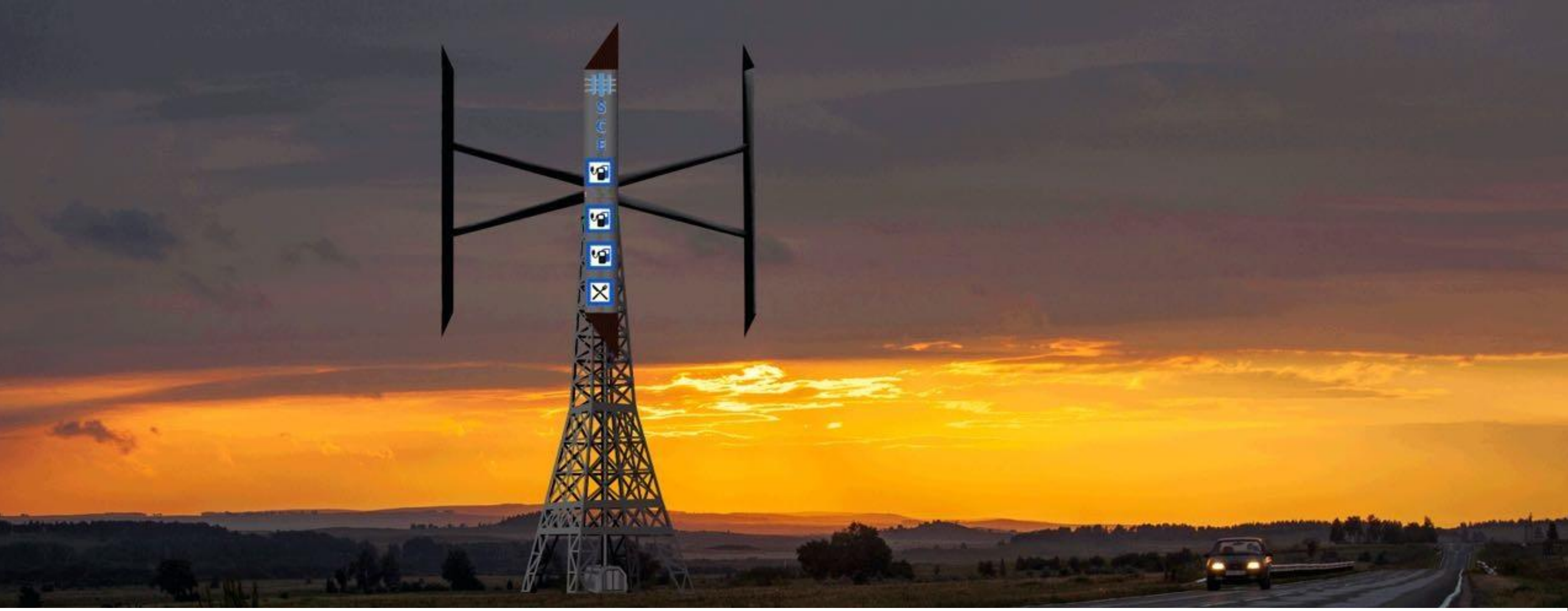

Vertical Wind Turbine GS-1000NT

German Sustainables GmbH - Technology

GS-1000NT® Wind Turbine

- History/Introduction
- Technical Description
- Advantages
- Development Insights
  1. CFD
  2. FEM
  3. Control System
  4. Structural & Mechanical Components
  5. Electrical Components
  6. / Hardware Impressions
- / Development Schedule
- / Design Review

History

1997

- Flug Werk GmbH
- F&E Development
- GS-1000NT

2004

- Gale Force GmbH
- Investment

2018

- German Sustainables GmbH
- Production & Sales

Development of technology from aircraft engineering

4,8 Mio € Investment up to readiness for series production

Tests and optimization of all parts

Failure Key Investor liquidation in 2017

Start-up by two former associates H. Bachner and C. Colling

CEO H-J. Brandt
CTO C. Colling

Introduction - Vertical Axis Wind Turbine (VAWT) with hydrostatic drive train

- German Sustainables GmbH (GS) develops and manufactures the GS-1000NT®, a completely new developed VAWT. The new wind power plant incorporates all advantages of vertical technology at similar power output in comparison to conventional HAWT.
- The major USP is the worldwide patented spoiler technology.
- Design and development is based on computer numerical models and processes as used in state-of-the-art aerospace developments.
- The GS-1000NT® concept features a simple and robust design, which leads to drastically lowered maintenance expenses. Great savings and ease of transportation are achieved, since the entire machine is of modular design and can be transported in standard ISO 40ft containers
- Furthermore GS-1000NT® suits very well for desert conditions as a result of its robust and simple design being non-sensitive to sand, high-temperatures and UV radiation. Development partners are the IFAS of RWTH University, as well as potent partners from the German and European industry such as Bosch-Rexrodt and GENSAN-Turkey.


