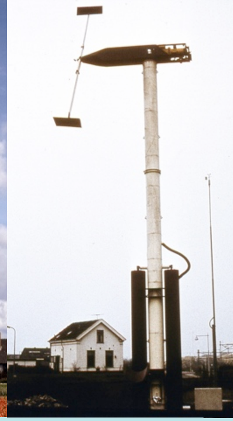
SET Analysis

Jos Beurskens

Former ECN Wind Energy

The modern History of Wind Energy in the Netherlands


40 years Wind Energy at TU-Delft

7 December 2016

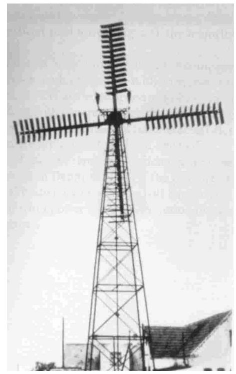
This presentation

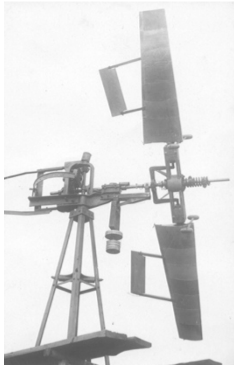
- Focus on the Netherlands and its surroundings
- Focus on technology (not on policy, market, economics)
- Lessons learned & lessons forgotten

Four distinct periods of wind energy development

Discontinuous operation
Mechanical output

Continuous operation
Electricity generation





1. Classical period

Classical windmills for mechanical driven applications.
>100.000 windmills in NW Europe.
Period ends because of steam engine and abundant wood and coal.

600-1890

2. Electricity producing wind turbines appear

Appearance of electricity as a public energy source triggers the use of wind mills as an additional generation option.
Basic aerodynamics.
Period ends because of cheap oil.

1890-1930

3. First innovation period

Need for rural electrification and energy shortage during WW II triggers new developments. Advanced aerodynamics. Period ends because of cheap gas and oil.

1930-1960

4. Second innovation and commercialisation period

Energy and environmental crisis in combination with technological development cause commercial break through.

1975-present

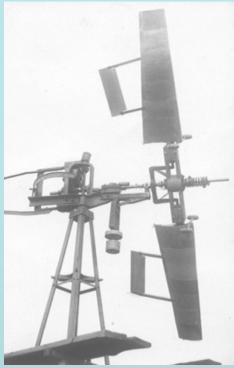
* Limits to Growth
* Oil Crisis

Periods 1 and 4 successful

The modern era (4)

Fundamental innovations in:

- Germany
- UK
- France
- Denmark
- USA
- USSR
- …….
- ~~NL~~



3. First innovation period

Need for rural electrification and energy shortage during WW II triggers new developments. Advanced aerodynamics. Period ends because of cheap gas and oil.

1930-1960

4. Second innovation and commercialisation period

Energy and environmental crisis in combination with technological development cause commercial break through.

1975-present

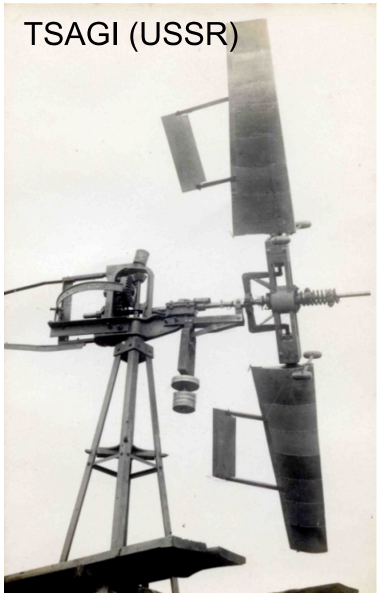
Early innovations (3)

Gedser (DK)

Grandpa’s Knob (USA)

Lykkegaard (DK)

Allgaier (D)

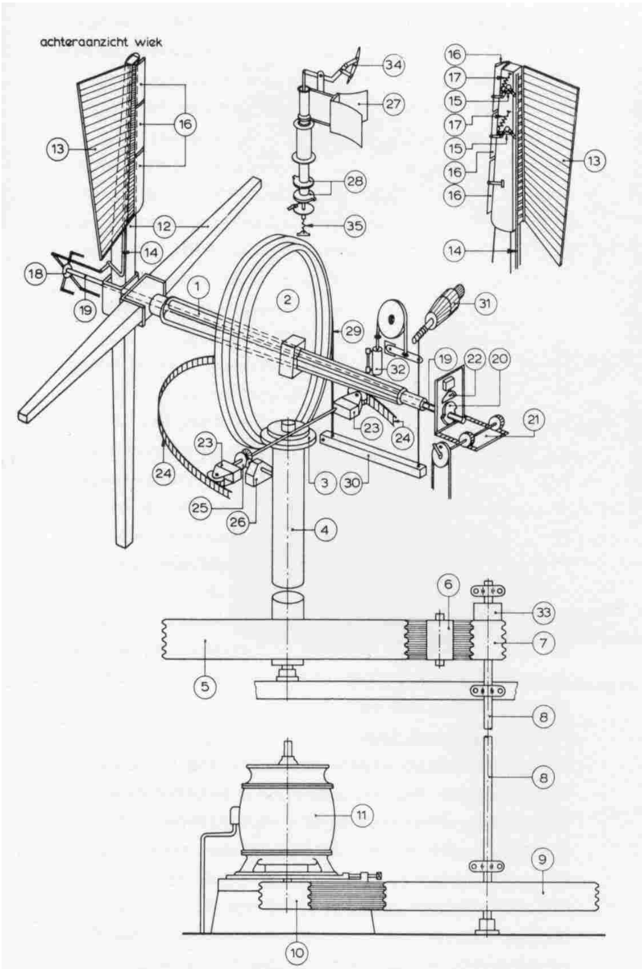


TSAGI (USSR)

Krim (USSR)

What the Netherlands did in period 3

De Traanroeier, Texel



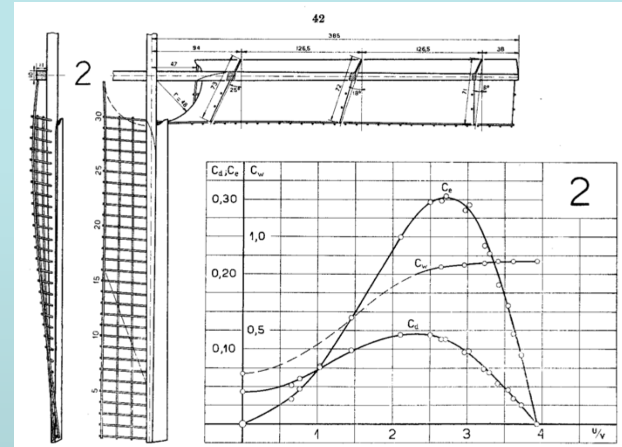


Fig. 4. Teekening van het model n°. 2 en graphische voorstelling van de gegevens der tabellen 6 en 7.

A. Havinga 1932

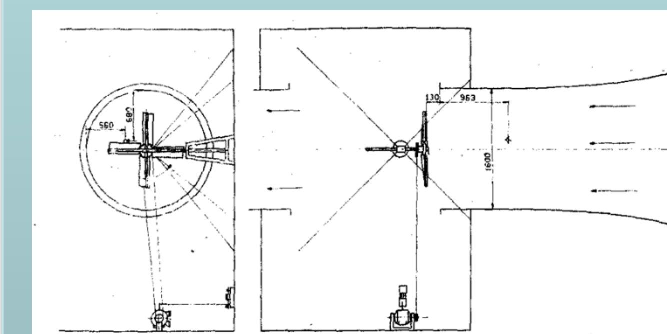


Fig. 1. Meet-inrichting. Het molen-model drijft met een snaar een meet-dynamo aan, welke buiten den luchtstroom is opgesteld. De plaats van den windsnelheidsmeter is in de figuur aangegeven.

