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Small nomadic counter-rotating wind turbine : design and experimentation

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Counter-rotating Wind Turbine Concept

Target : Develop a new high efficiency small scale wind turbine generator providing a power of a few Watts power

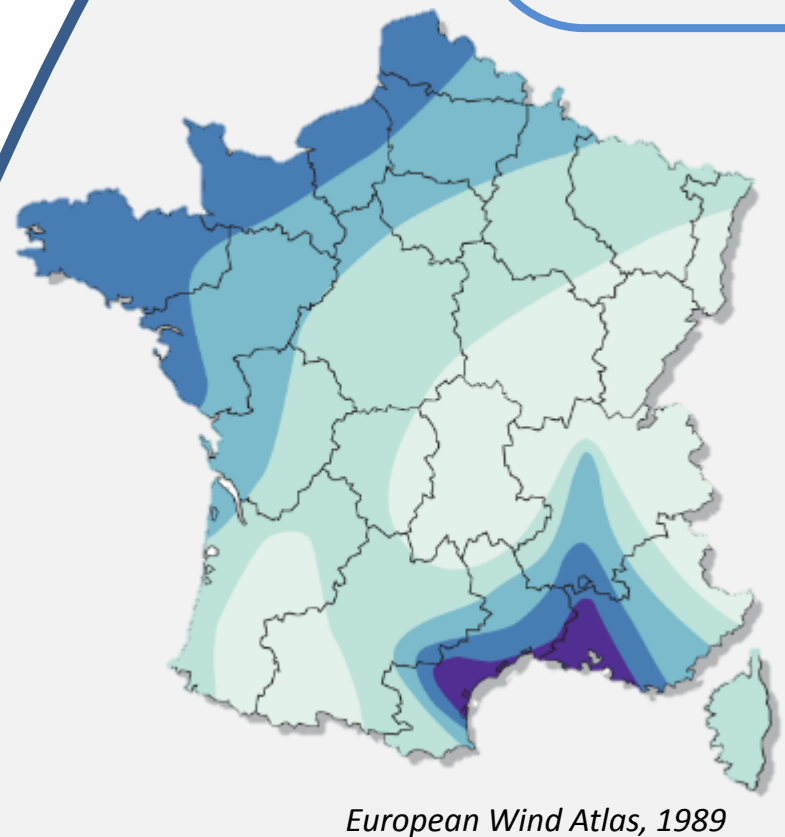
Application : Recharge low capacity batteries (Smartphone, GPS, lamp...)

Wind Source

Natural Wind :