SCE
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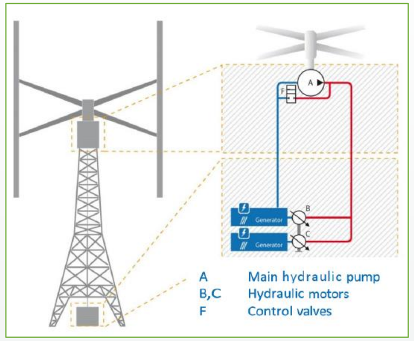
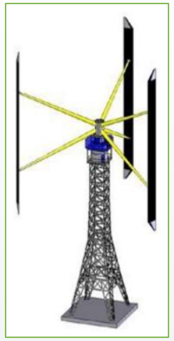
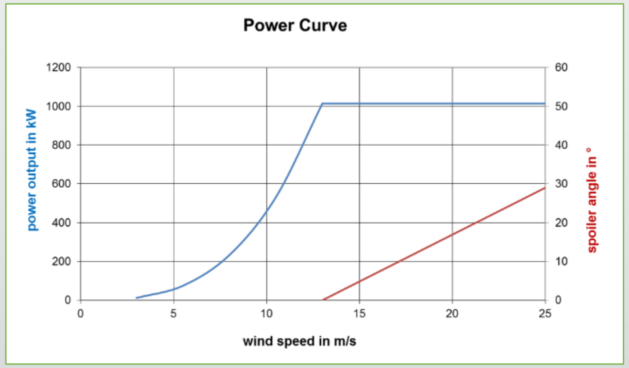

A
Main hydraulic pump
B,C
Hydraulic motors
F
Control valves
Generator
Generator




Power Curve
power output in kW
spoiler angle in °
wind speed in m/s
1200
1000
800
600
400
200
0
60
50
40
30
20
10
0
0
5
10
15
20
25

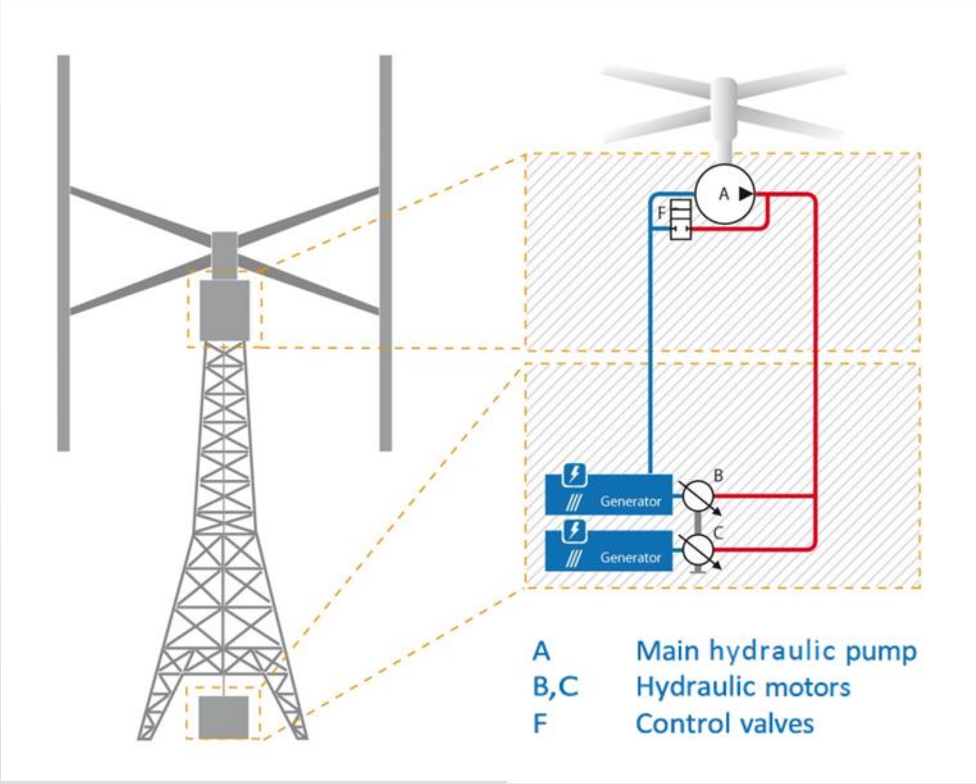
Technical Description - Vertical Axis Wind Turbine (VAWT) without heavy weight atop the tower (Nacelle)

Generators and generator drive:

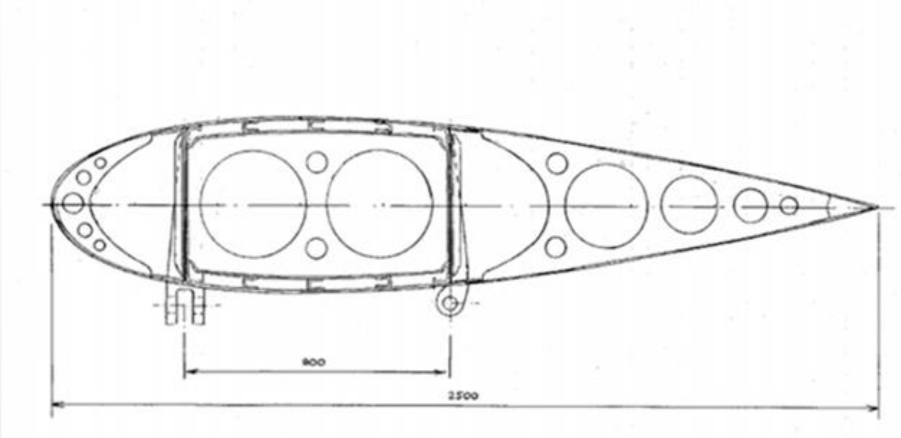
- Generator Output
  1. 2x 500 kW, 690 V
  2. synchronous with
  3. „Black start capability"
- Generator dimensions and weight

  each 0,75 m x 1,75 m @ 1,4 t
- Connection to grid

  Direct, as generator rpm is controlled to within 1,0% of the master grid-frequency allowing 50 or 60 Hz
- All components are housed in a climatized, hermetically sealed, tamper- and theft resistant 20 ft ISO container located at **ground** level



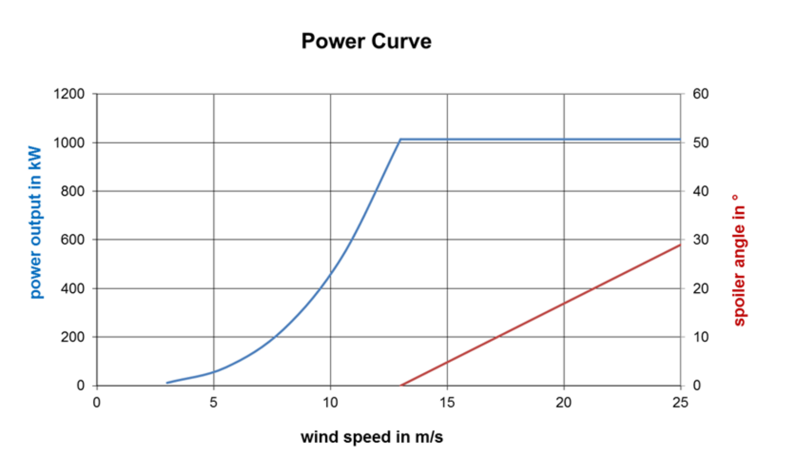
Technical Description - Numbers



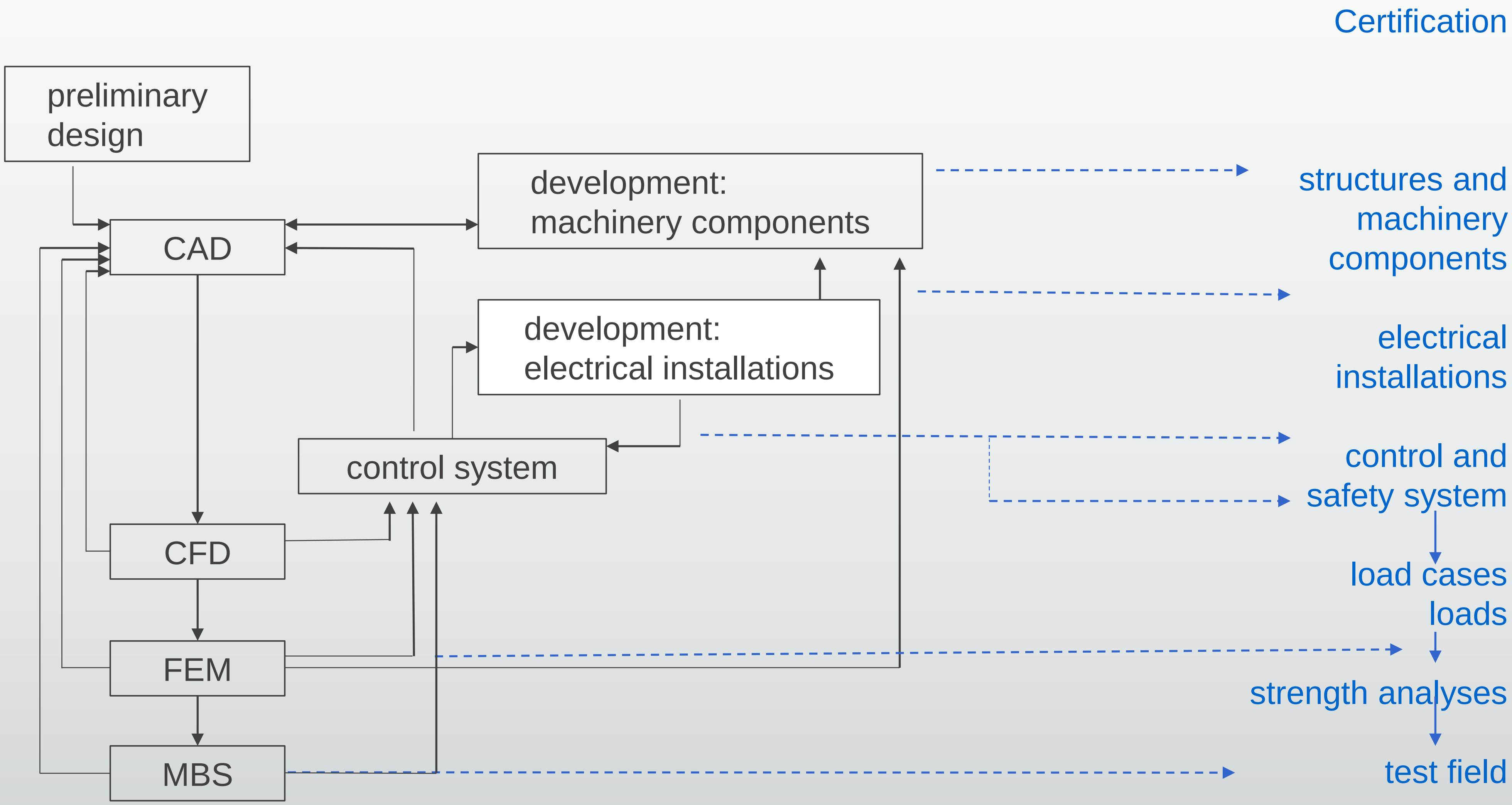
- Physical Dimensions
  1. Height overall 69 m
  2. Diameter 42 m
  3. Length of propulsion wings 39.5 m
  4. Depth of wing profile 2.5 m
- Performance Characteristics
  1. Rated power 1000 kW @ 13.5 m/s (@ 19.7 rpm)
  2. Kick-In wind speed 3.5 m/s
  3. Cut-Off wind speed 28.0 m/s
  4. Max rotational speed 25 rpm
- Materials
  1. Aluminum- / Steel-construction

