



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

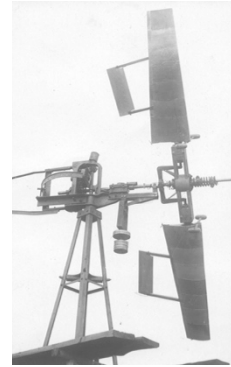
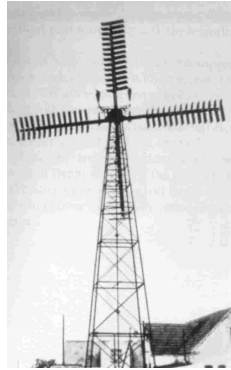
This presentation

- 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

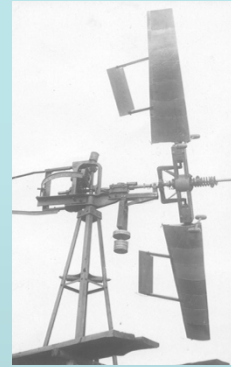
Periods 1 and 4 successful

* Limits to Growth
* Oil Crisis

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)



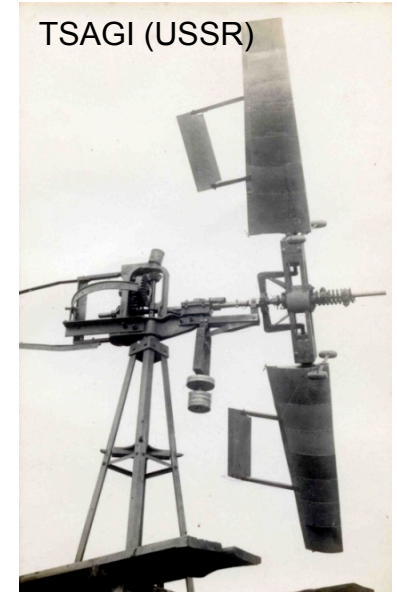
Grandpa's Knob (USA)



Lykkegaard (DK)



Allgaier (D)



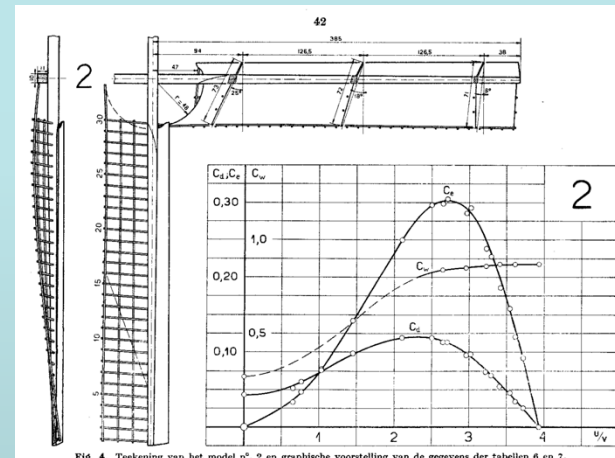
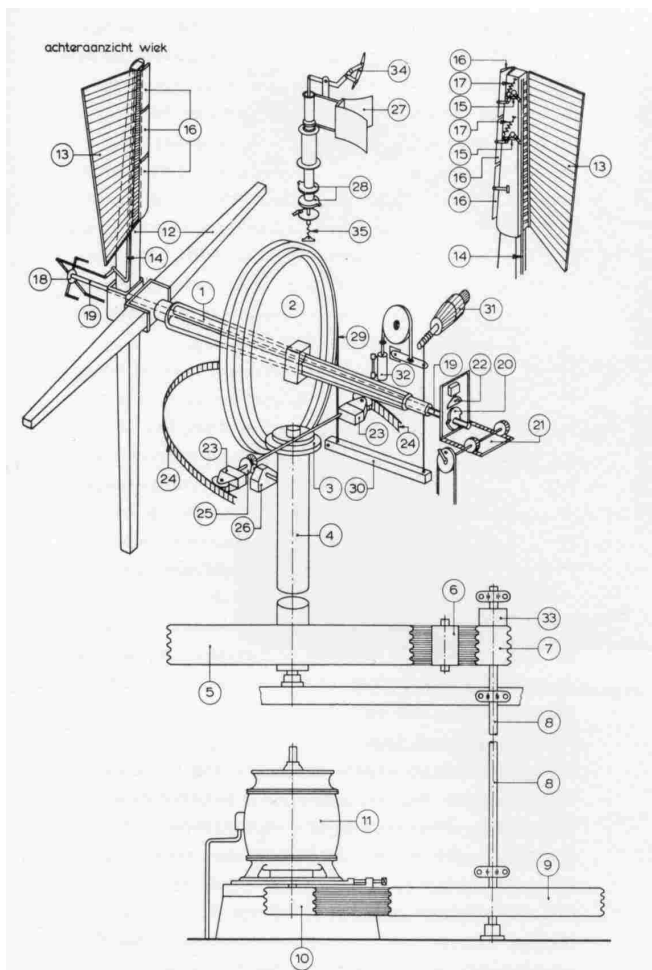
TSAGI (USSR)



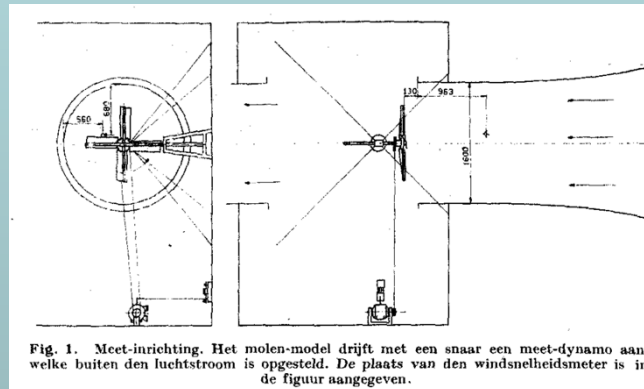
Krim (USSR)

What the Netherlands did in period 3

De Traanroeier, Texel



A. Haviga 1932



A. Von Baumhauer 1932

Conversion of traditional windmills for electricity generation was a failure

Fresh but difficult start of modern wind energy

Some countries started from scratch during the 1970's:

- Italy
- Netherlands
- Japan
-

Timeline of Dutch wind energy developments after 1973

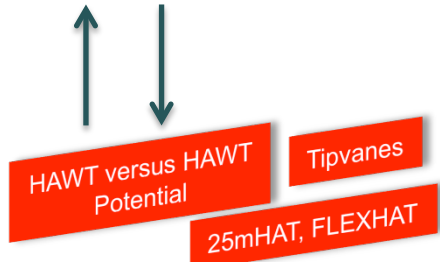
1973 Oil Crisis

Seeding

Harvesting

Autonomous industrial developments, Pioneers (199x: 22 suppliers)

Lagerweij vd Loenhorst, LMW, Polenko, Bouma, Berenwoud, Paques, Polymarin, VSH, Aerpac



1976 NOW 1

1981 NOW 2

1986 IPW

1990 TWIN

DE-Regeling

National programmes



BASIC

We@Sea FLOW GROW

TKI-WOZ

Offshore

1974 SWD/CWD

(Sri Lanka, Tanzania, Cabo Verde, Tunesia, Soudan, Peru, ...)