A. Von Baumhauer1932

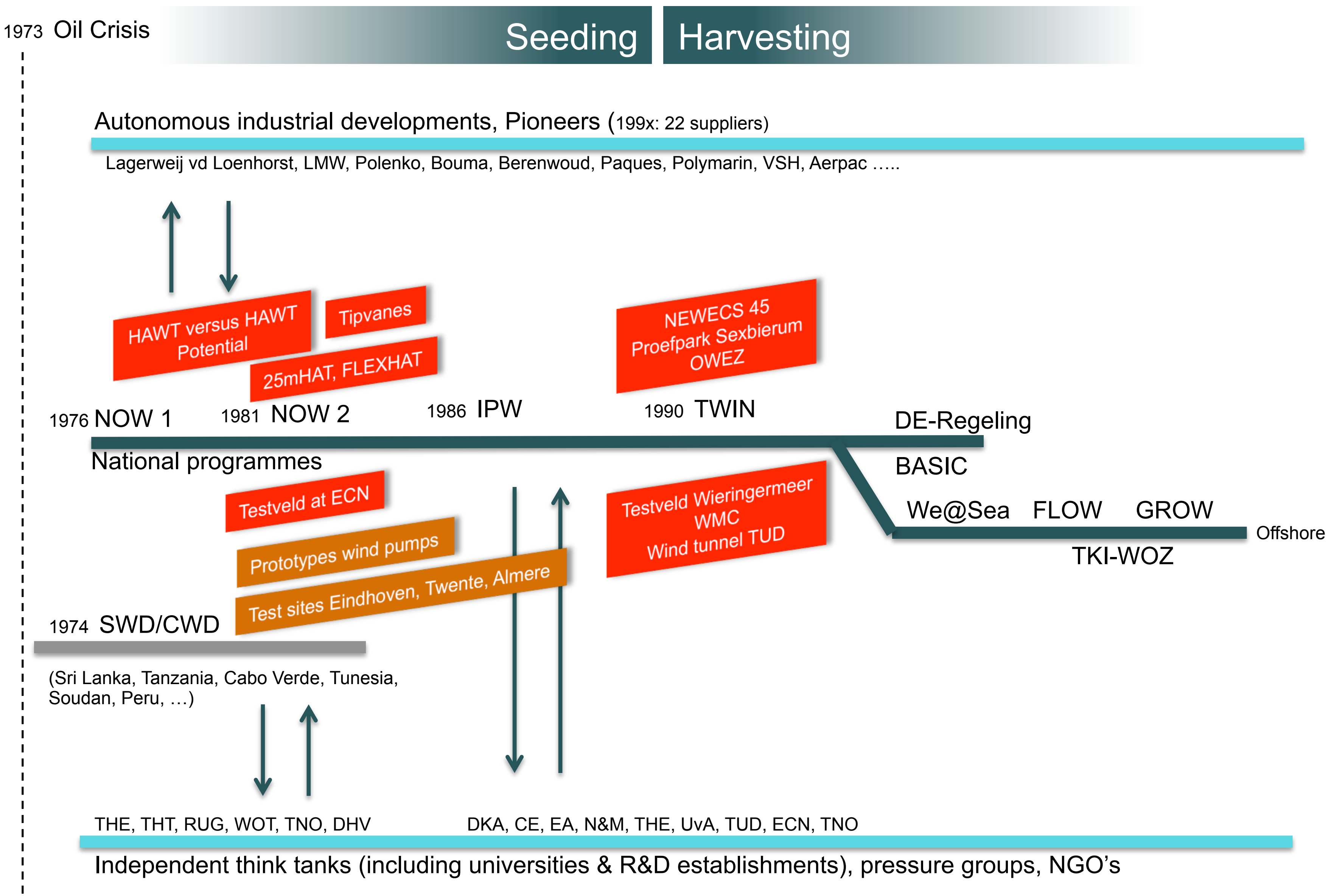
Conversion of traditional windmills for electricity generation was a failure

Fresh but difficult start of modern wind energy

Some countries started from scretch during the 1970's:

- Italy
- Netherlands
- Japan
- …….

Timeline of Dutch wind energy developments after 1973



Typical features of Dutch wind energy developments

time

- Potential both on- and offshore
- Integration of large scale wind in national grid
- Which technology: HAWT or VAWT?
- Technology development: R&D, Demo

- Development of supply side of the market (WERK)
- Demo's to develop demand side of market

- Integration of implementation, R&D, industrialisation
- Market incentives to stimulate demand
- Offshore, integrated approach

Developments in the Netherlands: intensive international interactions

Netherlands full partner from beginning in both LS and R&D programmes

- IEA (OECD established after Oil Crisis)
- EC (JOULE, Thermie, FP5, ….., Horizon 2010)
- EWEA
- IMTS
- MEASNET
- EUREC
- EAWE (European Academy for WE)
- Later: TP Wind > ETIP, EERA (*), EWEA > WindEurope

Some pioneers

De Kleine Aarde (Boxtel)

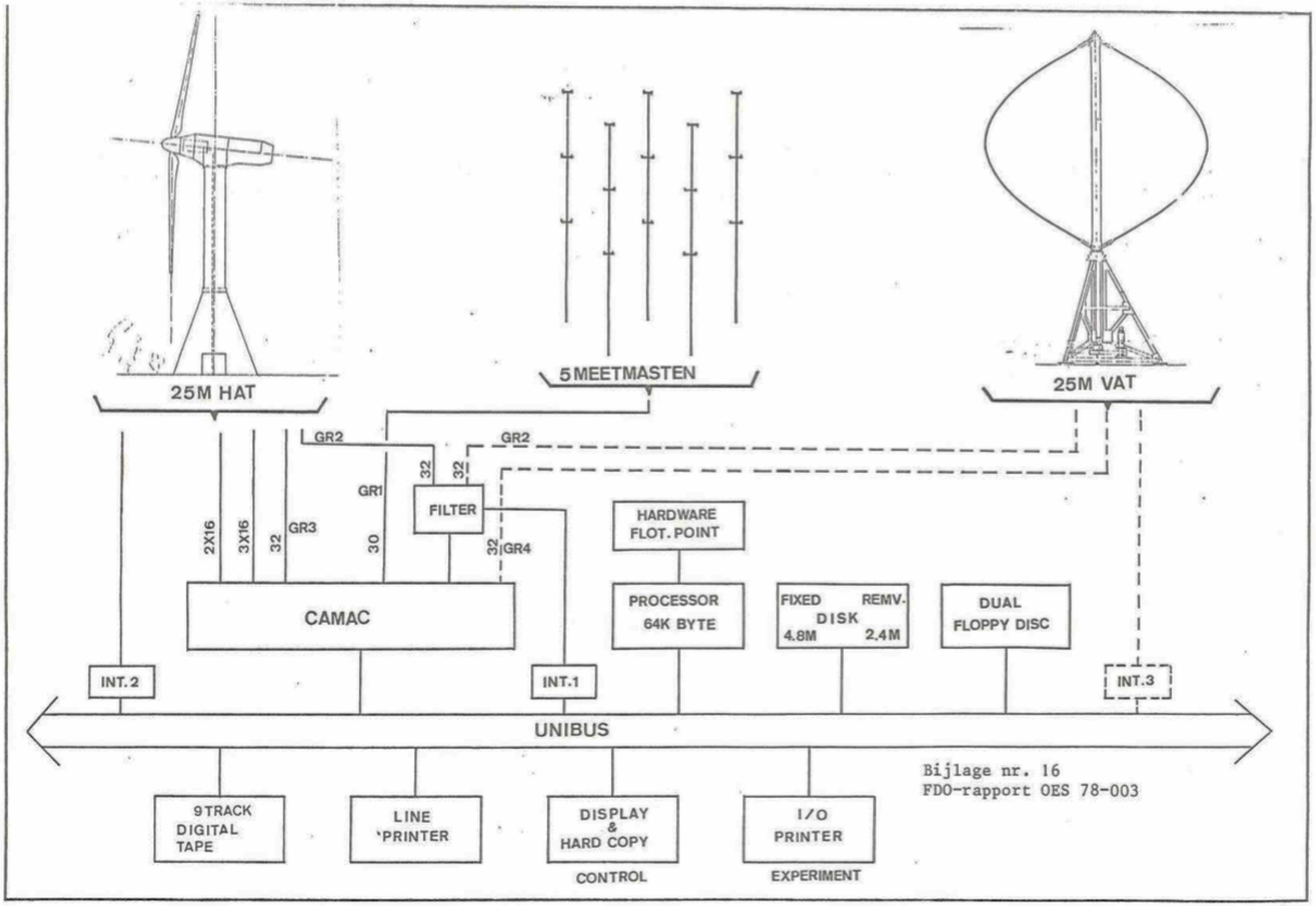
Sloten, Amsterdam
Chris Westra, Roel van Duin, e.a.