Technical Description - Vertical Axis Wind Turbine (VAWT) Power-Curve

- The GS-1000NT® propulsion wing is equipped with a patented spoiler system, which enables operations even under very high wind speeds between13 m/s und 28 m/s, at constant rotational speed and torque.
- The control concept of the spoiler system leads to a higher power generation efficiency as well as high operational safety, in comparison to crudely stall regulated VAWT‘s.
- Two hydraulic-driven synchronous generators make the use of any trouble-causing gear boxes in the GS-1000NT® obsolete. The synchronous generators are housed in a container at ground level, accessible, easy to maintain and simple to transport.



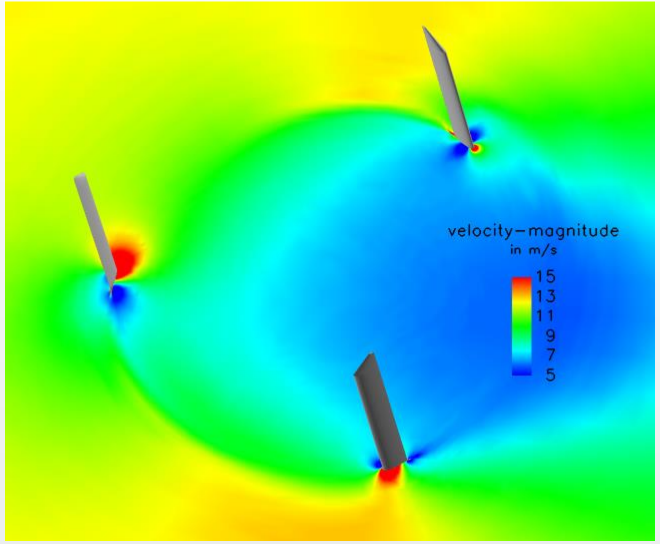
Development Insights

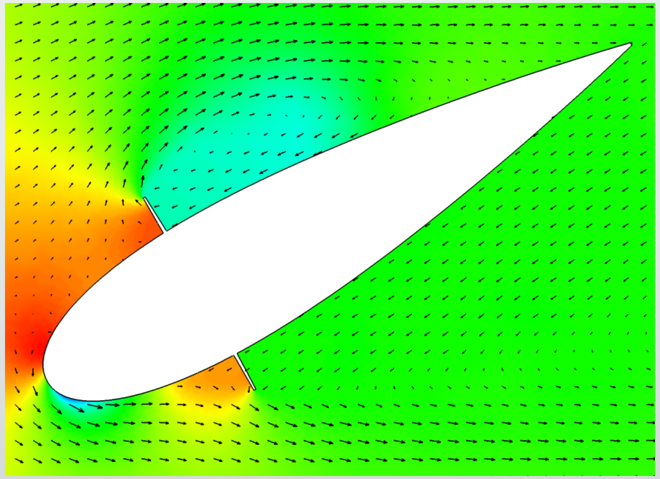


Development Insights – CFD Aerodynamics

The aerodynamic design and the calculation of the aerodynamic loads result from CFD simulations.