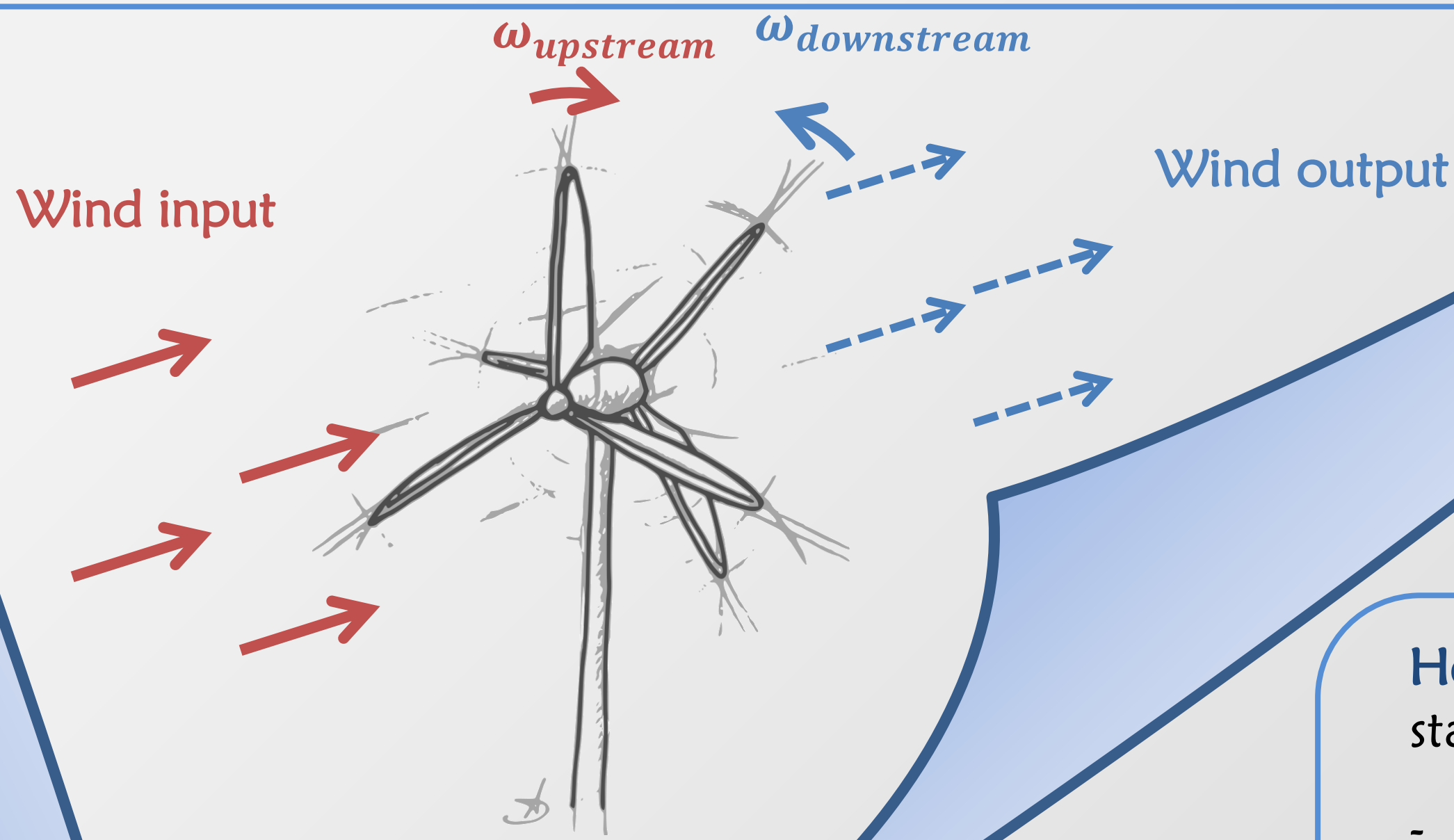
- $V_{mean} = 3,9 \text{ m.s}^{-1}$
- $V_{dominant} = 5 \text{ m.s}^{-1}$

Relative Motion



| Sheltered terrain | Open plain | At a sea coast | Open sea | Hills and ridges |
|-------------------|------------|----------------|----------|------------------|
| <3.5 | <4.5 | <6.0 | <5.5 | <7.0 |
| 3.5-4.5 | 4.5-5.5 | 6.0-6.0 | 5.5-7.0 | 7.0-8.5 |
| 4.5-5.0 | 5.5-6.5 | 6.0-7.0 | 7.0-8.0 | 8.5-10.0 |
| 5.0-6.0 | 6.5-7.5 | 7.0-8.5 | 8.0-9.0 | 10.0-11.5 |
| >6.0 | >7.5 | >8.5 | >9.0 | >11.5 |

European Wind Atlas, 1989



Propellers Design



Heliciel : Design of two optimized propellers stages function of :

- Wind input, Rotation output
- Global geometrical conditions
- Aerodynamic profiles, Pitch angle
- Blades number