Fons de Beer

Henk Lagerweij

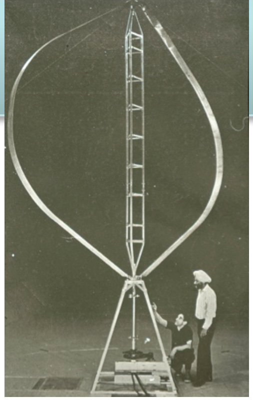
THE: Adri Kragten

HAWT versus VAWT

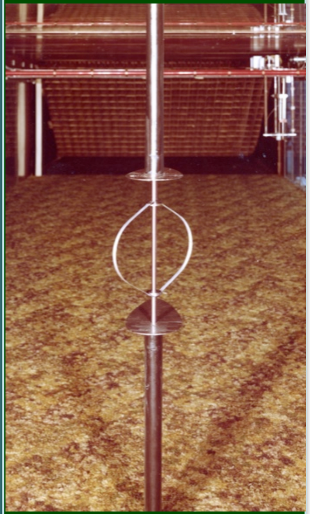


Schema verwerking meetgegevens.

Early VAWT developments of the Netherlands



CTI-TNO



0.2 m Ø

Fokker-VFW Schiphol Airport

ECN

5.6 m Ø

NLR

5.6 m Ø. 3 bladed

NLR

LAPAN Indonesia

15 m Ø. Pioneer I

Time line 25mHAT experiments

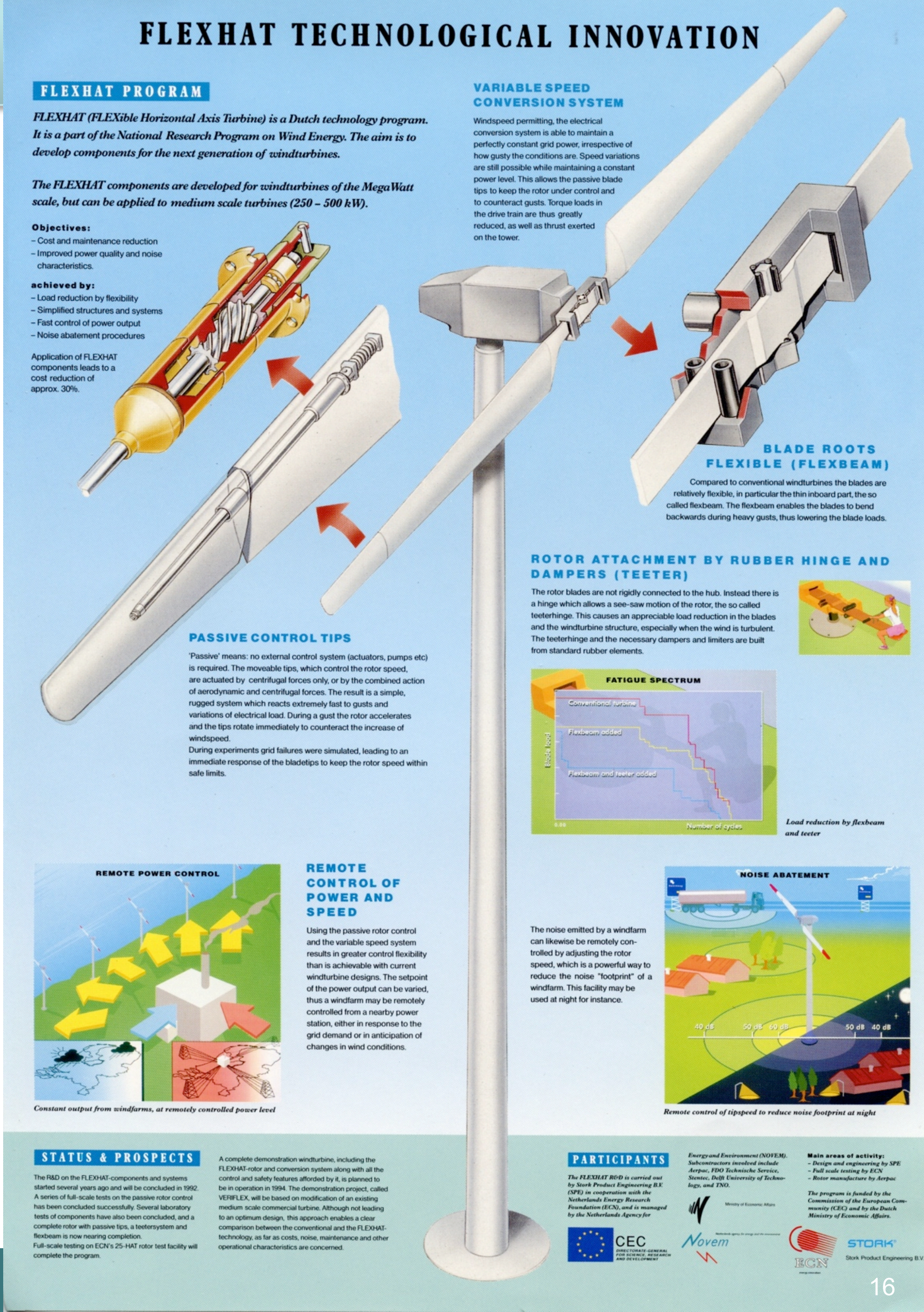
- 04-1981 — First rotation
- 03-1983 — Boundary layer measurements by THDelft
- 05-1983 — Measurements of radar cross section by dr. Neher Lab, PTT
- 06-1984 — Big overhaul

- 09-1987 — Directional acoustic measurements with Syntacan, TNO-TPD
- 09-1988 — Testing of Stork VSH-20-WPX-THR blades with braking tips
- 07-1989 — Installation of FLEXHAT 20-WPX-PRT1 blades, tip1 ←
- 10-1989 — Testing of FLEXHAT blades ←
- 10-1991 — Testing of FLEXTEETER hub ←
- 03-1992 — Testing of FLEXTEETER rotor ←
- 08-1994 — Dismantling hub for mounting VERA-HAT blades
- 11-1995 — Start VERA-HAT measurements
- 07-1998 — Decision decommissioning 25mHAT becomes a monument!

