INTERNATIONAL ENERGY AGENCY

Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems
TASK 11

49th IEA Topical Expert Meeting

Challenges of Introducing Reliable Small Wind Turbines

Stockholm, Sweden, September 2006
Organised by: Swedish National Energy Agency

Photo: Sven Ruin

Scientific Co-ordination:
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For more information about IEA Wind see www.ieawind.org

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IEA RD&D Wind Task 11

Topical Expert Meeting #49

Challenges of Introducing Reliable Small Wind Turbines

TASK 11
BASE TECHNOLOGY INFORMATION EXCHANGE

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The objective of this Task is to promote wind turbine technology through cooperative activities and information exchange on R&D topics of common interest. These cooperative activities have been part of the Agreement since 1978.

The task includes two subtasks. The objective of the first subtask is to develop recommended practices for wind turbine testing and evaluation by assembling an Experts Group for each topic needing recommended practices. For example, the Experts Group on wind speed measurements published the document titled "Wind Speed Measurement and Use of Cup Anemometry".

The objective of the second subtask is to conduct joint actions in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates Joint Actions in research areas of current interest, which requires an exchange of information. So far, Joint Actions have been initiated in *Aerodynamics of Wind Turbines, Wind Turbine Fatigue, Wind Characteristics, Offshore Wind Systems and Wind Forecasting Techniques.* Symposia and conferences have been held on designated topics in each of these areas.

In addition to Joint Action symposia, Topical Expert Meetings are arranged once or twice a year on topics decided by the IEA RD&D Wind Executive Committee. One such Expert Meeting gave background information for preparing the following strategy paper "Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020". This document can be downloaded from source 1 below.

Since these activities were initiated in 1978, more than 60 volumes of proceedings have been published. In the series of Recommended Practices 11 documents were published and five of these have revised editions.

All documents produced under Task XI and published by the Operating Agent are available to citizens of member countries from the Operating Agent, and from representatives of countries participating in Task XI.

More information can be obtained from:

1. www.ieawind.org
2. http://www.ieawind.org/summary_page_xi.html

May 11, 2006

INTRODUCTORY NOTE

IEA TOPICAL EXPERT MEETING 49

ON

CHALLENGES OF INTRODUCING RELIABLE SMALL WIND TURBINES

BACKGROUND

Small wind turbines have great potential, for example to provide electric power on remote locations. Market studies indicate a quickly growing demand for small wind turbines and hybrid power systems, which combine wind and some other generation technology. However, it is known that many small wind turbines

- do not live long because of technical failures and/or excessive maintenance requirements
- have misleading or non-existent power curves, production and noise data
- are not designed according to existing safety standards and have caused accidents
- are illegal to use, because they do not fulfill legal product requirements

While government programs in the early days fostered the manufacturers of medium-sized wind turbines to produce good products, this was not the case for small wind turbines. One example is Sweden, where the wind turbine investment subsidy was linked to requirements for 3rd party type approval and making operating statistics public. Small wind turbines were however excluded from the program. Another example is the United Kingdom, where the Clear Skies Renewable Energy Grants have some product requirements, but these are based only on self-declaration by the manufacturer.

Contributing to the problems with small wind turbines, is also the fact that they are often purchased by private individuals, without the professional competence and procurement practices normally used when buying medium and large wind turbines.

GOAL OF MEETING

The goal of this IEA meeting is to find ways to ensure that small wind turbines are reliable in the following sense:

1. Reliable long life: technical failures and excessive maintenance reduced
2. Reliable performance: published power curve, production and noise data should be reliable
3. Reliable safety: appropriate safety standards followed and accidents avoided
4. Reliable from a legal point of view: the buyer should not face the risk of buying a product that is illegal to operate

Number 3 and 4 have the highest priority of these. Even a small wind turbine can cause severe accidents, including death. In addition to the human suffering, accidents with small wind turbines can also give wind energy in general a bad reputation.

In order to accomplish the goal above, the meeting will attempt to clarify the product requirements by law in various parts of the world and map the testing activities carried out by different bodies and test centers, e.g. UL.