THE, THT, RUG, WOT, TNO, DHV

DKA, CE, EA, N&M, THE, UvA, TUD, ECN, TNO

Independent think tanks (including universities & R&D establishments), pressure groups, NGO's

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

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



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



Fons de Beer



De Kleine Aarde (Boxtel)

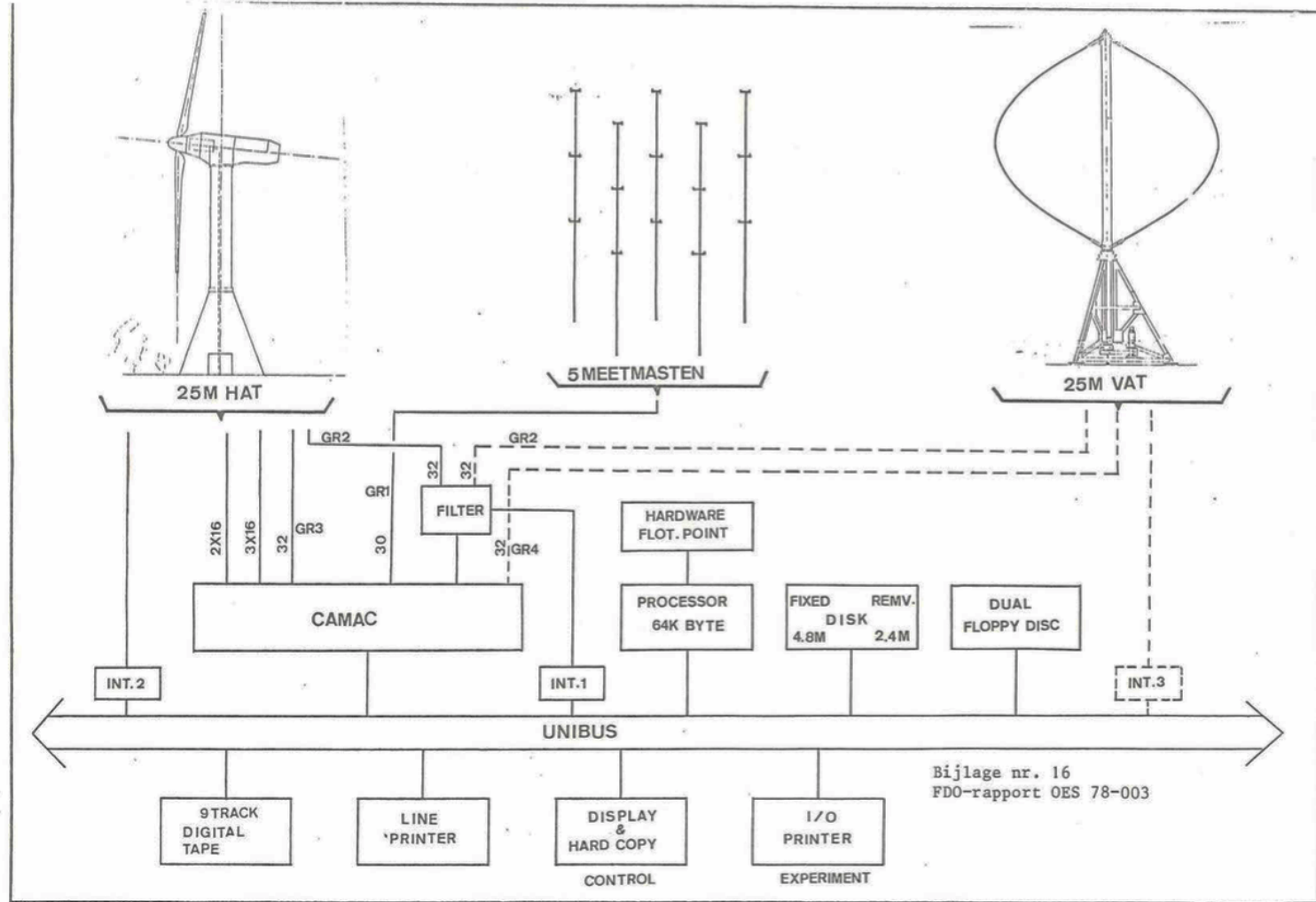


Henk Lagerweij



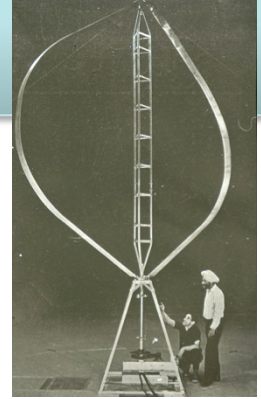
THE: Adri Kragten

HAWT versus VAWT

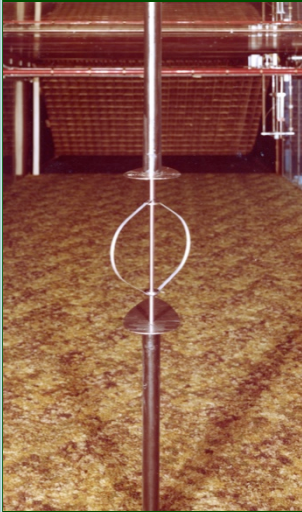


Schema verwerking meetgegevens.