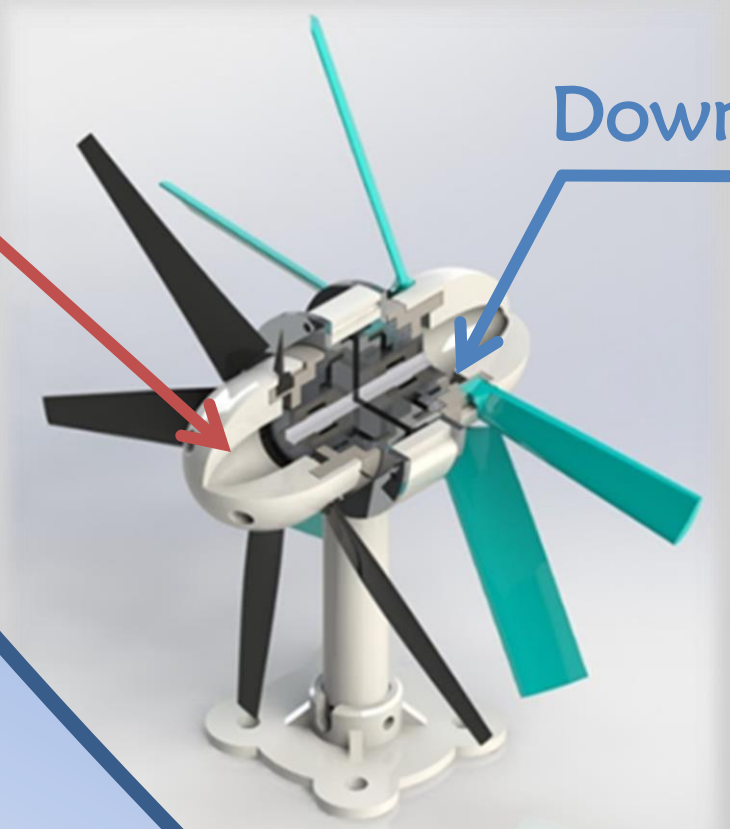
Goal : Maximize the mechanical power output

Small nomadic counter-rotating wind turbine : Design and experimentation

Florian Huet¹, Emile Roux and Aurélien Carré
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Upstream stage