During 2006, the new edition of IEC standard 61400-2 "Safety of small wind turbines"[1] is planned to come into force, both as an IEC and an CENELEC standard. The consequences of this will also be discussed during the meeting. Will it be ignored by the small wind turbine industry, or will it be a helpful tool to improve safety?

This standard will be applicable to wind turbines with a swept area of up to 200 m^2, and that size definition of "small wind turbines" will also apply to this meeting.

INTENDED AUDIENCE

The target audience for this meeting is government policy makers, authorities responsible for defining and enforcing legal product requirements, certification bodies, test centers, consumer organizations, small wind turbine manufacturers, researchers and consultants.

A short presentation, of their experiences in the field, is expected from participants. Title of presentation can be chosen freely in line with the intention in the Introductory Note. The allocated time is 15-25 minutes including questions and discussion. However, the time is dependent on the number of presentations.

TENTATIVE AGENDA

The tentative agenda covers the following items:

1. Introduction by host
2. Introduction by Operating Agent, Recognition of Participants
3. Collecting proposals for presentations
4. Presentation of Introductory Note
5. Individual presentations
6. Discussion
7. Summary of meeting

OUTCOME OF MEETING

The outcome of the meeting is the proceedings including a short summary of the presentations and a compilation of topics that are crucial for the future implementation of small wind turbines.

FURTHER READING

For background information, see for example Paul Gipe's articles about small wind turbines on www.wind-works.org, in particular:

www.wind-works.org/articles/NeedTest.html

[1] http://www.iec.ch/cgi-bin/procgi.pl/www/iecwww.p?wwwlang=E&wwwprog=dirwg.p&ctnum=2361

INTRODUCTORY NOTE

IEA TOPICAL EXPERT MEETING

ON

CHALLENGES OF INTRODUCING RELIABLE SMALL WIND TURBINES

Presentation by Sven Ruin, TEROC AB, consultant specialized in wind energy and hybrid power systems

Small wind turbines have great potential, for example to provide electric power on remote locations. However, it is known that many small wind turbines

- do not live long because of technical failures and/or excessive maintenance requirements

- have misleading or non-existent power curves, production and noise data

- are not designed according to existing safety standards and have caused accidents

- are illegal to use, because they do not fulfill legal product requirements

The state of small wind turbines is in sharp contrast to larger wind turbines. Some typical characteristics:

	Small turbines	Medium & large turbines
Designed by	People with various backgrounds, from beginners to professionals	Professionals, with long experience of wind turbine design
Design tools	Varies	State-of-the-art
Manufacturer's resources	Often small (too small?)	Enough
Wind turbine buyers	Private individuals or small companies, who buy their first wind turbine	Large companies, with professional competence and procurement practices
Market fostering	Hardly any (or focused on promoting domestic manufacturers). Example from Sweden: Small wind turbines were exempt from subsidies and related requirements.	Helped the business start right. Example from Sweden: Government subsidies were linked with requirements for 3rd party type approval and making operating statistics public.
Customer satisfaction	Ranges from good to very bad	Ranges from good to quite good

Typical characteristics, continued:

	Small turbines	Medium & large turbines
Power performance & production data	Manufacturer's estimate published (often an overestimate, sometimes even though a proper independent measurement has been carried out)	Independently measured according to standard procedure
Cause for severe breakdowns	Temporary mistakes & systematic problems – some small wind turbines are even sold with known safety faults	Temporary mistakes
Distance to homes	Often small, within the possible blade throw distance	Large (mainly because of noise requirements)
Risk related to energy produced	Higher	Lower

Goal of this meeting – find ways to ensure that small wind turbines are reliable in the following sense:

1. Reliable long life: technical failures and excessive maintenance reduced

2. Reliable performance: published power curve, production and noise data should be reliable

3. Reliable safety: appropriate safety standards followed and accidents avoided

4. Reliable from a legal point of view: the buyer should not face the risk of buying a product that is illegal to operate

Legal requirements:

• European Economic Area: CE mark – means that the manufacturer or importer self declares that the product complies with the relevant guidelines. They also have to supply the declaration of conformity and save the relevant documentation. Does NOT require 3rd party review. Supervising authorities may randomly check on the fulfillment of legal requirements. In case of accidents, the documentation may also have to be presented in court. In reality, many small wind turbines are illegal to operate.