- development of the CFD model
  1. software validation → Fluent
  2. mesh validation → 2-dim mesh 60 T. cells / 3-dim mesh 3 Mio. Cells
- calculation of the performance characteristics
  1. aim: 1MW rated power
  2. rotor design optimization → Ø 42 m
     - design of the wing tips
  3. control system
     - spoiler control above 13 m/s wind speed
     - idling above 25 m/s wind speed
- calculation of the load cases
  1. input data for strength analyses →
  2. FEM load assumptions for the certification





Development Insights - FEM Strength Analysis

- Calculated load cases up to now

  all aerodynamic loads under normal and extreme wind conditions

- Results of the static analysis

	weight in t	units	total weight in t
Propulsion wings	3.0	3	9.0
Support arms	3.6	6	21.6
Rotor head	14.0	1	12.0
Main hydr. pump	4.5	1	4.5
Tower	85.0	1	85.0
total			132.1

	witout ice	partial ice	total ice
Rotation speed (rpm)	24	20	0
Rotation speed (rps)	0.400	0.333	0.000
First freq (Hz)	0.519	0.450	0.406

Development Insights - FEM Strength Analysis

- Calculated load cases up to now

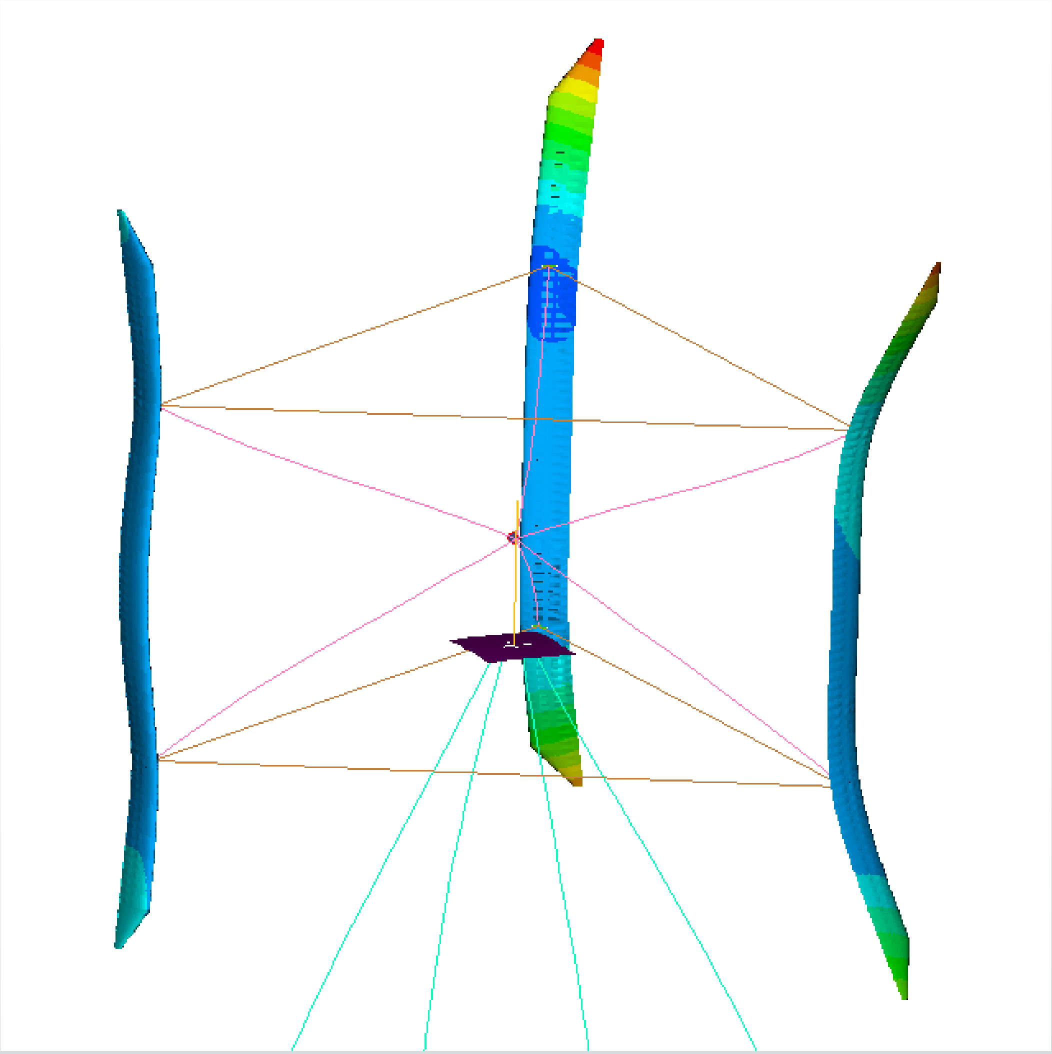
  all aerodynamic loads under normal and extreme wind conditions

- referred to Guidelines of the DNV-GL and TÜV-Süd
- Structure

  the following layouts have been examined during the conceptual design:

  1. Layout 1: Generator at the bottom; 4-leg tower
  2. Layout 2: Generator at the top; 4-leg tower
  3. Layout 3: Generator at the top; lattice frame tower

- Layout 3 gives the maximum structural integrity at lowest cost, only to be challenged by the new hydrostatic drive @ a mere 15% weight of the previous generator-solution.