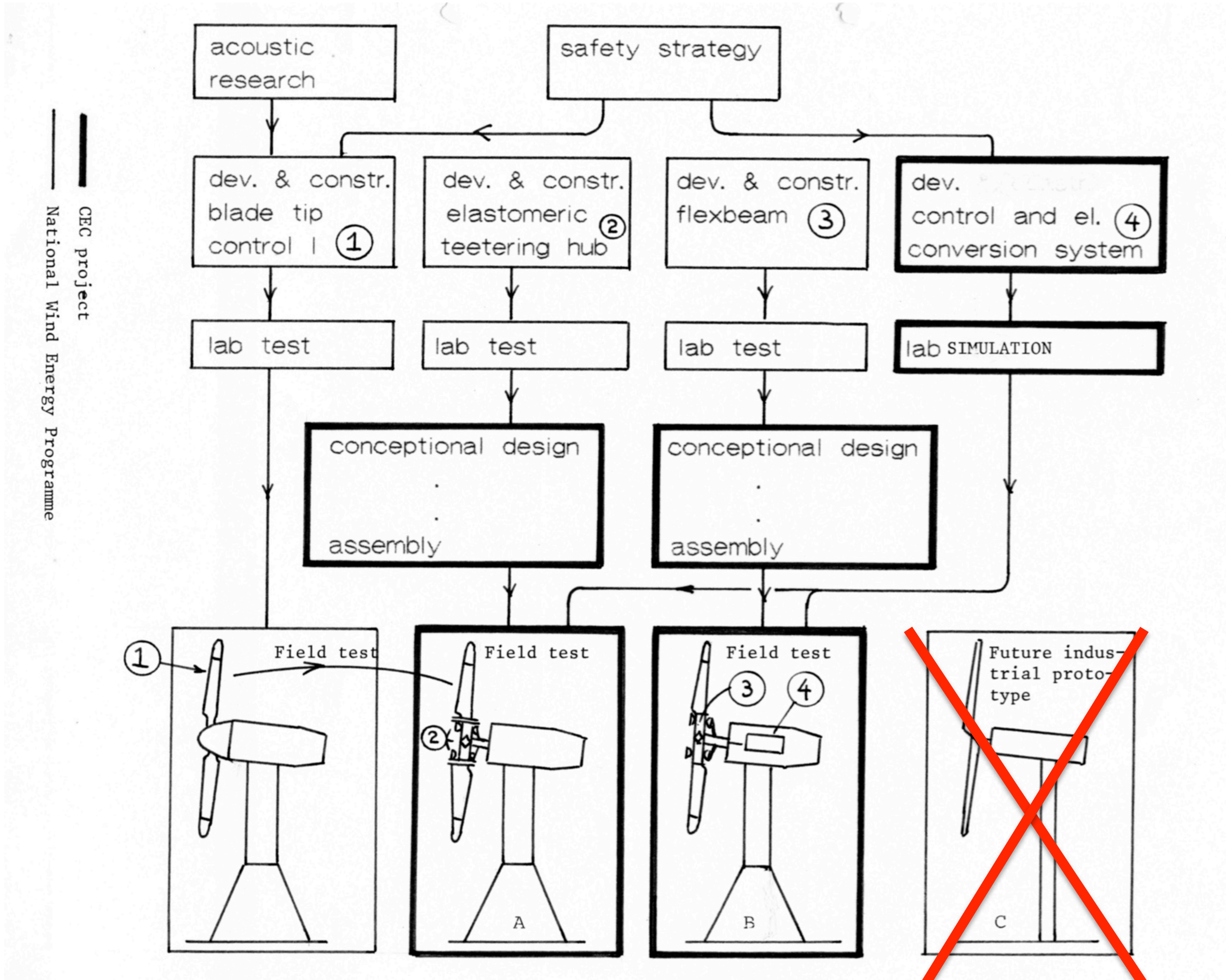
Advanced concepts

The FLEXHAT concept

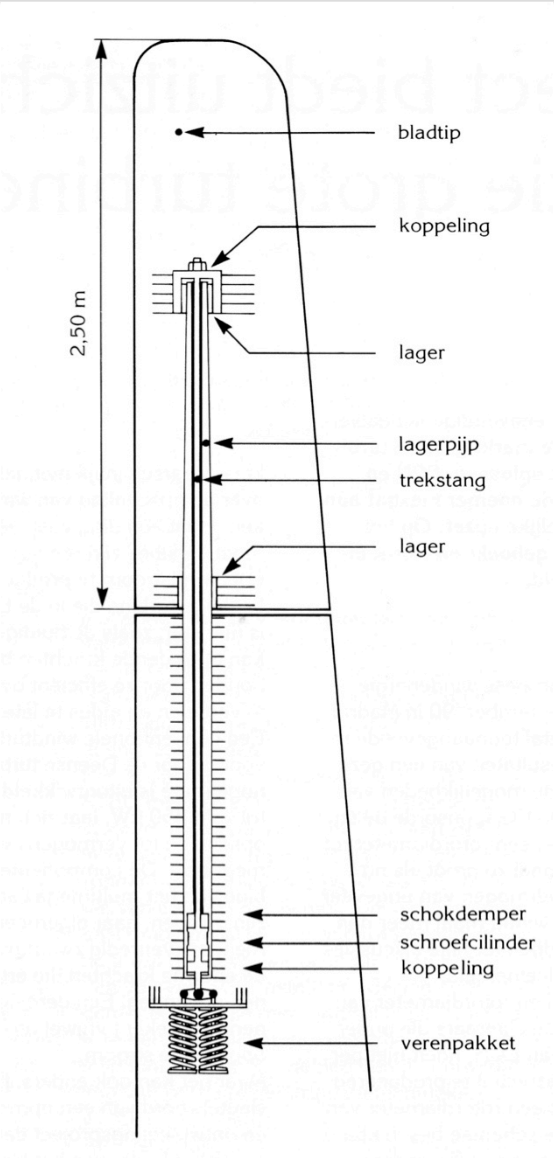
- Higher tip speed ratio:
  2 blades
- Flexible hub
- Passive partial blade control
- Power electronic converters allowing variable rotational speed
  (25mHAT, Lagerweij were the first!)



The FLEXHAT programme

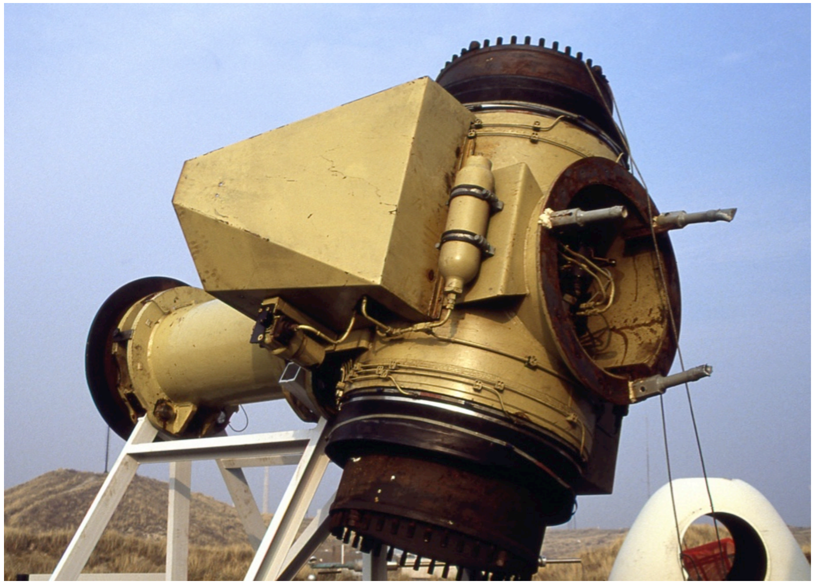


FLEXHAT: Testing of Stork VSH-20-WPX-PRT1 blades with passively controlling flaps at the blade tips



FLEXHAT: Testing of Stork VSH-20-WPX-PRT1 blades with passively controlling flaps at the blade tips

FLEXHAT: Testing of FLEXTEETER rotor

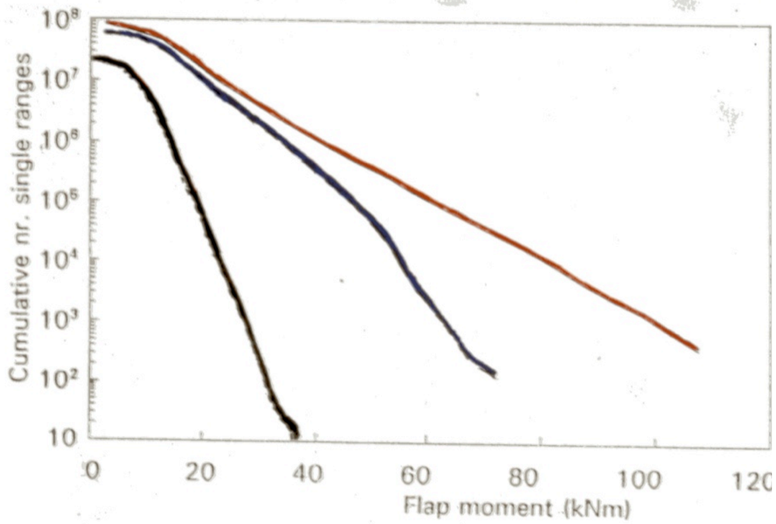





Results of FLEXTEETER experiments

Experimental results:

cumulative load spectra of blade root flap moment



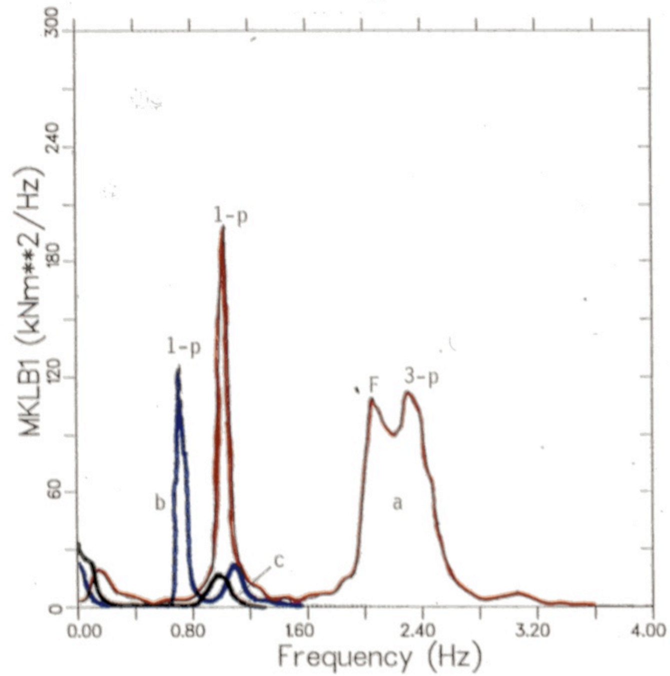
red: rigid hub, stall

blue: Flexteeter in stall, fixed rpm

green: Flexteeter, tip control, variable rpm

Experimental results:

power spectral density of blade root flap moment



red: rigid hub, stall

blue: Flexteeter in stall, fixed rpm

green: Flexteeter, tip control, variable rpm

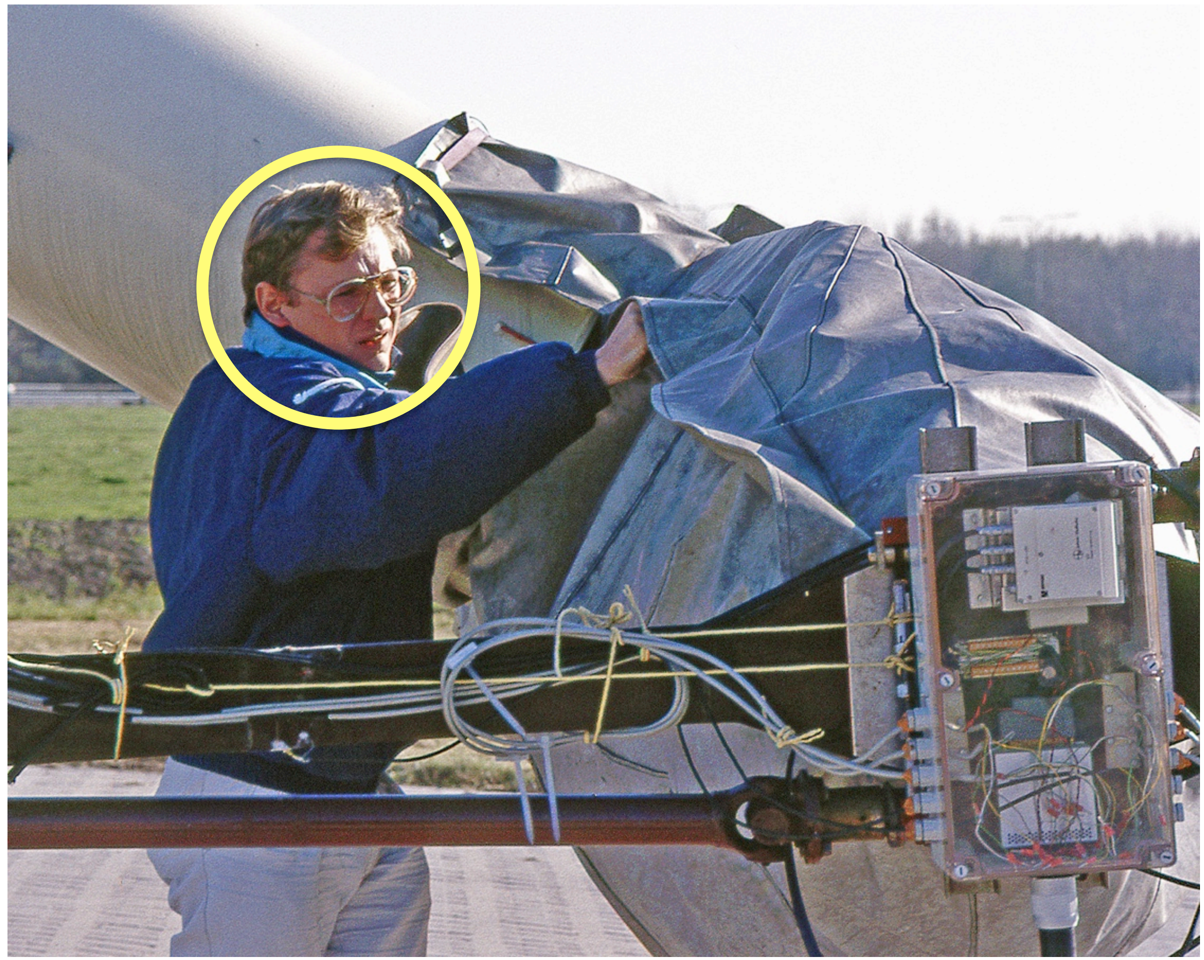
Flexibility & Passive Blade pitch control

Lagerweij vd Loenhorst (NL)

Berewoud KET

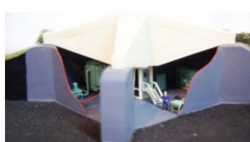
FLEXCON

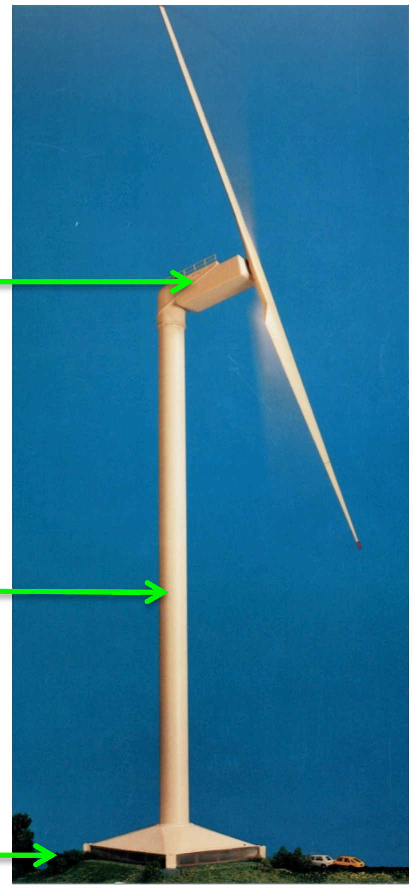
Flexibility & Passive Blade pitch control

