C



- 2 parameter control for generator power and sail trimming

Appendix D


0.30
0.20
0.10
0.00
Cp-Wert
0,5
1
1,5
2
2,5
3
Schnelllaufzahl
0°
5°
10°
15°
20°
30°
40°
50°
60°
70°
80°


Theoretisches Maximum nach Betz
Cp
A
B
C
D
E
F
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
A : Savonius Rotor
B : Amerikanischer Vielflügel
C : Segelrotor Kreta
D : Vierblatt, Stahl
E : Dreiblatt, Tragflächenform

Electrical layout of the SAILWIND 4

Appendix E