• What are the legal requirements on other markets around the world?

A new edition of IEC 61400-2 “Safety of small wind turbines” has come into force during 2006. See www.iec.ch

This is also a CENELEC standard. As a CENELEC standard, it is claimed to be mandatory in Europe, at least for large contracts.

Applicable to wind turbines with a swept area of up to 200 m^2 (15.9 m diameter).

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C E T C CANMET ENERGY TECHNOLOGY CENTRE

Small Wind Energy Technology in Canada

49th IEA Topical Expert Meeting
Stockholm, Sweden, September 27-28, 2006

CLEAN ENERGY TECHNOLOGIES

Antoine Lacroix, ing., M.Sc.
Wind Energy R&D Group
Ottawa, Ontario

Canada

C E T C CANMET ENERGY TECHNOLOGY CENTRE

Small Wind Turbine Market Survey

- Background:
  - Why? SWT market not well-understood
  - Goals:
    - Profile current market for small wind electric turbines
    - Develop an action plan for the development of this market
- Research method
  - Interviews with 23 experts in Canada and the U.S.
    - Manufacturers, utilities, distributors, retailers, researchers and industry associations.
  - Survey to all players in SWT supply chain:
    - Sales data, current and future markets
    - Response rate: 46 of 135 players (34%)
    - Assumed coverage: 75% of market

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C E T C CANMET ENERGY TECHNOLOGY CENTRE

Canadian Context - Markets

- Market 1 – Off-grid cottages and lodges
  - Primary market for SWT < 1.5 kW
  - Mobile uses, cottages, lodges, specialty power
  - Drivers: noise reduction, energy independence
  - Barriers: reliability, awareness of options
- Market 2 – Residential on-grid
  - Small but growing market, SWT < 3 kW
  - Homes on large lots for supplemental power or on-grid
  - Drivers: energy independence (not ¢/kWh)
  - Barriers: first cost (huge!), knowledge of resource, grid access

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Canada

C E T C CANMET ENERGY TECHNOLOGY CENTRE

Canadian Context - Markets

- Market 3 – Farms and commercial
  - Small but growing market for 5 kW to 50 kW
  - Large and small grid connected farms (many), commercial and institutional buildings (few)
  - Drivers: energy independence, cost savings (¢/kWh)
  - Barriers: net metering, high costs (capital and production)
- Market 4 – Northern applications and communities
  - Has had “huge potential for last 20 years”, but patchy record
  - Potential for 50 kW to 300 kW
  - Drivers: high energy cost, energy independence
  - Barriers: capacity building & long-term maintenance, each installation is unique

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Small Wind Turbine R&D

- Universal Small Wind Turbine
  - Testing on the following components to be carried out at WEICan
    - Universal Inverter (2006)
      - Currently tested at WEICan
      - 50, 60 Hz; 3 and 1 phase, AC & DC
    - 60 kW Direct-Drive Generator (2007)
      - Permanent magnet
    - Turbine (2008)
- Small Wind Turbines Testing
  - Testing of two small wind turbines (2.5 and 3 kW) in single-phase net metering at WEICan
  - Other testing
    - 3-phase net-metering variable speed benchmark

2.5-kW turbine and single-phase inverter for net-metering applications

Wind Energy Institute of Canada (WEICan)

- New facility established in North Cape, Prince Edward Island, to strengthen Canada's position in wind energy research and development.
- Builds on the Atlantic Wind Test Site, with 25 years of experience in research, development and testing of wind energy technologies.
- Focus is on four key areas of work:
  - testing and certification;
  - research and innovation;
- Industry training and public education; and,
- Technical consultation and assistance.