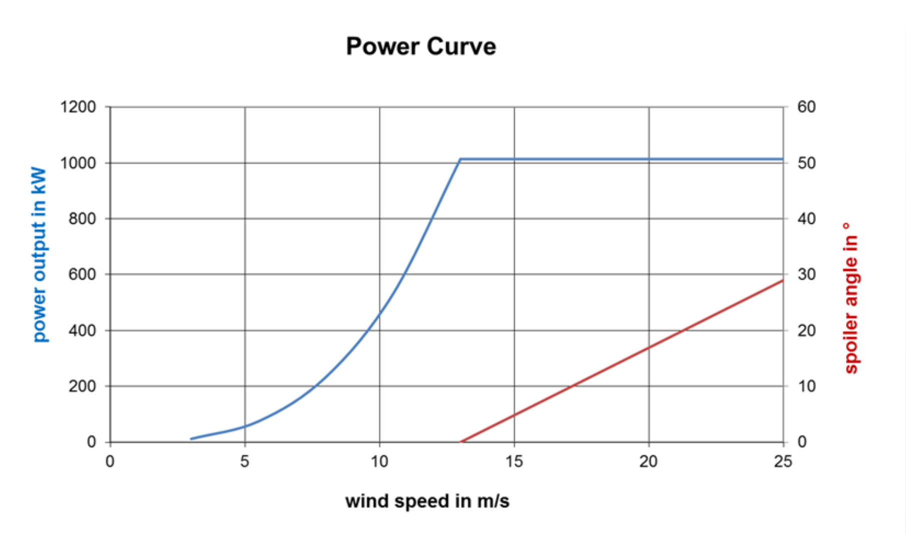


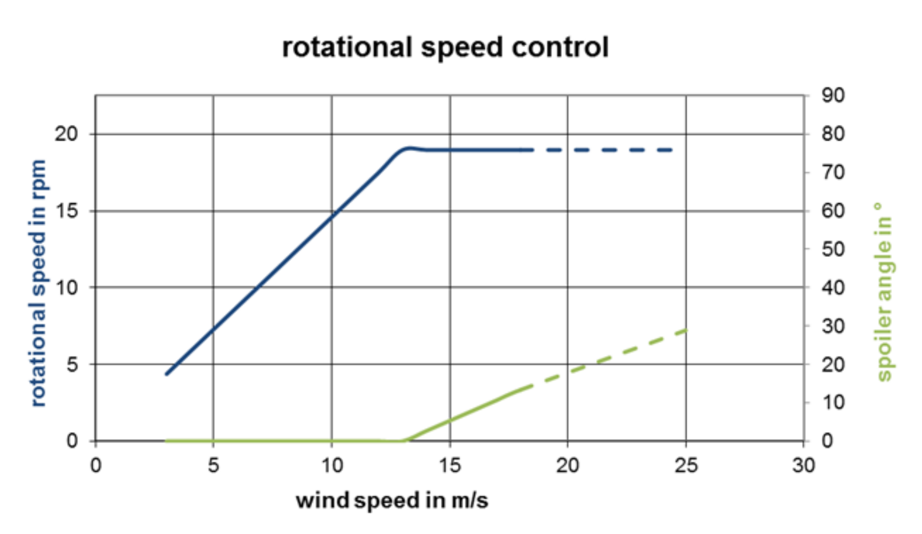
Development Insights - FEM Strength Analysis

- Power curve

  Generator and rotor characteristics are matched
- rotational speed control
  1. spoiler control is defined
- safety systems
  1. safety concept
  2. spoiler control
  3. hydrostatic drive
  4. mechanical brake w. locking device
- Fault conditions

  all relevant fault conditions are considered
- Design load cases are considered
- Control concept completed





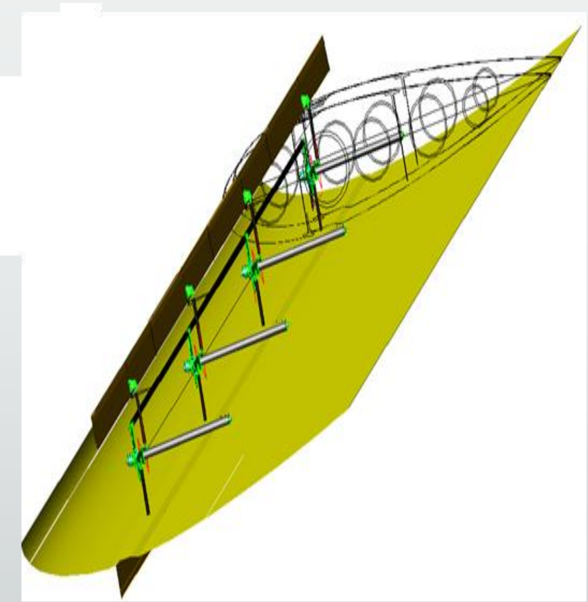
Development Insights - FEM Strength Analysis