Downstream stage

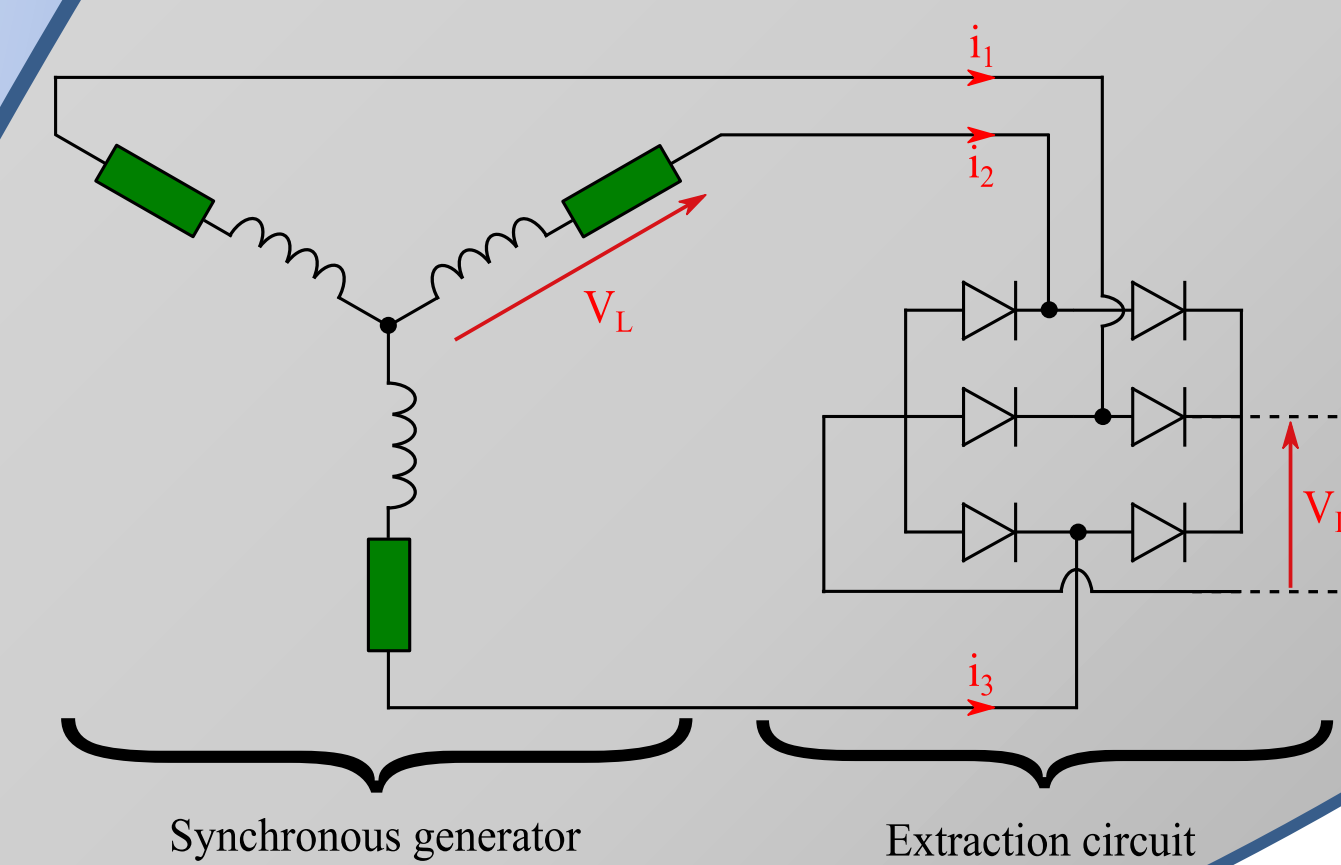


Electromechanical Conversion

Generator : Synchronous three-phases electric generator with permanent magnets

Extraction Circuit : three-phases bridge rectifier

$$V_{DC} = \frac{3\sqrt{2}}{\pi} V_L$$



Synchronous generator

Extraction circuit

Conclusions Prospects

First Promising Results : Higher efficiency than standards small scale wind turbine (~30 %)

Propellers Optimization : The first prototype allows to test various propeller geometries