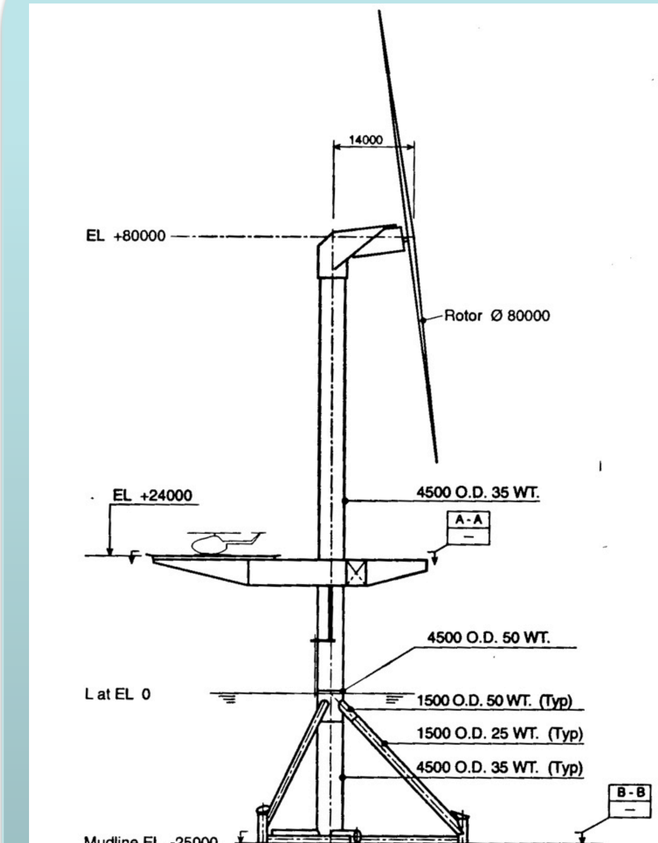


Spin-offs of FLEXHAT research

FLEXHAT → GROHAT concept



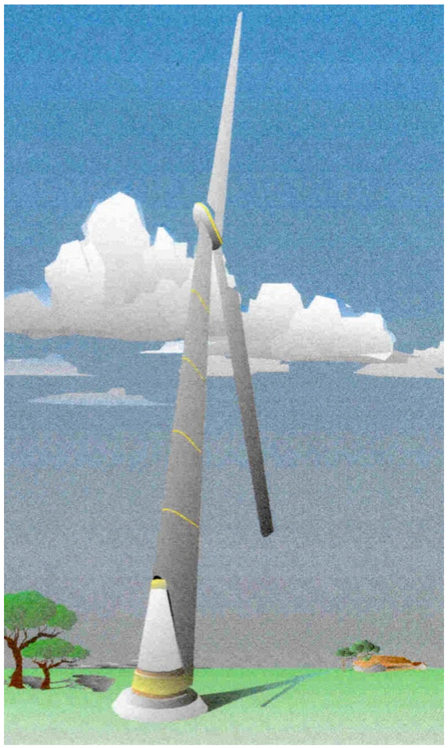




NL contribution to IEA, Annex VII, 1978 -1980

Spin-offs of FLEXHAT research

Ultimate WT

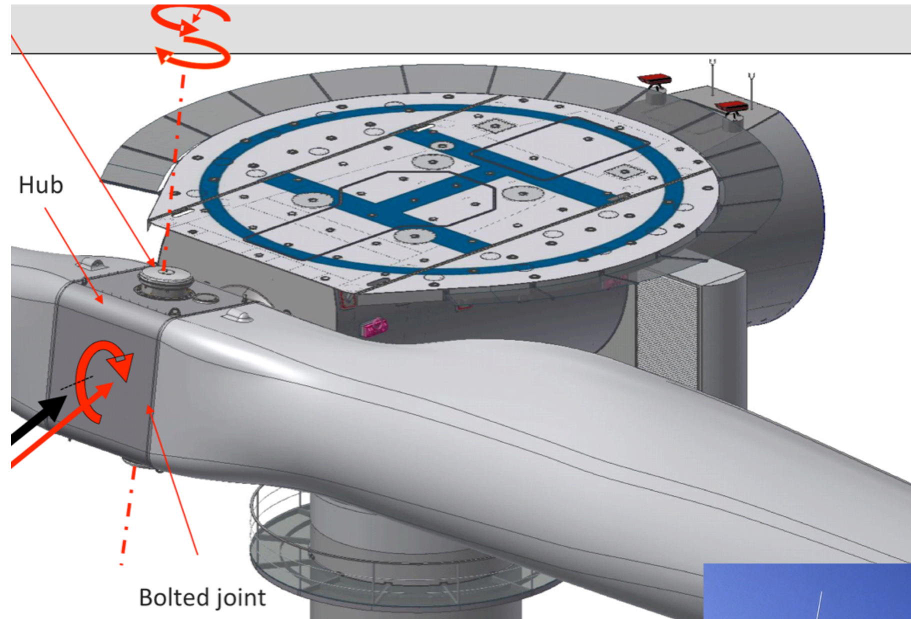


Full flexible rotor configuration
Down wind
Aerodynamically shaped tower

2BENERGY

Rigid hub
Down wind
Active stall

SEAWIND



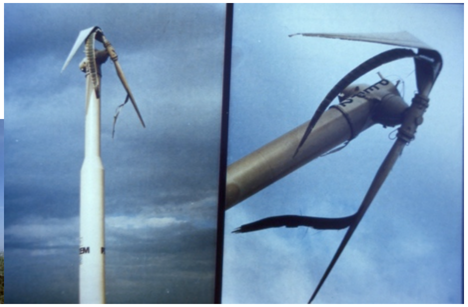
Teetering hub
Replaceable elastomeric bumpers
Up wind
Power control by yaw

Gamma 60 (1992-1997)

More 25mHAT spin-offs

Commercial version for Sexbierum experimental wind farm

PEP series (Schiedam, Vlissingen, Curaçao)



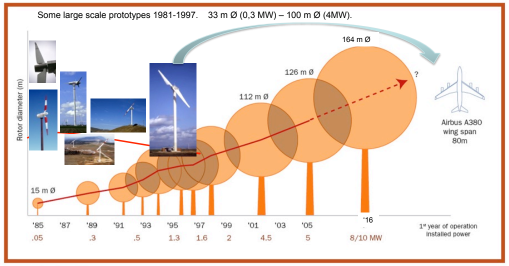
NEWECS 45, Medemblik

NEWECS 55

Up scaling

Up scaling


Lagerwey

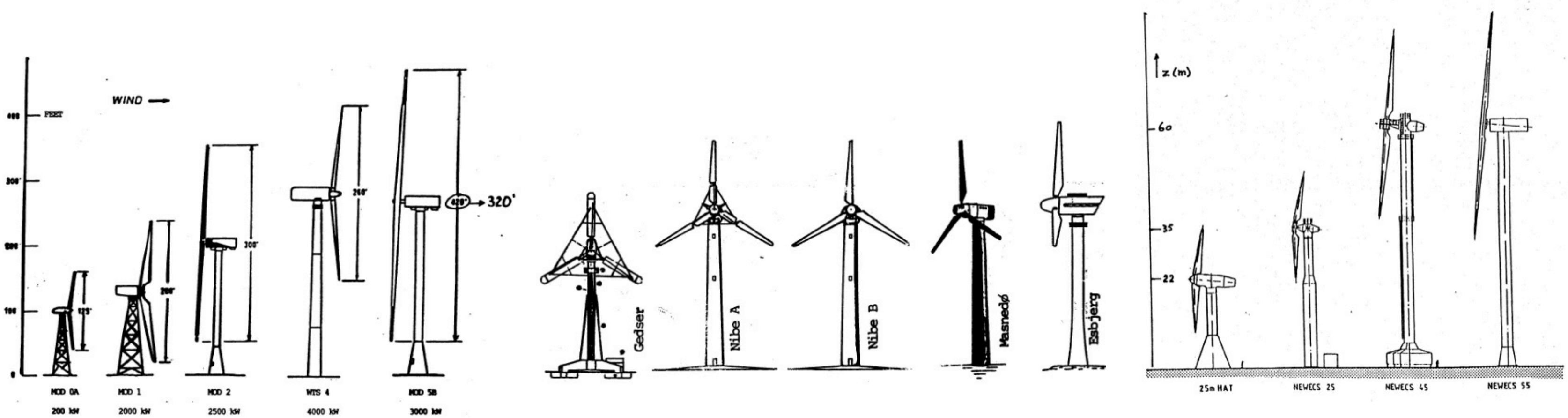

Some large scale prototypes 1981-1997. 33 m Ø (0,3 MW) – 100 m Ø (4MW).
Rotor diameter (m)
15 m Ø
112 m Ø
126 m Ø
164 m Ø
?
Airbus A380 wing span 80m
'85 '87 '89 '91 '93 '95 '97 '99 '01 '03 '05 '16
.05 .3 .5 1.3 1.6 2 4.5 5 8/10 MW
1st year of operation
installed power


Stork NEWECS 45


Lagerwey

Up scaling

Experimental turbines resulting from government programmes



USA | DK | NL

Up scaling: Early offshore designs

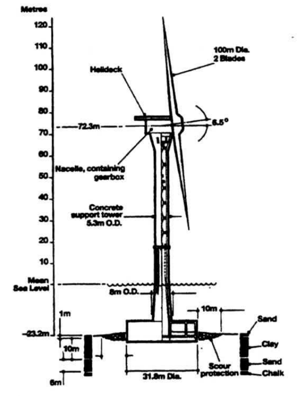


Figure 1a. British 100m/6MW wind turbine [1]

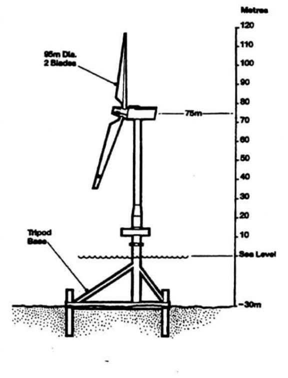


Figure 1b. Swedish 95m/5MW wind turbine [1]

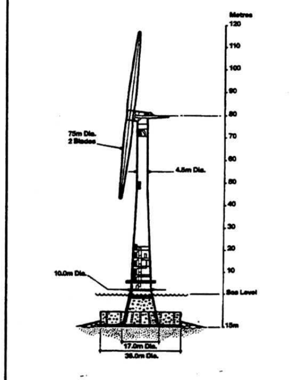


Figure 1c. Swedish 75m/4MW wind turbine [1]

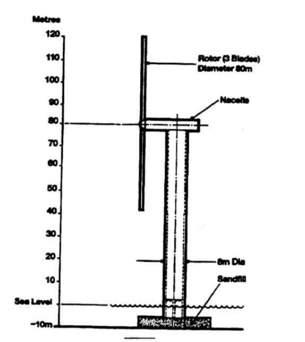


Figure 1d. Danish 75m/3MW wind turbine [1]