Early VAWT developments of the Netherlands



CTI-TNO



0.2 m Ø

Fokker-VFW Schiphol Airport

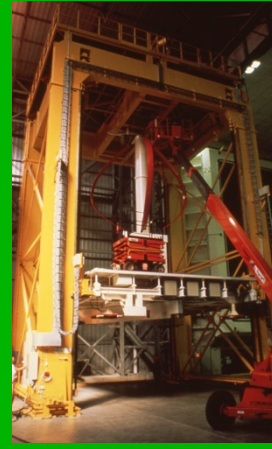


ECN



5.6 m Ø

NLR



5.6 m Ø. 3 bladed

NLR

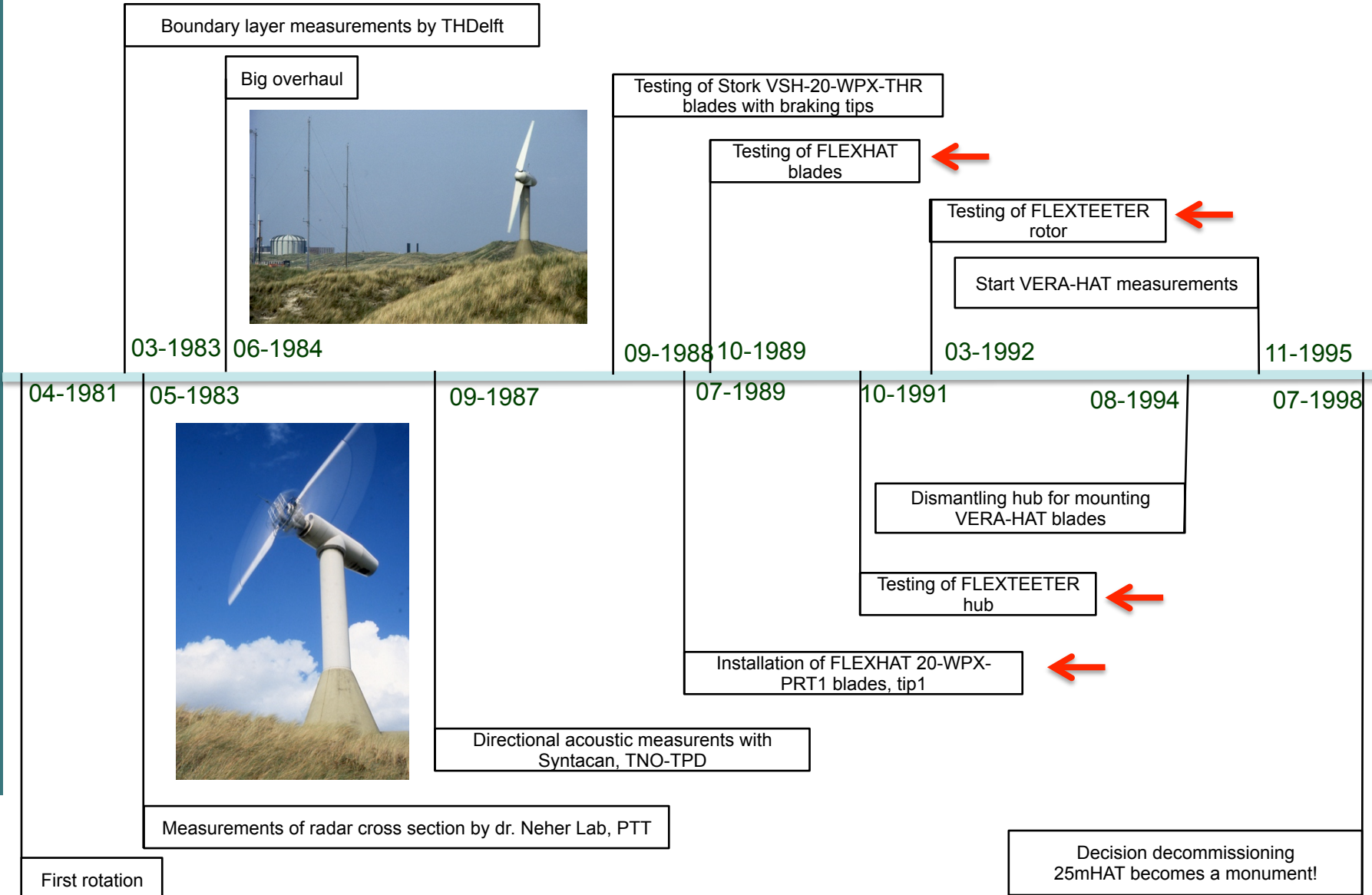
LAPAN
Indonesia



15 m Ø. Pioneer I



Time line 25mHAT experiments



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!)

FLEXHAT TECHNOLOGICAL INNOVATION

FLEXHAT PROGRAM

FLEXHAT (FLEXible Horizontal Axis Turbine) is a Dutch technology program. It is a part of the National Research Program on Wind Energy. The aim is to develop components for the next generation of wind turbines.

The FLEXHAT components are developed for wind turbines of the MegaWatt scale, but can be applied to medium scale turbines (250 – 500 kW).

Objectives:

- Cost and maintenance reduction
- Improved power quality and noise characteristics.

achieved by:

- Load reduction by flexibility
- Simplified structures and systems
- Fast control of power output
- Noise abatement procedures

Application of FLEXHAT components leads to a cost reduction of approx. 30%.

PASSIVE CONTROL TIPS

'Passive' means: no external control system (actuators, pumps etc) is required. The moveable tips, which control the rotor speed, are actuated by centrifugal forces only, or by the combined action of aerodynamic and centrifugal forces. The result is a simple, rugged system which reacts extremely fast to gusts and variations of electrical load. During a gust the rotor accelerates and the tips rotate immediately to counteract the increase of windspeed. During experiments grid failures were simulated, leading to an immediate response of the bladetips to keep the rotor speed within safe limits.



Constant output from wind farms, at remotely controlled power level

REMOTE CONTROL OF POWER AND SPEED

Using the passive rotor control and the variable speed system results in greater control flexibility than is achievable with current wind turbine designs. The setpoint of the power output can be varied, thus a windfarm may be remotely controlled from a nearby power station, either in response to the grid demand or in anticipation of changes in wind conditions.

STATUS & PROSPECTS

The R&D on the FLEXHAT-components and systems started several years ago and will be concluded in 1992. A series of full-scale tests on the passive rotor control has been concluded successfully. Several laboratory tests of components have also been concluded, and a complete rotor with passive tips, a testsystem and flexbeam is now being completed. Full-scale testing on ECN's 25-MW HAT rotor test facility will complete the program.

A complete demonstration wind turbine, including the FLEXHAT-rotor and conversion system along with all the control and safety features afforded by it is planned to be in operation in 1994. The demonstration project, called VENTUREX, will be based on modification of an existing medium scale commercial turbine. Although not leading to an optimum design, this approach enables a clear comparison between the conventional and the FLEXHAT-technology as far as costs, noise, maintenance and other operational characteristics are concerned.

VARIABLE SPEED CONVERSION SYSTEM

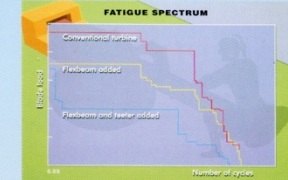
Windspeed permitting, the electrical conversion system is able to maintain a perfectly constant grid power, irrespective of how gusty the conditions are. Speed variations are still possible while maintaining a constant power level. This allows the passive blade tips to keep the rotor under control and to counteract gusts. Torque loads in the drive train are thus greatly reduced, as well as thrust exerted on the tower.

BLADE ROOTS FLEXIBLE (FLEXBEAM)

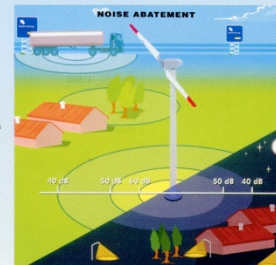
Compared to conventional wind turbines the blades are relatively flexible, in particular the thin inboard part, the so called flexbeam. The flexbeam enables the blades to bend backwards during heavy gusts, thus lowering the blade loads.

ROTOR ATTACHMENT BY RUBBER HINGE AND DAMPERS (TEETER)

The rotor blades are not rigidly connected to the hub, instead there is a hinge which allows a see-saw motion of the rotor, the so called teeterhinge. This causes an appreciable load reduction in the blades and the wind turbine structure, especially when the wind is turbulent. The teeterhinges and the necessary dampers and limiters are built from standard rubber elements.