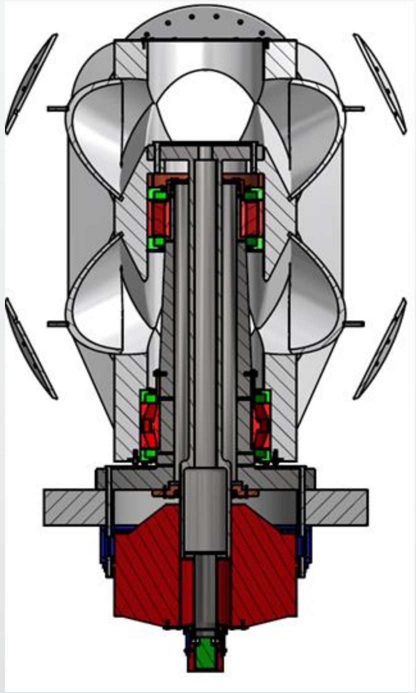
- Tower and foundation

  Lattice frame tower structure with patented maintenance-free connections will be used. For the pilot plant P1 the foundation belongs to the scope of supply.

- Rotor
  1. Propulsion wings: Aluminum
  2. Rotor arms: Steel
  3. „Flying Wires“: Steel
- Rotor hub: Steel
  1. rotor bearing unit integrated into the hub
- Spoiler
  1. The development of the spoiler system

     is completed and patented





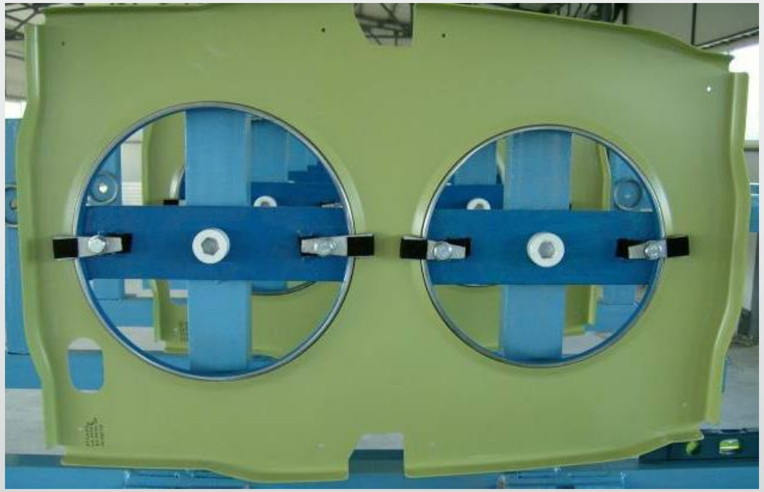
Hardware Impressions

- Top left:

  Heatable wing leading edge.

- Top right:

  Production of propulsion wings



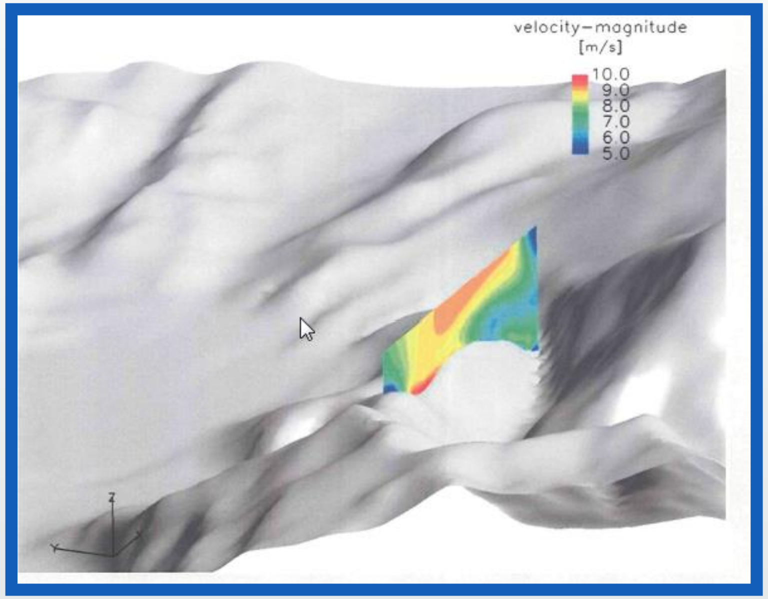
- Bottom left:

  Wing torsion box which will house control system components

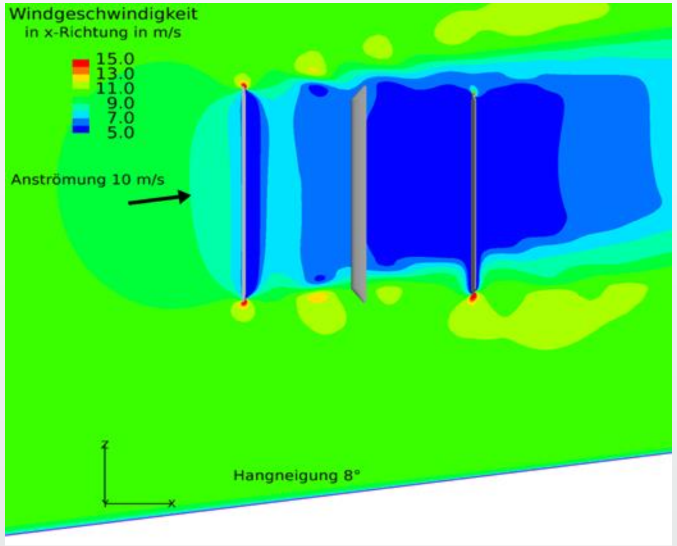
- Bottom right:

  Propulsion wing ready for skinning

Application in mountanous areas

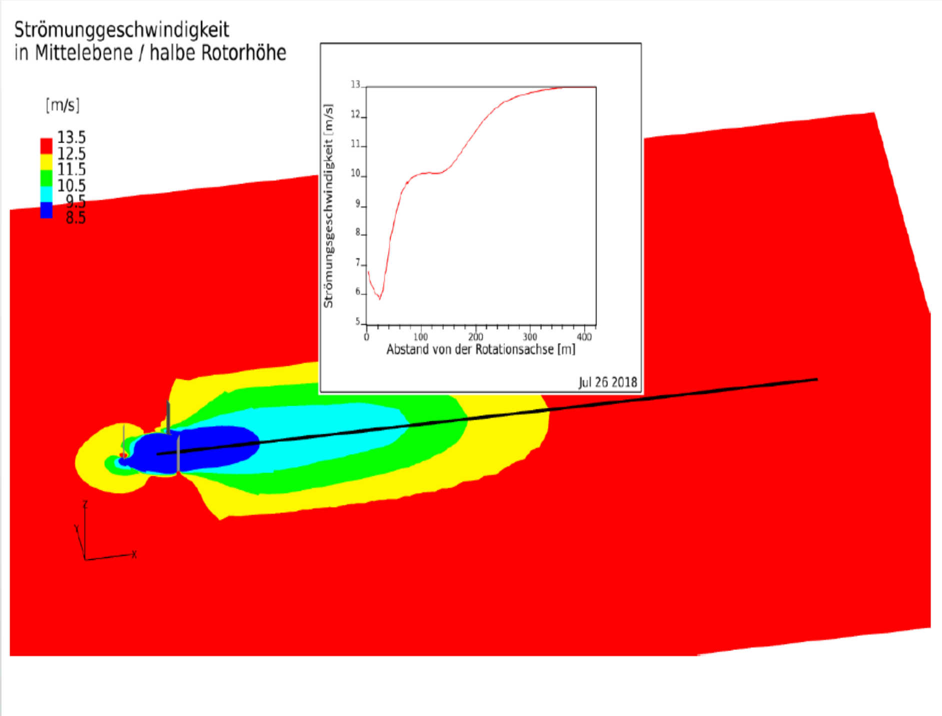


- An absolute no-go for conventional HAWT is the installation on mountain inclines, leading to angled airflow over the propellers and a dramatical loss of efficiency. However, GS-1000NT excels with an increase of harvested power!



Wake vortex

- **Flow mechanical evaluation of the wake of the VAWT GS-1000NT. CFD Consultants GmbH performed past intensive studies on aero dynamics of the VAWT GS-1000NT. Among other things, a three-dimensional simulation model of the rotor was developed and researched for various rotational- and wind speed. As a result, for each load case the complete, temporary variable flow fields are calculated and analyzed in the space around the rotor. Hence the decrease of the wake pattern of the plant has been fully assessed.**
- According to current knowledge, it is most pronounced upon reaching rated wind speed.
- In the figure below, the upper half of the rotor is shown in gray. The colored layer is located in the plane of the rotor. The wind flows from the left parallel to the x-axis with 13,0m/s on the system. The system rotates with 20RPM in clockwise direction according to the energy extraction from the wind and slowed flow velocity. The two-dimensional diagram shows the wind speed behind the rotor along the black line. The zero point is located in the axis of the rotor, the end point at x=420m at ten times the rotor diameters. Measurable vortexes are at a distance of three rotor diameters approximately 3m/s or 23%, five rotor diameters down-stream about 1,5m/s or 12% and ten rotor diameters behind the system no trailing vortexes can be found.



Management - Team

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Seit 01.10.2019

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Development Schedule

With secured financing, the required hardware will be purchased and along with strong industrial partners the pilot installation will be completed at the end of the 3rd quarter of 2020. In parallel, the C-Design Assessment (provisional certification) will be pursued in cooperation with DNV-GL.