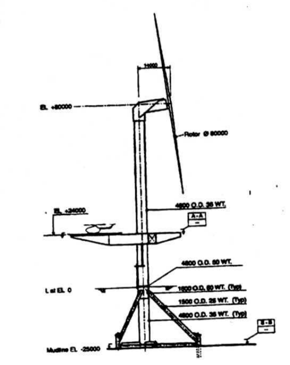


Figure 1e. Dutch 80m/6.5MW wind turbine [2]

- Researched since 1973
- NL, DK, S, GB, USA (IEA)
- Wide range of issues studied
  (resource, foundations, loads, machine concepts, transportation, installation, logistics, economics)
- Offshore industry invlved from beginning

Blades

Netherlands's industry initiated development and manufacturing of blades

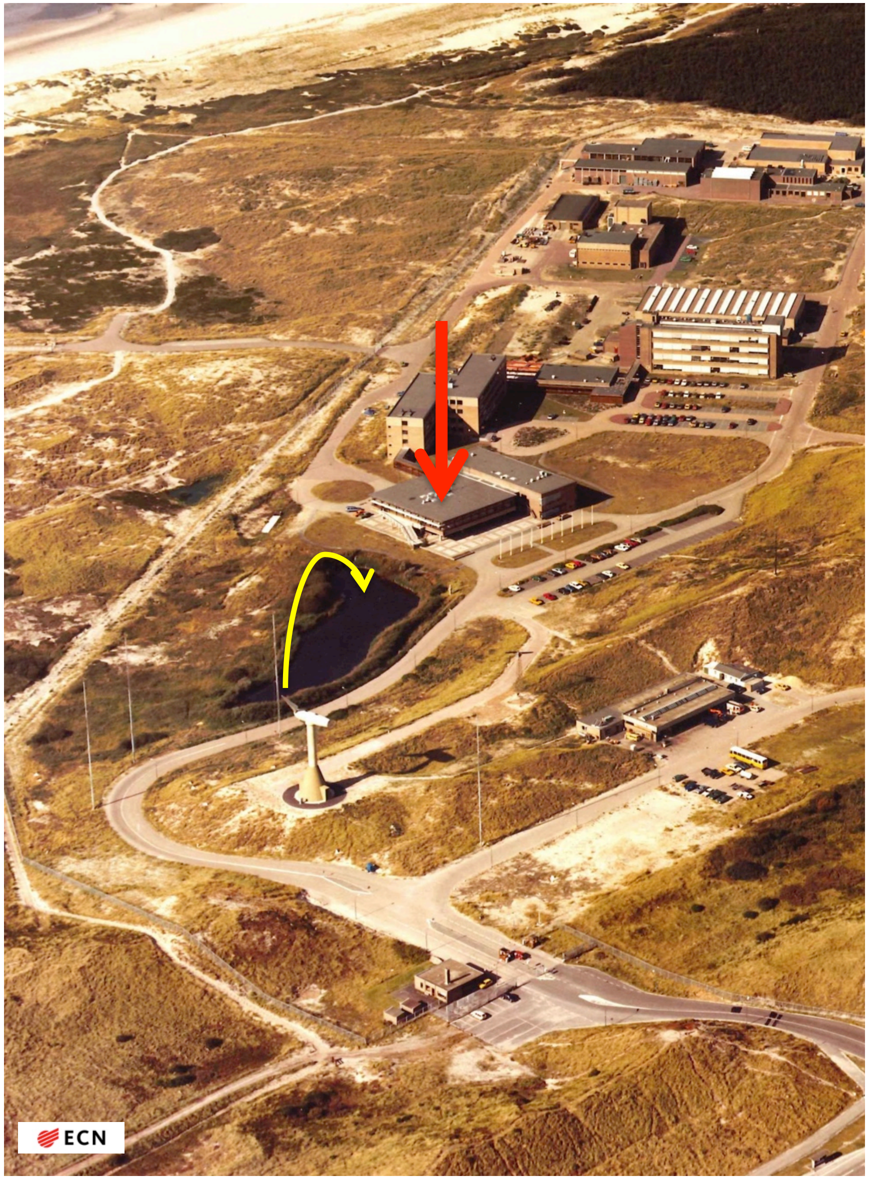
Polymarin

Bouma > LM / GE

VSH

Lagerweij van de Loenhorst

Testing of Stork VSH-20-WPX-THR blades with braking tips



Blade structural testing facilities

ECN

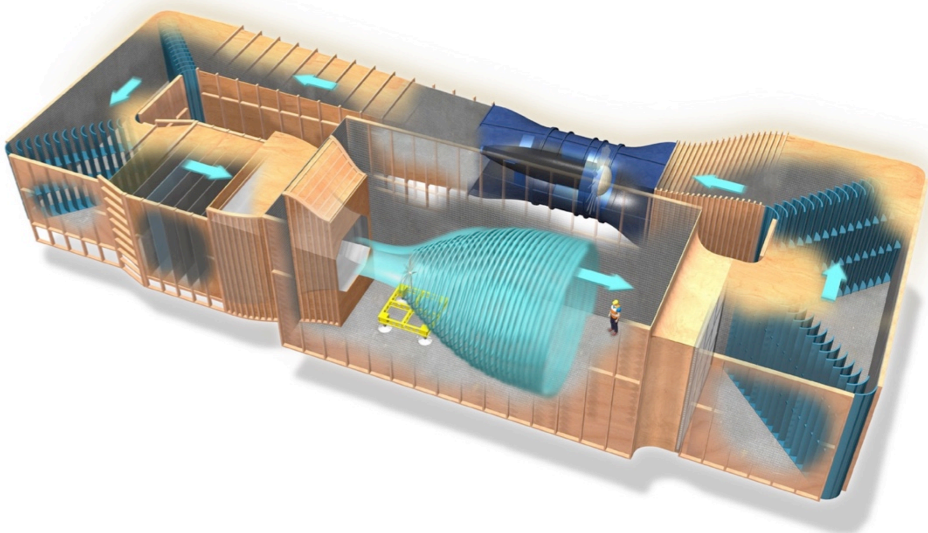
TUDelft

WMC

Wieringermeer (10-09-2002)

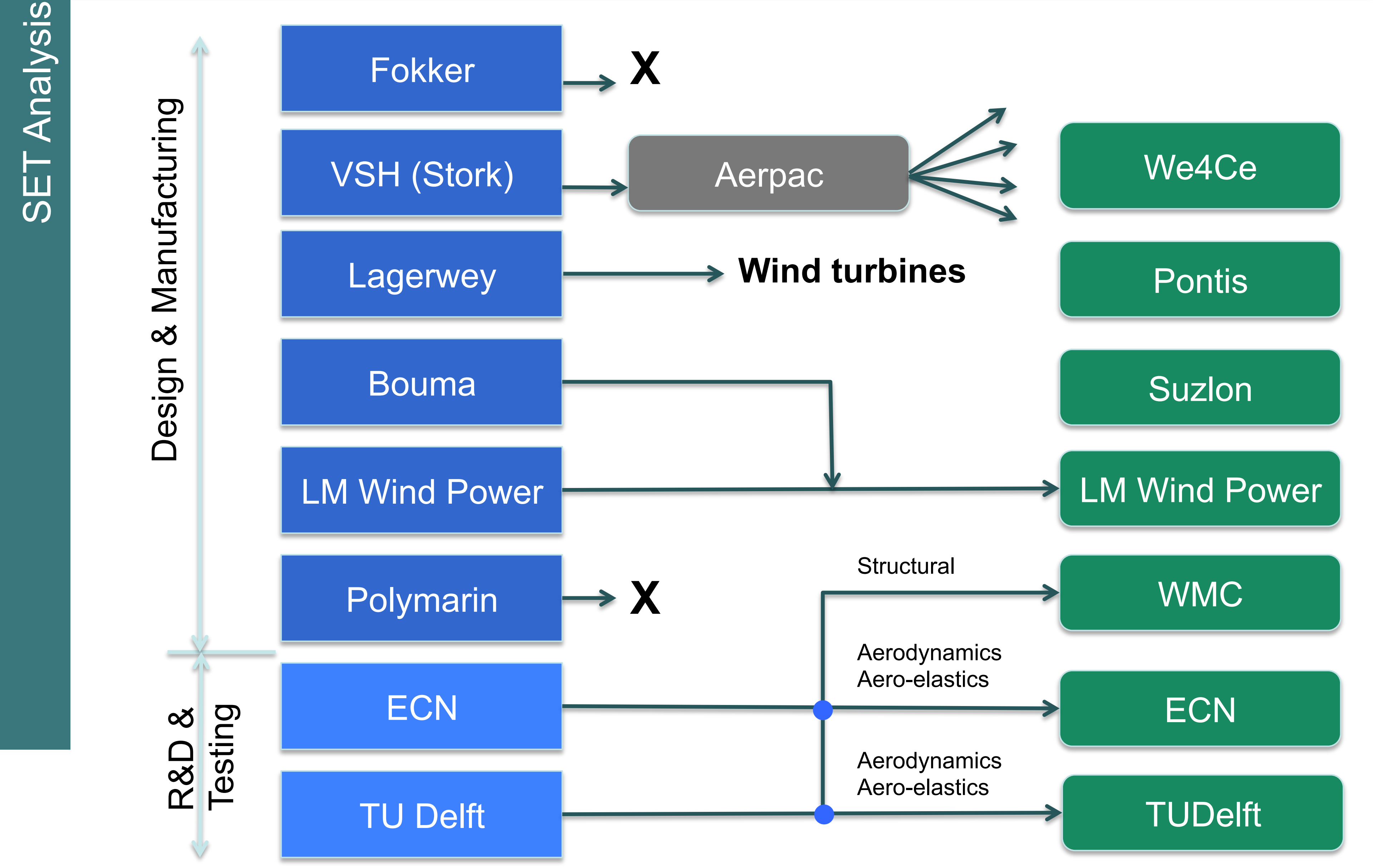
Wind tunnel: aerodynamic and aero-elastic design