Load reduction by flexbeam and teeter



Remote control of tipped rotor to reduce noise footprint at night

PARTICIPANTS

The FLEXHAT R&D is carried out by Stork Product Engineering B.V. (SPE) in cooperation with the Netherlands Energy Research Foundation (ECN) and is managed by the Netherlands Agency for

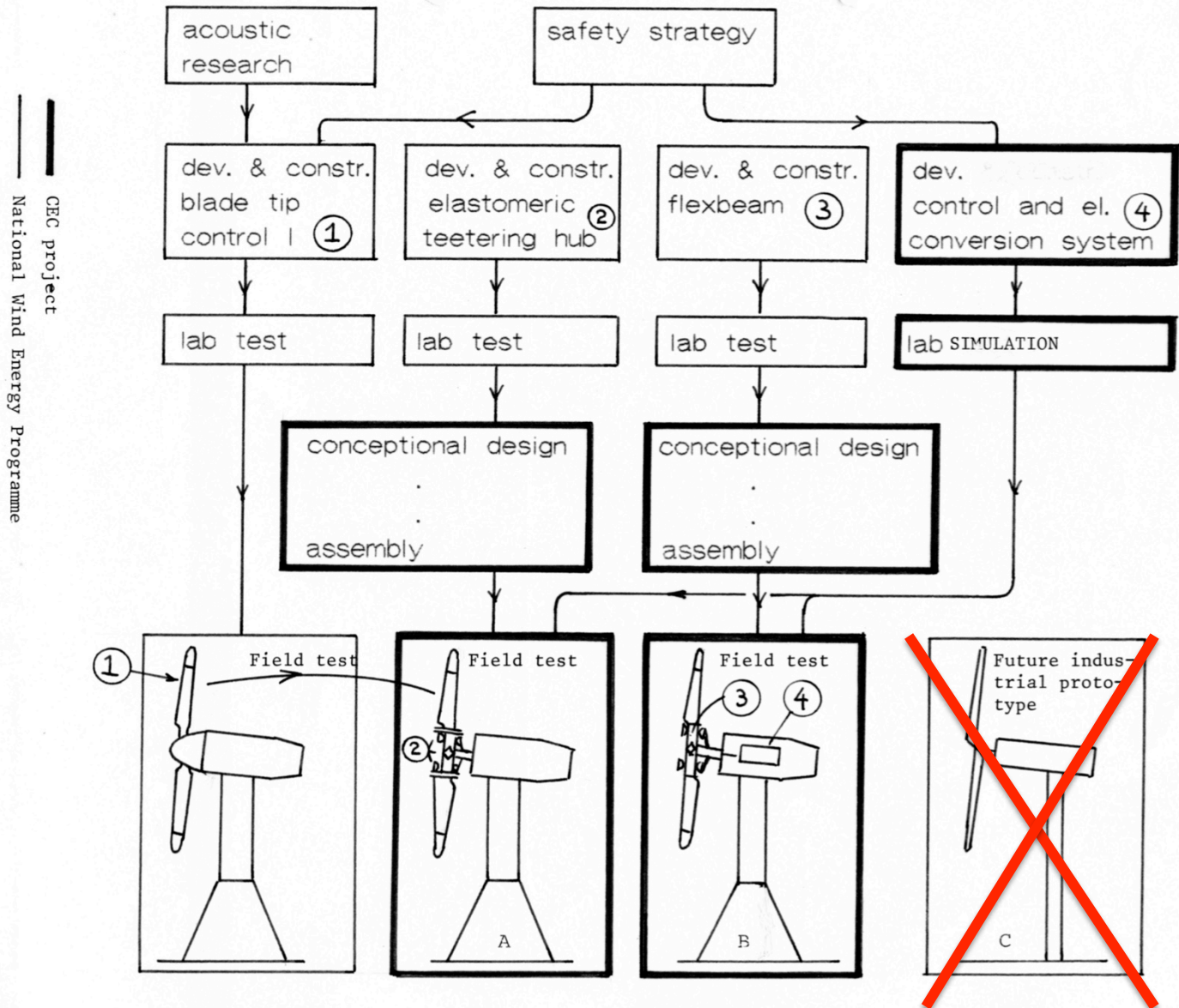
Energy and Environment (NOFF). Subcontractors involved include: Aerotec, FPD Technische Service, Stork, and TNO.

Main areas of activity: Design and engineering by SPE; Full scale testing by ECN; Blade manufacturer by Aerotec; and TNO.

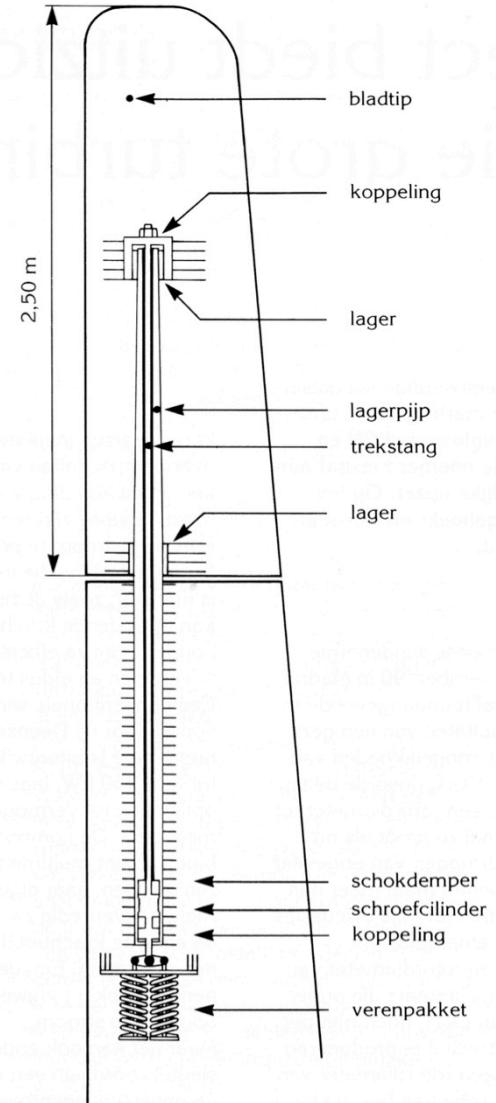
The program is funded by the Commission of the European Community (CEC) and by the Dutch Ministry of Economic Affairs.