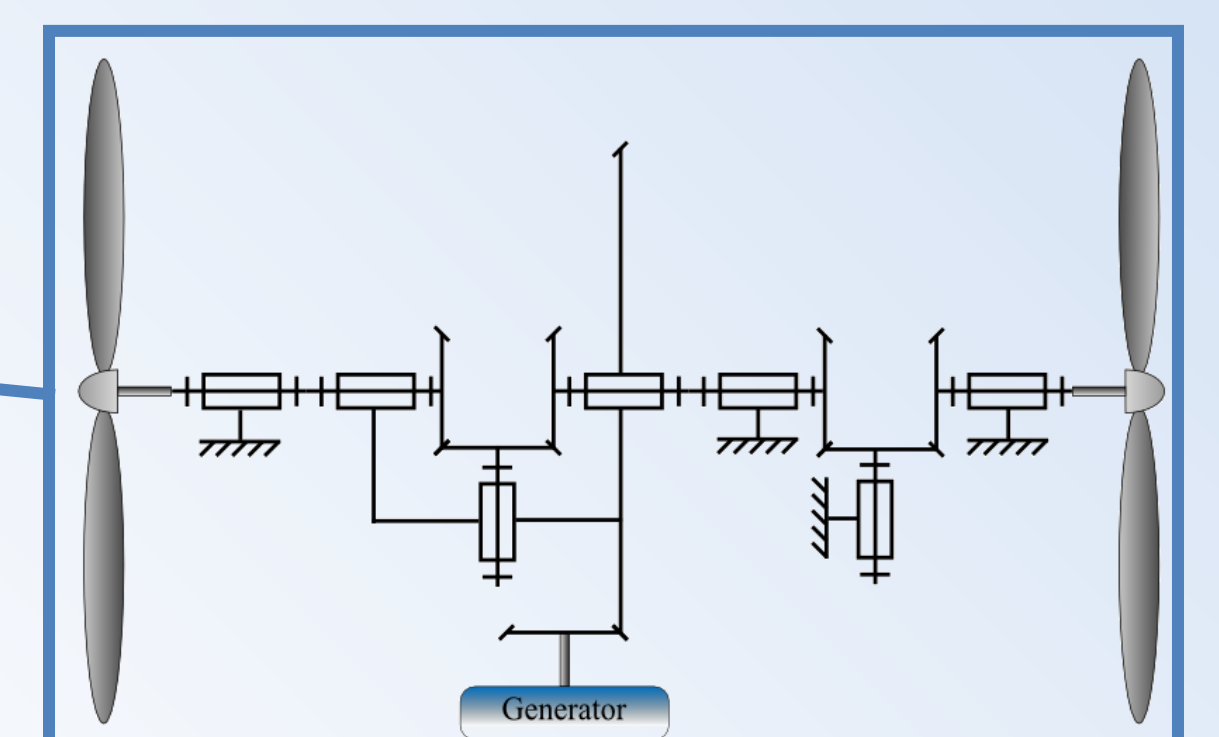
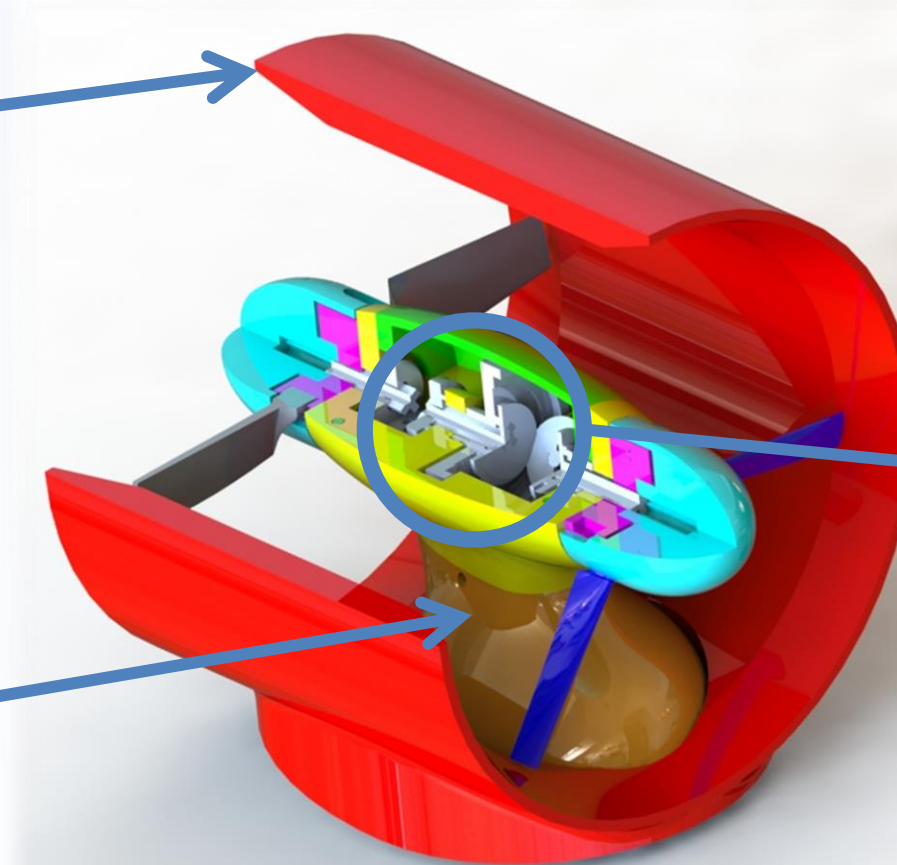
Next Prototype

Increase Locally The Speed : Integrate a venturi into the prototype to increase wind speed and concentrate the air flow

Improve The Transmission : Use a single generator while separating both stages thanks to a mechanical differential