WEICan under construction

North Cape, Prince Edward Island

Rendering of the future WEICan in North Cape, PEI

C E T C CANMET ENERGY TECHNOLOGY CENTRE

Wind Turbine Test Platforms Available at WEICan

- 50 kW
  - test the Universal Inverter which will enable use for net-metering and battery charging or hydrogen production
- 65 kW
  - suitable for remote off-grid applications and hybrid systems such as wind-diesel
  - will be used to test the direct-drive generator
- 80 kW
  - Recently refurbished. This turbine can be used for advanced inverter and control system technology development

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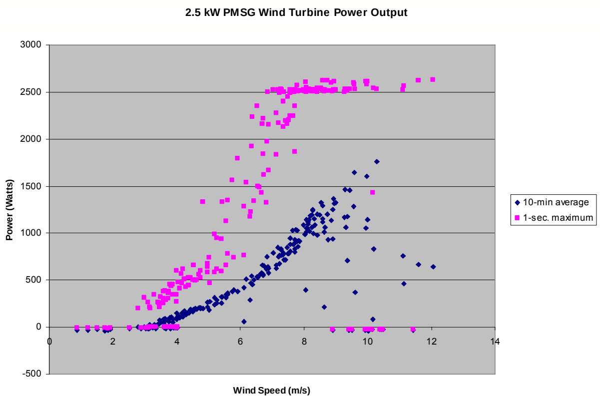
C E T C CANMET ENERGY TECHNOLOGY CENTRE

Small Wind Turbine Performance Testing



- Small wind turbine test bench at WEICan
- Testing for power curve and reliability

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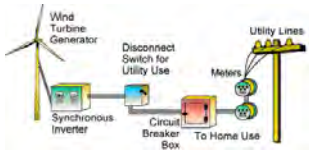
C E T C CANMET ENERGY TECHNOLOGY CENTRE

Net Metering

- Policies are enacted in several provinces to allow residents to produce electricity and get the equivalent of the retail value
  - Conditions vary:
    - Billing cycle
      - Annual, monthly
    - Maximum output
      - Set by each province



Source: Iowa Energy Center Wind Energy Manual

  - Interconnection possible in single or three phases
    - single phase
      - Bulk of market
      - Residences with large lots, majority of farms
  - Single phase grid-connection is usually achieved through an inverter
    - A 5-kW turbine with CF = 25%
    - ≈ 10,950 kWh

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Wind-Diesel Development

- First Canadian Wind-Diesel demonstration project
  - Located in Ramea, Newfoundland, the project consists of six 65 kW wind turbines, with an installed wind energy capacity of 390 kW
  - NRCan's unique control system, WDICS, developed at AWTS, integrates the wind energy with the existing diesel generating system on Ramea Island
  - >12 months of successful operation have yielded positive results
  - Utility (Newfoundland and Labrador Hydro) now supportive of further developments
  - Production of hydrogen is considered

6 x 65-kW wind turbine in Ramea, NF

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Canada's SWT Future - Opportunities

- Opportunities:
  - Off-grid battery charging and specialty power
    - Mainly mini wind turbines
    - Expected to grow without significant stimulus
    - Issue is product choice (many models available), durability
  - Residential
    - Mainly 500 W to 10 kW, often in hybrid with PV
    - Future is on-grid; requires net metering
    - Main issue is first cost (aesthetics and noise to a lesser degree)

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Canada's SWT Future - Opportunities

- Opportunities (cont'd)
  - Farms, Commercial and Institutional
    - Mainly small wind turbines (10 to 30 kW)
    - Markets in farms, cooperatives and communities
    - Issue is energy independence, payback < 10 years
  - Northern applications
    - Mainly medium wind turbines
    - Potential for high-penetration wind-diesel
    - New approach: PPA with IPP (Nunavut and Newfoundland)
    - High potential impact on Canadian manufacturing
    - Springboard to international market

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CETC CANMET ENERGY TECHNOLOGY CENTRE