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

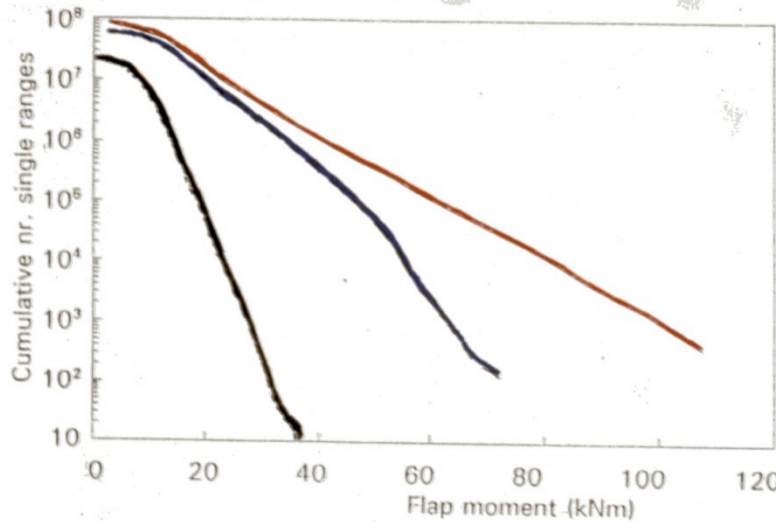


FLEXHAT: Testing of FLEXTEETER rotor



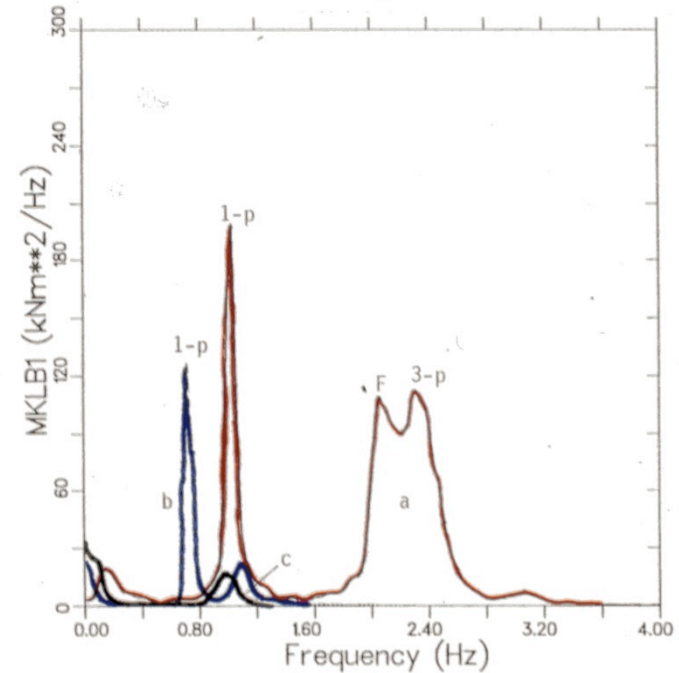
Results of FLEXTEETER experiments

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

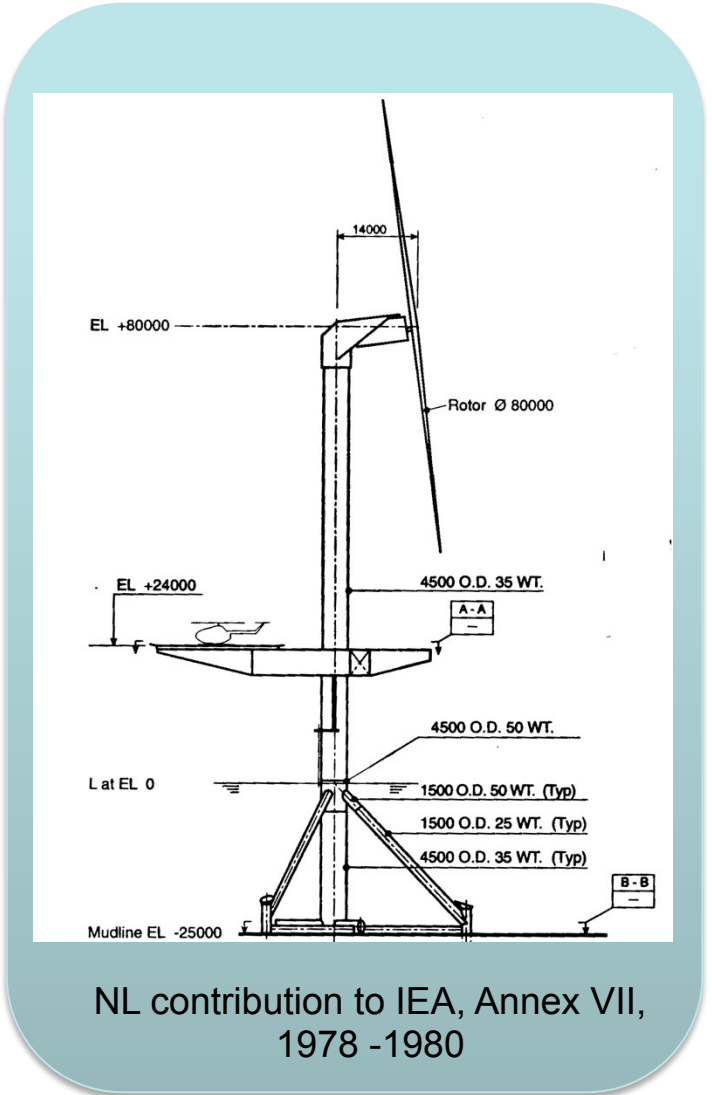
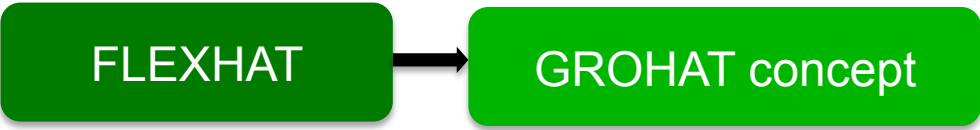


FLEXCON

Flexibility & Passive Blade pitch control



Spin-offs of FLEXHAT research



NL contribution to IEA, Annex VII, 1978 -1980

Spin-offs of FLEXHAT research

Ultimate WT



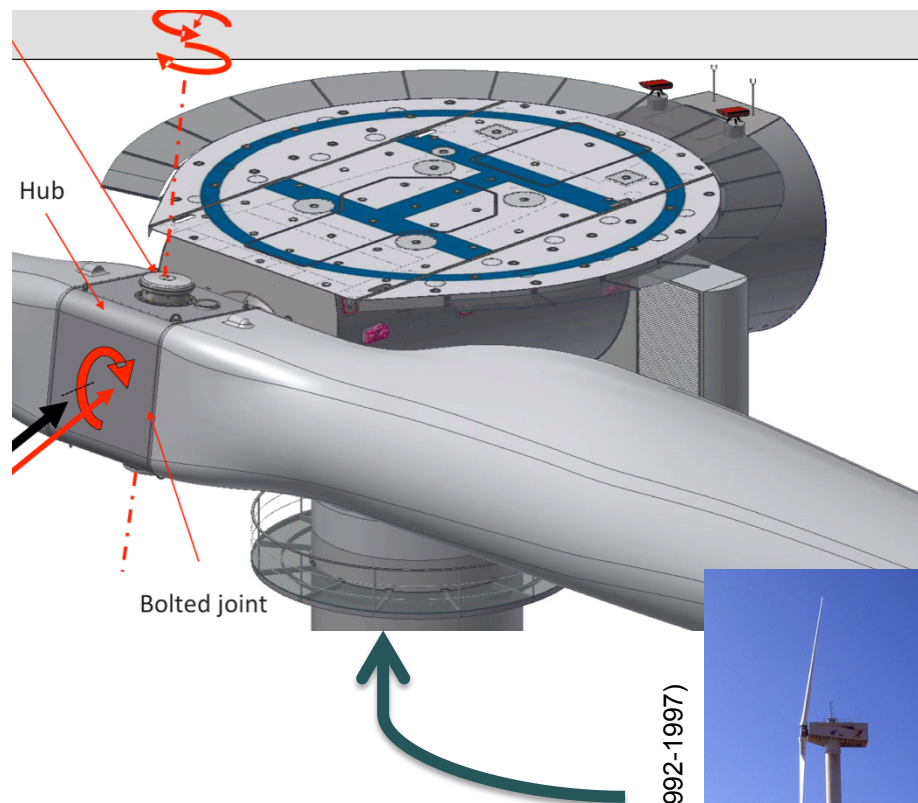
Full flexible rotor configuration
Down wind
Aerodynamically shaped tower

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)