Venturi

Generator



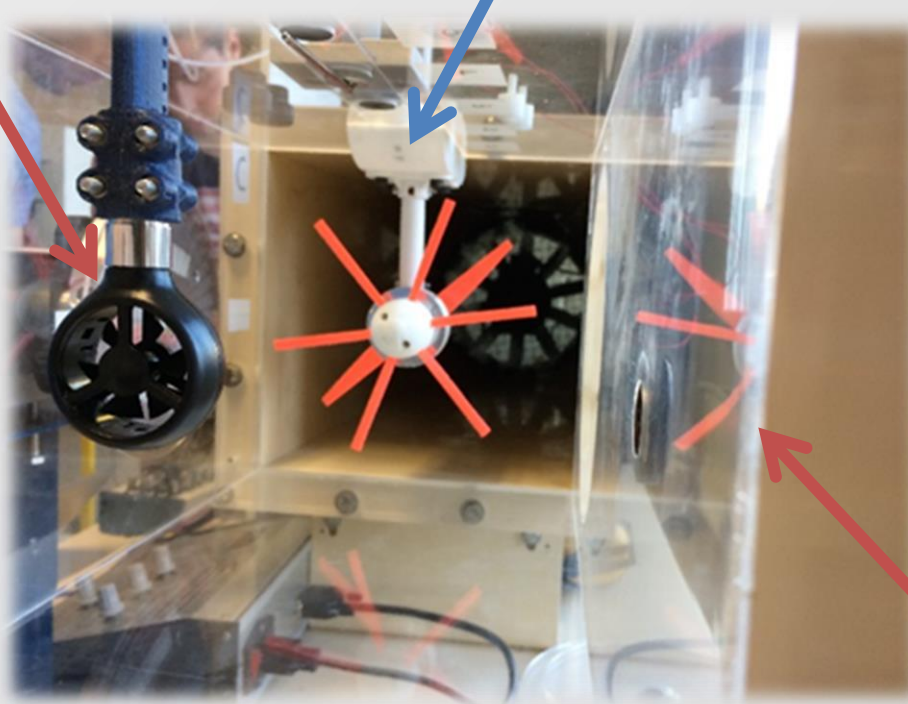
Optimized Differential Transmission



Experimental Setup

Anemometer

Wind Turbine



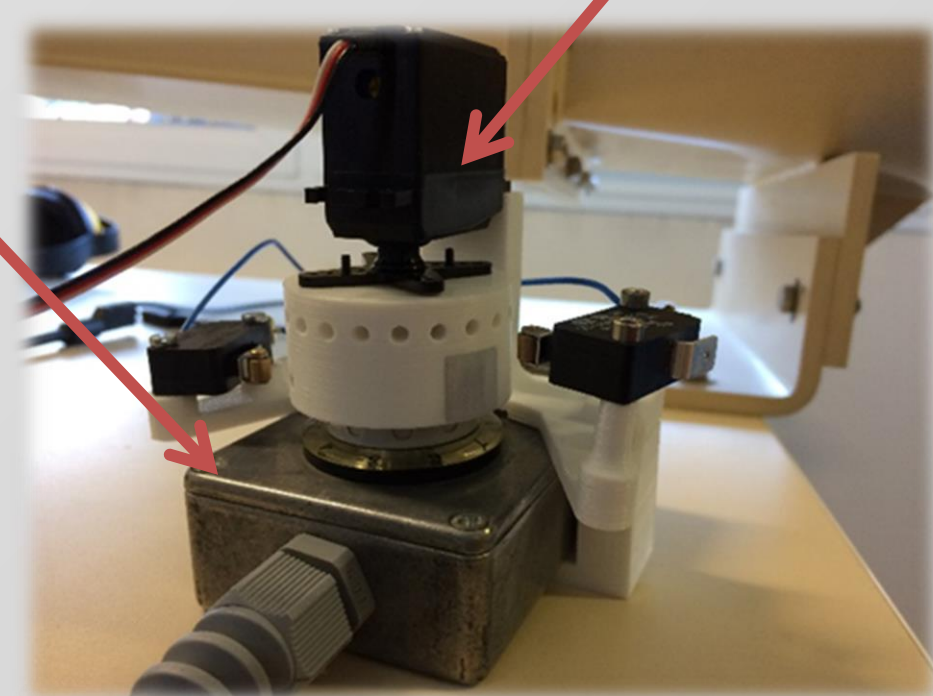
Wind Tunnel :