TNO-CWD tunnel



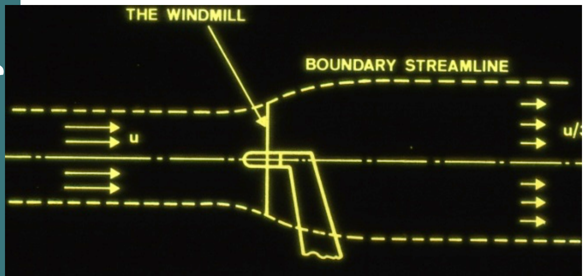
OJF- TUDelft

Blade technology spin-offs

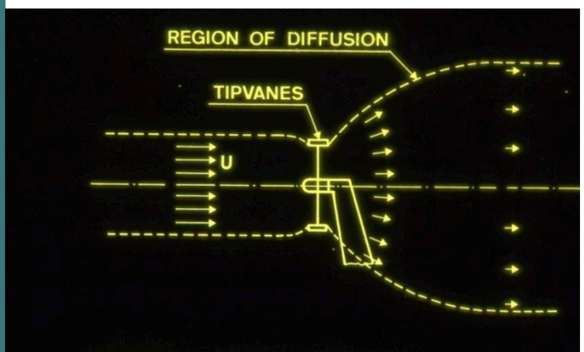


Tip vanes

Concentrating flow in rotor disc: tip vane research

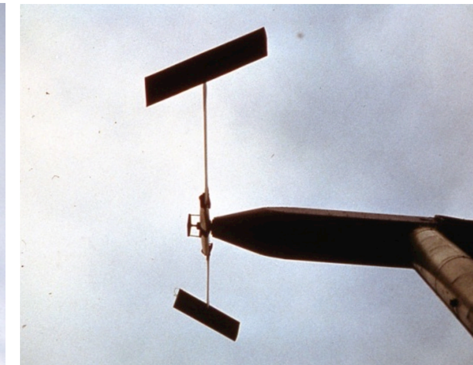


Conventional wind turbine



Wind turbine with diffuser or tip vanes

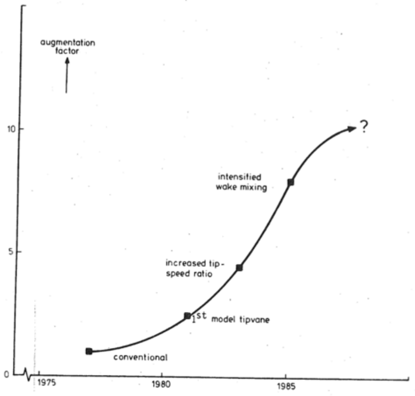
Theo van Holten



Concentrator concepts

Concentrating flow in rotor disc: tip vane research

Tip vane test facility at EA, Hook of Holland

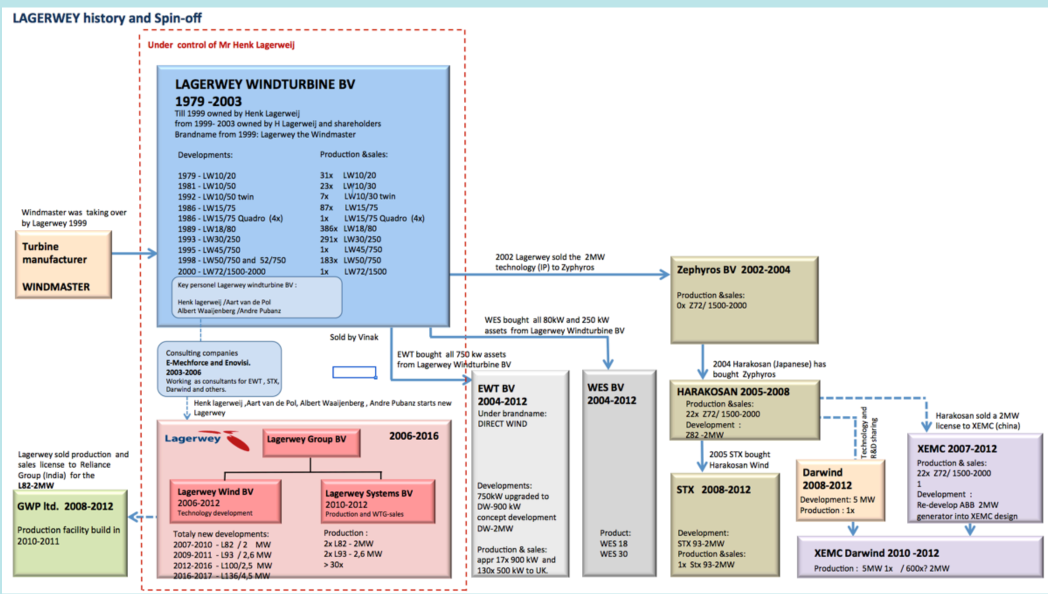


Concluding remarks

Spin-offs and innovations

VSH: Aerpac, etc.

Lagerweij: 11 enterprises



The nucleus of WE break through

In 80's, > 80% of wind turbine sales were of the "Danish concept".
At present > 90% have variable speed and advanced (blade pitch) control.

How comes?

It is the IGBT stupid!

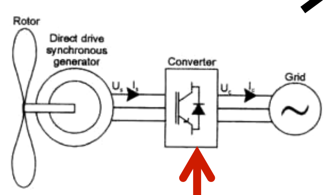
The nucleus of WE break through

Power Quality
no harmonic distortion,
reduction flicker,
adjustable reactive power,
limited inrush currents,
power output control

Variable Rotational Speed
load matching,
reduction mechanical loads,
blade pitch control

Direct Drive Conversion
no gear box
other types of generators possible
(copper multi-pole, pm, HTS)

IGBT's



More Control Parameters
active vibration damper
multi parameter control
safety

Non Grid Connected Operation
AWDS
desalination
refregeration

Up scaling
(indirectly)

Lessons forgotten

- Dramatic fatigue load reduction potential of fully flexible rotor (hub) configurations
- Passive blade power control

Focus of the Netherlands in the past and at present

- Rotor, including blades
- System engineering
- Offshore engineering
- Wind turbine concepts

Not addressed:

- Other non conventional concepts (multi rotor)
- Field rotor aerodynamics at ECN and TUD
- Decentralised test projects (proefprojecten)
- Aerodynamic & aero-elastic modelling
- Test stations (ECN, TUD, Flevo)
- Control engineering
- Autonomous systems
- Offshore technology
- O&M research
- One-bladers

Thank you for your attention!

Gratulations to Gerard!

Good by and see you soon Gijs!