NEW ECS 45, Medemblik



NEW ECS 55



Up scaling

Up scaling



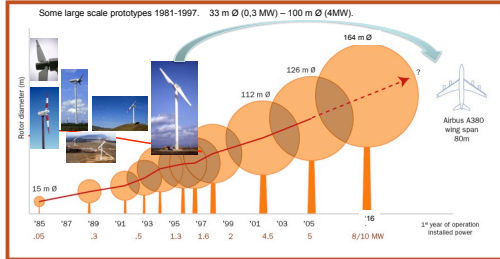
Lagerwey



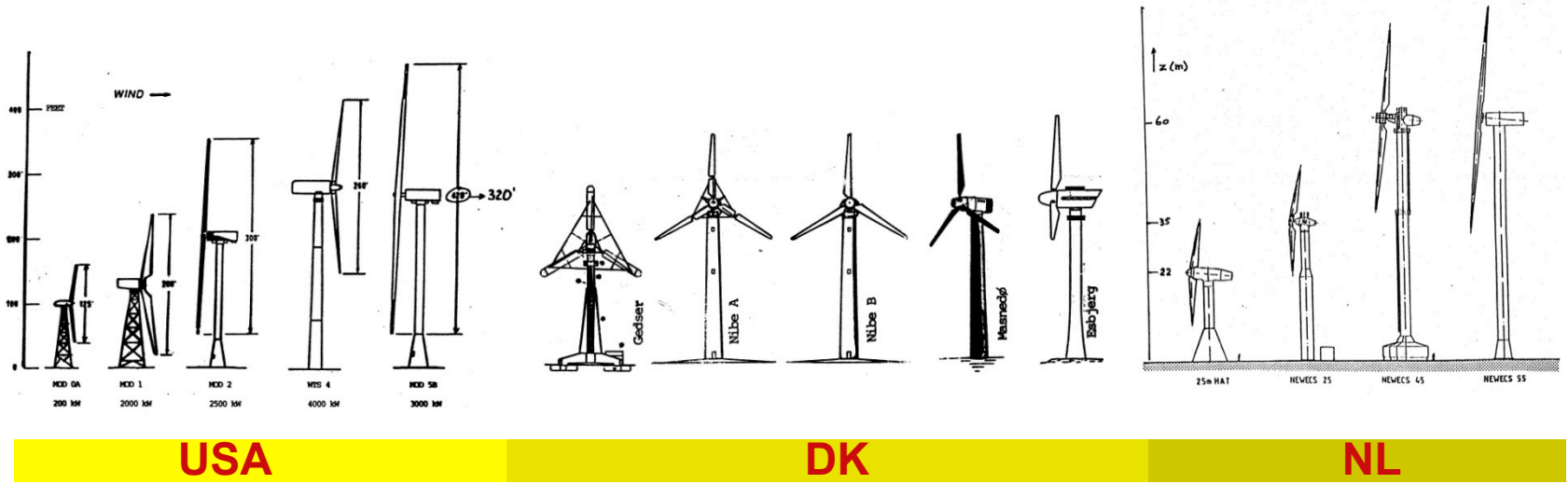
Stork NEW ECS 45



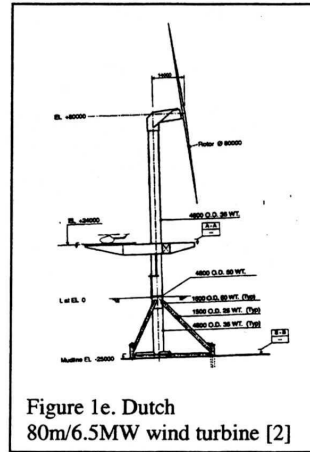
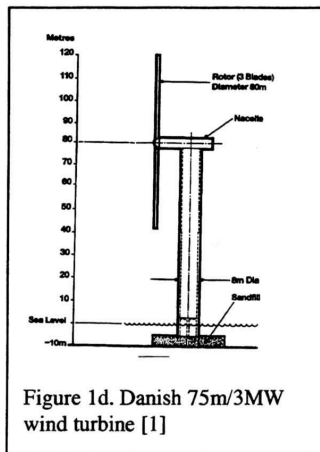
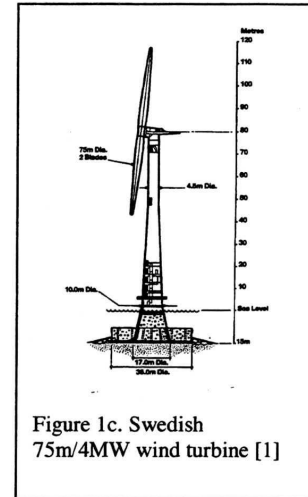
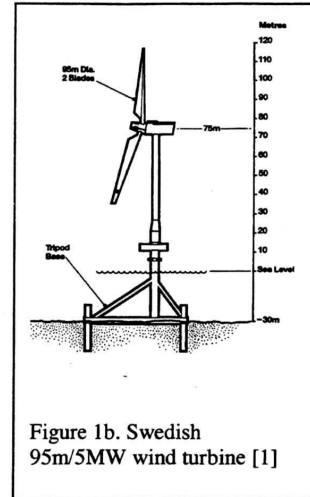
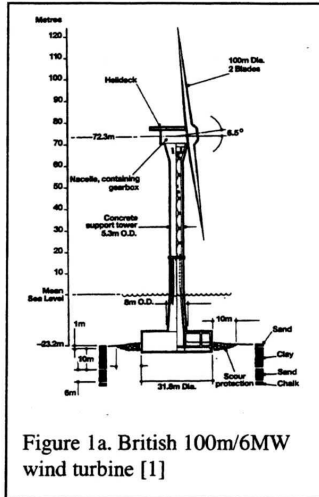
Lagerwey