- Section 23 x 23 cm²
- $V_{max} = 45 \text{ m.s}^{-1}$
- Closed loop controlled flow

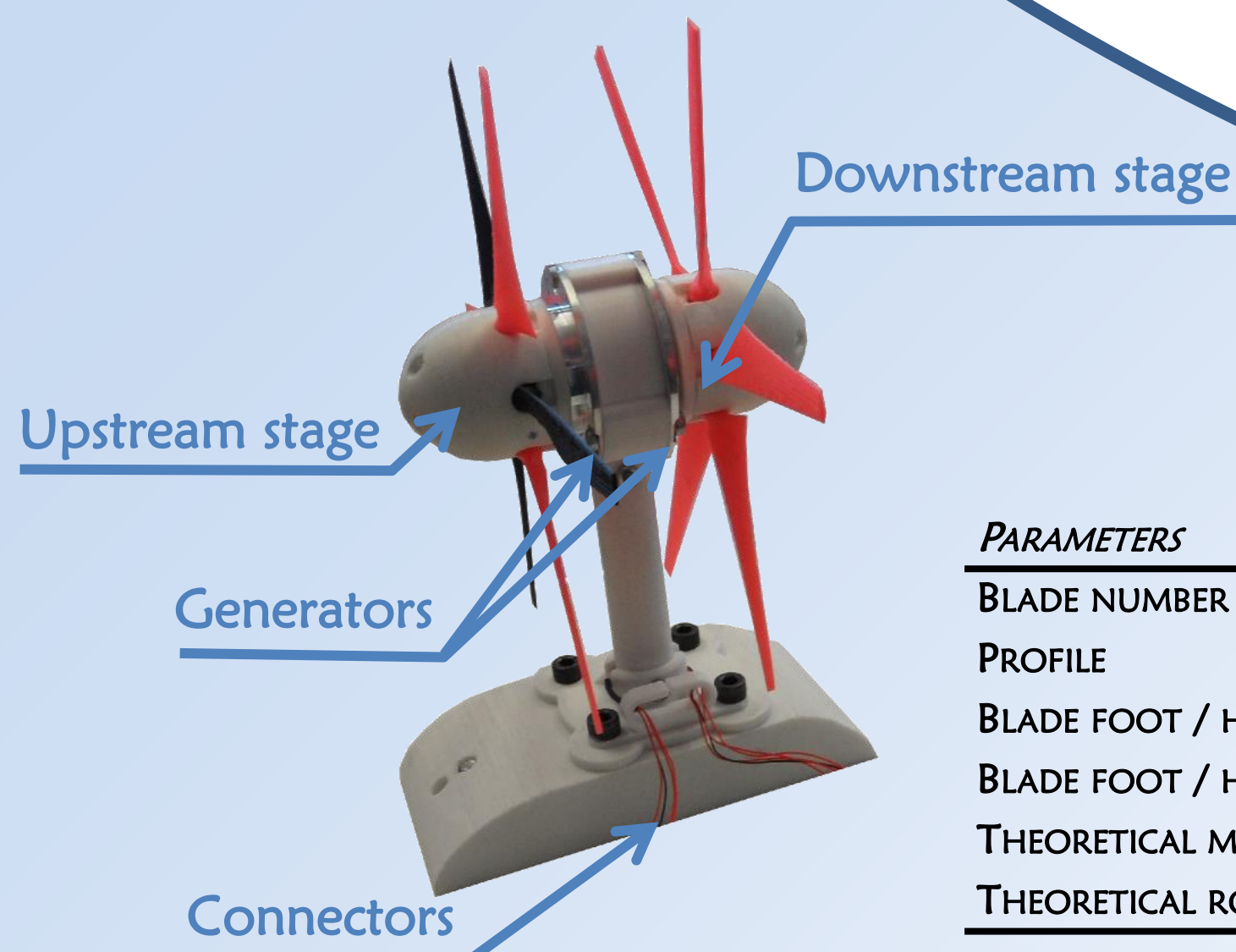
Wind Tunnel

Servo Actuator

Manual Controller Wind Speed



Energy Harvesting



| PARAMETERS | PROPELLER STAGE | |
|-------------------------------|-----------------|---------------|
| | UPSTREAM | DOWNSTREAM |
| BLADE NUMBER | 6 | 6 |
| PROFILE | NACA1412 | NACA6412 |
| BLADE FOOT / HEAD DIAMETER | 40 MM / 180 MM | |
| BLADE FOOT / HEAD WIDTH | 17 MM / 7 MM | 17 MM / 17 MM |