Canada's SWT - Barriers

- Most significant barriers:
  - Technical
    - Standardized performance (independent verification)
    - Grid connection (generic battery-less inverter)
    - Noise, durability
  - Market
    - First cost: the major barrier, period.
    - Lack of consumer awareness and difficulty in choosing and costing options
  - Policy
    - Lack of coordinated policy targeting SWT
    - Local issues (non-uniformity in bylaws, permitting)
    - Access to grid: interconnection (power quality) and net metering (threshold and disposition)

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Canada's SWT – Barriers (Cont'd)

- Low cost for conventional energy and a surplus of generation capacity in many areas
- Canadian weather
  - Increase loading due to atmospheric icing and increased air density
  - Icing also a safety hazard
  - Gearboxes and generators are also affected components

Bornay 3 kW turbine in single-phase net metering at WEICan

Two 1800-Watt Windy Boy inverters connected in parallel in single-phase 120/240 V.

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Canada

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27th and 28th of September 2006, Swedish Energy Academy Stockholm, Sweden

IEA RD&D Wind, Annex XI
Challenges of Introducing Reliable Small Wind Turbines

Big Experience with Small Wind Turbines (SWT)

Experiences of 15 years with 235 SWT in the WMEP

Paul Kühn

ISET
Institut für Solare
Energieversorgungstechnik
Kassel/ Hanau, Germany

- Introduction: ISET and WMEP
- Causes for Failure
- Affected Components and Downtime
- Technical Availability
- Frequency of Failure and Costs
- Summary and Outlook

ISET - Institut für Solare Energieversorgungstechnik

Applications-oriented Research and Development
in Electrical Engineering and Systems Technology
for the Use of Renewable Energies
and Decentralised Power Supply

- Wind Energy
- Photovoltaics
- Use of Biomass
- Hydro Power and Marine Energies

- Energy Conversion and Storages
- Static Converters
- Hybrid Systems
- Energy Economy

Institut für Solare Energieversorgungstechnik
Verein an der Universität Kassel e. V.

ISET – SWT Testing Activities

Paul Kühn 31-Oct-06
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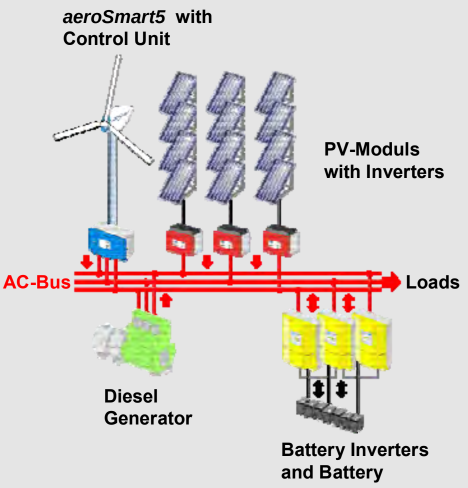
<u>Setup of the System:</u>



<u>Measurements (1 Hz and 60 Hz):</u>

meteorological parameters at hub height

electrical current, voltage and power of all system components

yaw orientation, tower acceleration...

Prototype of the *aeroSmart5* at the ISET test facility „Alte Schanze“

Test of a 5 kW SWT for Modular Autonomous Supply Systems

ISET

WMEP at a glance

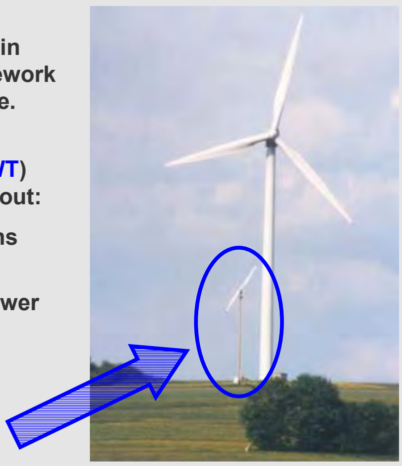
Paul Kühn 31-Oct-06
- 4 -

ISET has been monitoring the development of wind energy use in Germany since 1989, in the framework of the “250 MW Wind” programme.