Experimental turbines resulting from government programmes



Up scaling: Early offshore designs



- 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

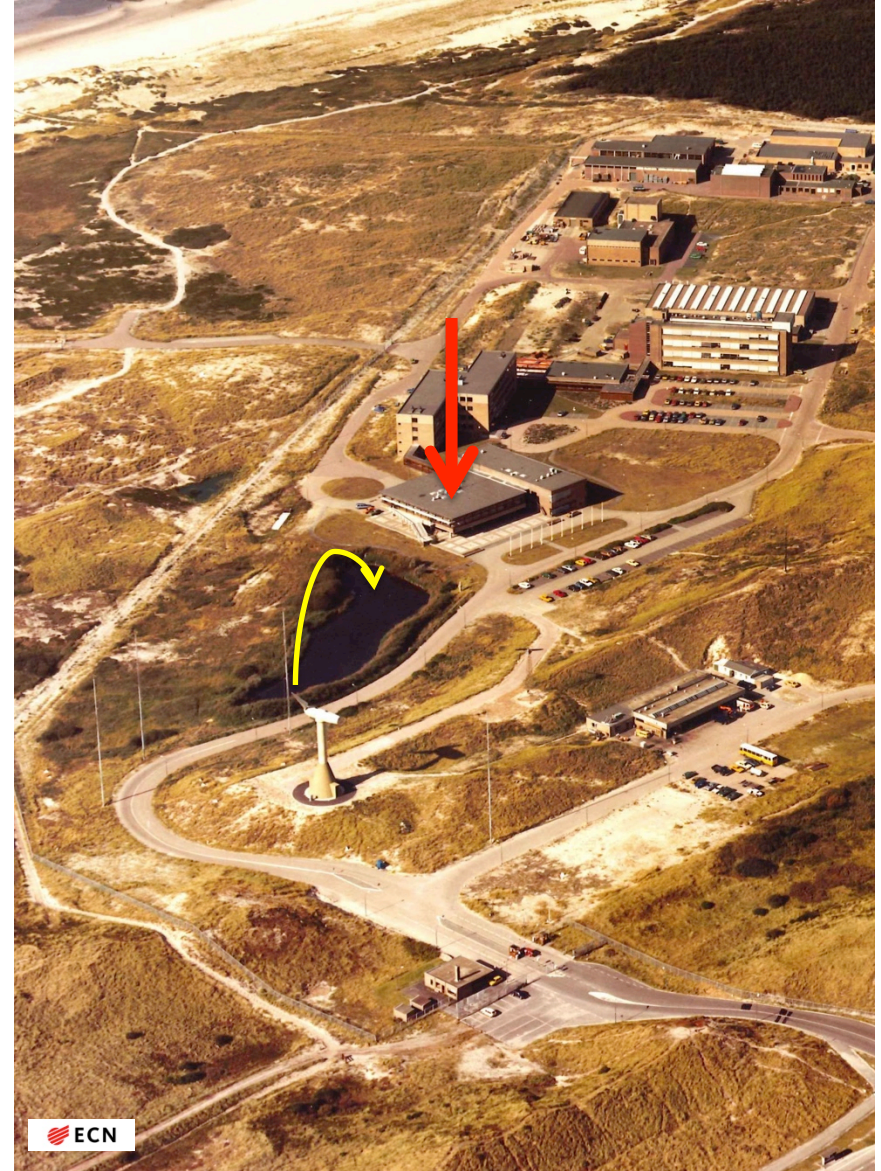


VSH



Lagerweij van de Loenhorst

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



Blade structural testing facilities



ECN



TU Delft

WMC

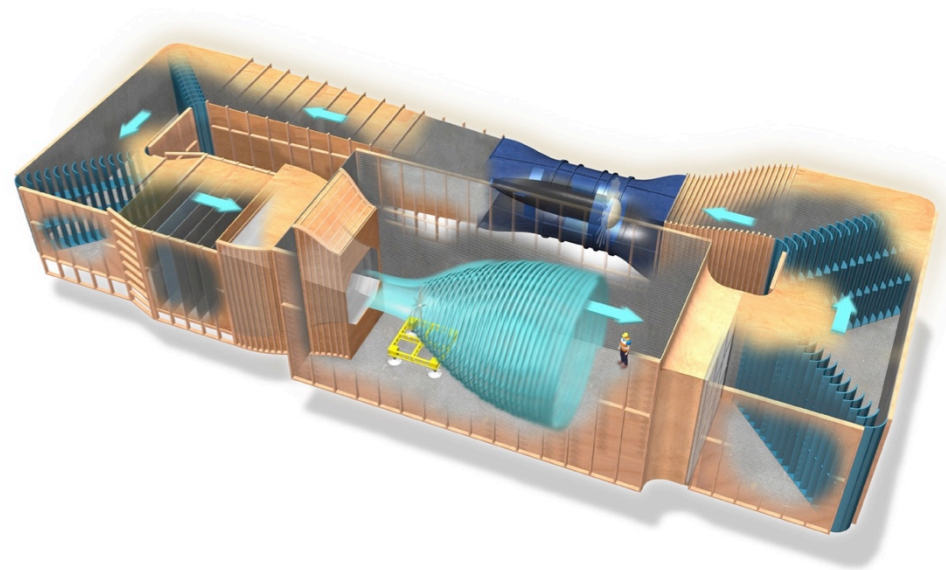


Wieringermeer (10-09-2002)