| THEORETICAL MAXIMUM POWER | 0.8 W | 2.2 W |
| THEORETICAL ROTATION VELOCITY | 2800 RPM | 6000 RPM |

Theoretical Maximum Wind Power :

$$P_{max_th} = \frac{16}{27} P_{kinetic} = \frac{8}{27} \rho S v^3$$

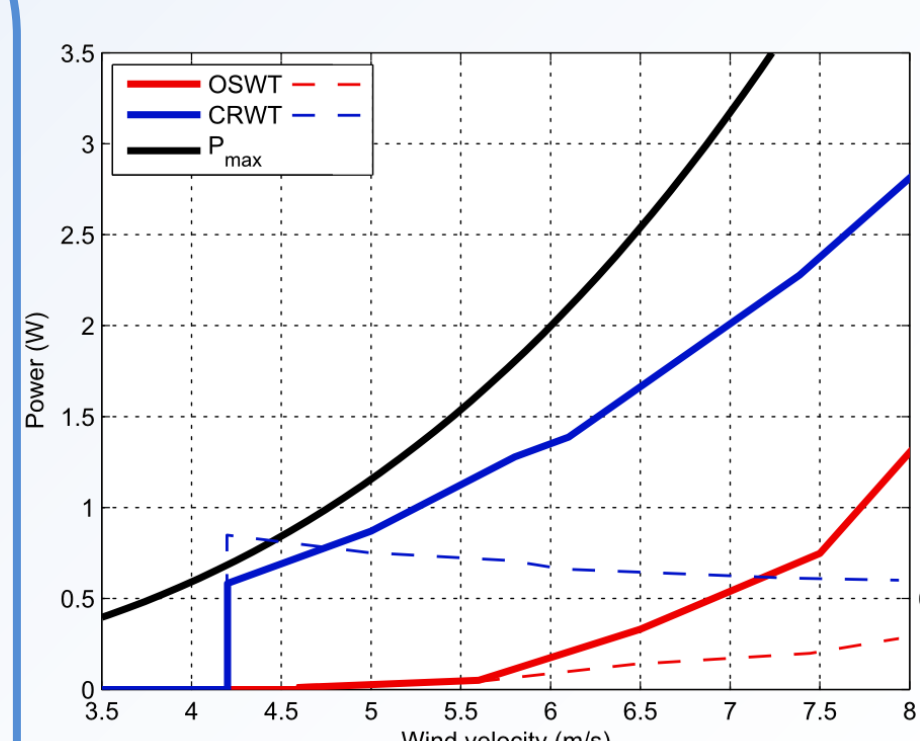
One Stage Wind Turbine (OSWT) :

$P_{OSWT} = 0 \text{ W}$ at 4,2 m.s⁻¹, 1.3 W at 8 m.s⁻¹

Counter-rotating Wind Turbine (CRWT) :

$P_{CRWT} = 0.6 \text{ W}$ at 4,2 m.s⁻¹, 2.8 W at 8 m.s⁻¹

Maximum efficiency 85 % at 4,2 m.s⁻¹



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