Wind tunnel: aerodynamic and aero-elastic design

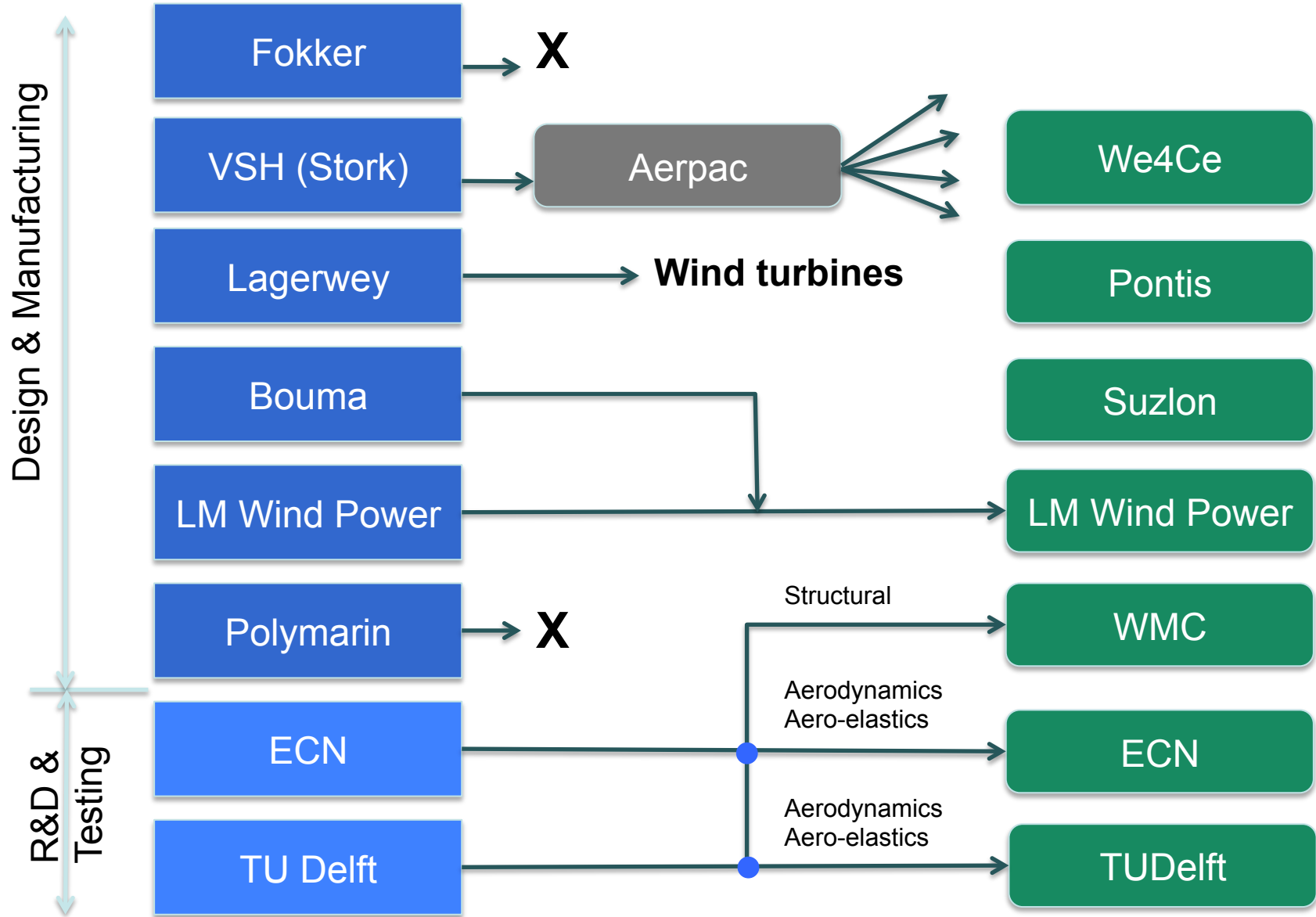


TNO-CWD tunnel



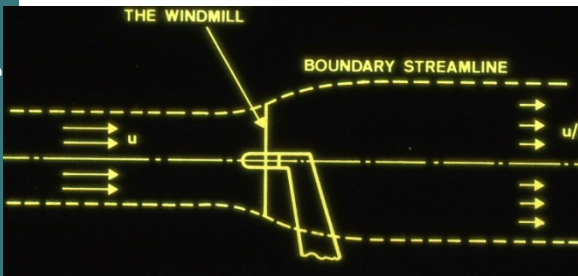
OJF- TUDelft

Blade technology spin-offs

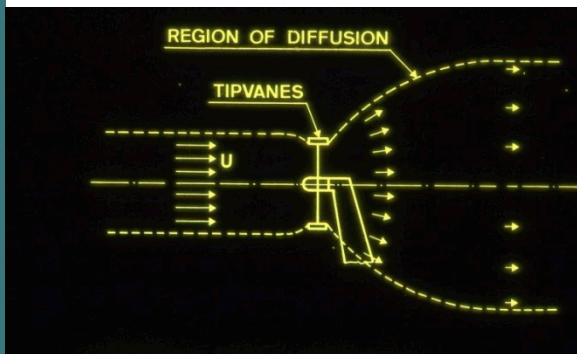


Tip vanes

Concentrating flow in rotor disc: tip vane research



Conventional wind turbine



Wind turbine with diffuser or tip vanes



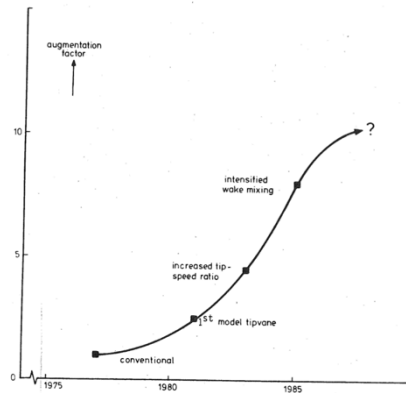
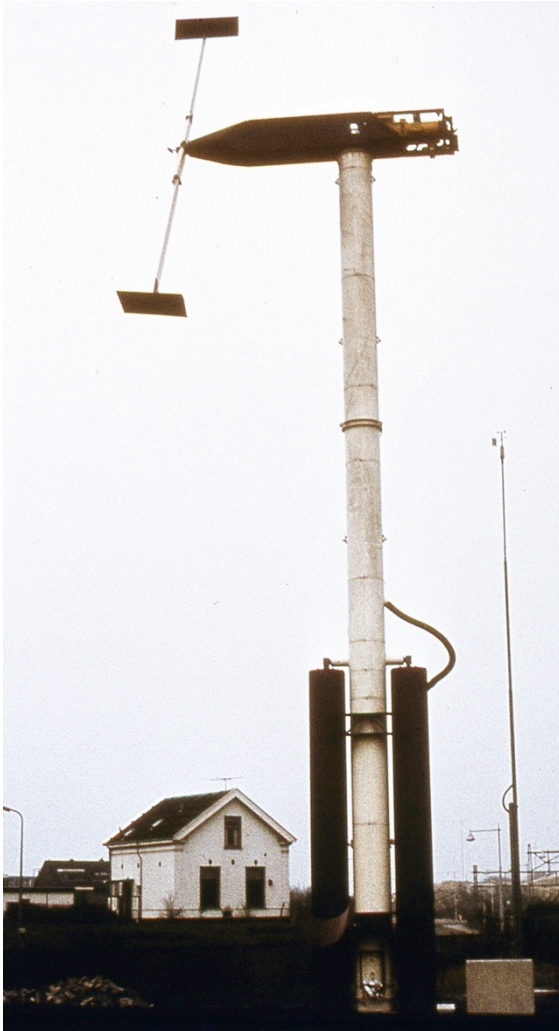
Theo van Holten



Concentrator concepts

Concentrating flow in rotor disc: tip vane research

Tip vane test facility at EA, Hook of Holland

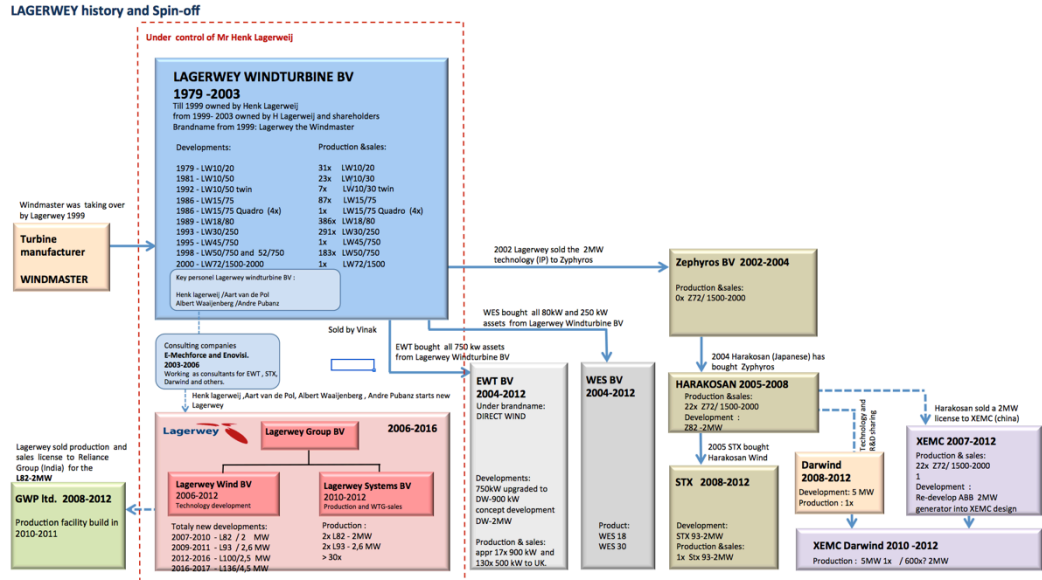


Concluding remarks

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.

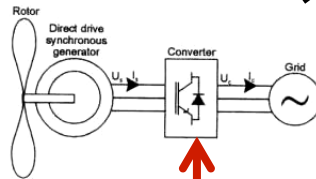
How comes?

It is the IGBT stupid!



The nucleus of WE break through

IGBT's



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)

More Control Parameters

active vibration damper
multi parameter control
safety

Non Grid Connected Operation

AWDS
desalination
refrigeration

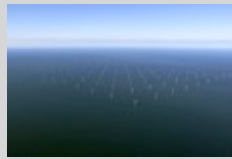
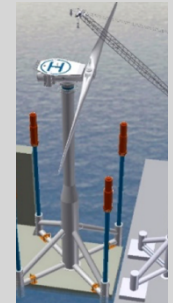
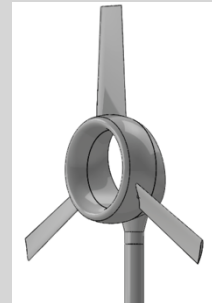
Up scaling (indirectly)

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

- 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!
Congratulations to Gerard!
Good by and see you soon Gijs!