Operational results gathered by questionnaire (more than 1 500 WT) and measurements (200 sites) about:

- effects by external conditions
- energy yields
- fluctuation of fed in wind power
- reliability of WT
- economy of wind energy

This contribution:
Operational results of 235 SWT



Evaluation Programme Wind Energy in Germany, WMEP

ISET

WMEP and SWT

ISET

SWT in the WMEP

WMEP - Data Acquisition

Out of more than 62 000 reports concerning maintenance and repairs :

4 200 reports from SWT


WARTUNGS– UND INSTANDSETZUNGSBERICHT
WMEP 250 MW-Wind
Arbeit ausgeführt am
Tag Monat Jahr
Bericht-Nr.
Postleitzahl
Anlagen-Kennummer
Betreiber
Hersteller und Typ
Störungsursache cause of failure
Sturm
Netzausfall
Blitzschlag
Eisansatz
Fehlfunktion der Anlagenregelung
Bauteilverschleiß oder -defekt
Bauteillockerung
Andere Ursachen
Ursache unbekannt
Anlaß der Arbeiten reason for report
Regelmäßige Wartung (Nur Durchsicht und Funktionskontrolle)
Regelmäßige Wartung mit Austausch von Verschleißteilen oder Beseitigung gefundener Mängel
Unplanmäßige Reparatur nach Betriebsstörung
Störungsauswirkung consequenses
Überdrehzahl
Überlast
Geräuschentwicklung
Vibrationen
Reduzierte Leistungsabgabe
Verursachung von Folgeschäden
Anlagenstillstand
Andere Auswirkungen
Stillstandzeiten downtime
Nicht abgeschaltet
Abgeschaltet
von
bis
Tag Monat Uhrzeit
Stand des Stundenzählers
Störungsbehebung repair
Einwandfreie Anlagenfunktion ohne Reparatur nach :
Anlagen-Reset
Änderung von Regelungsparameter
Reparierte oder ausgetauschte Bauteile
Rotornabe
Nabenkörper
Blattverstellmechanismus
Blattlager
Rotorblätter
Blattverschraubung
Blattkörper
Getriebe
Lager
Zahnräder
Getriebewellen
Dichtungen
Mechanische Bremse
Bremsscheibe
Kosten laut Rechnung costs

ISET

Maintenance and Repair Reports

WMEP - Data Acquisition


Störungsbehebung

Einwandfreie Anlagenfunktion ohne Reparatur nach :
Anlagen-Reset
Änderung von Regelungsparameter

Reparierte oder ausgetauschte Bauteile

Rotornabe (rotor hub)	***Getriebe*** (gearbox)
Nabenkörper	Lager
Blattverstellmechanismus	Zahnräder
Blattlager	Getriebewellen
Rotorblätter (rotor blades)	Dichtungen
Blattverschraubung	***Mechanische Bremse*** (mechanical brake)
Blattkörper	Bremsscheibe
Aerodynamische Bremsen	Bremsbeläge
Generator (generator)	Bremssattel
Wicklung	***Antriebsstrang*** (drive train)
Schleifringe/Bürsten	Rotorlager
Lager	Antriebswellen
Elektrik (electrical system)	Kupplungen
Stromrichter	***Hydraulikanlage*** (hydraulic system)
Sicherungen	Hydraulikpumpe
Schütze/Schalter	Pumpenantrieb
Leitungen/Anschlüsse	Ventile
Geber (sensors)	Hydraulikleitungen
Anemometer/Windfahne	***Windrichtungsnachführ.*** (yaw system)
Rüttelschalter	Azimut-Lagerung
Temperaturfühler	Antriebsmotor
Öldruckschalter	Zahnkranz/Ritzel
Leistungsmesser	***Tragende Teile/Gehäuse*** (supporting structure, housing)
Drehzahlmesser	Fundament
Regelung (control system)	Turm/Turmverschraubung
Elektron. Regelungseinheit	Gondelrahmen
Relais	Gondelverkleidung
Meßkabel und Anschlüsse	Leiter/Aufstieg

Repairs: categorisation with respect to main component groups and their individual parts

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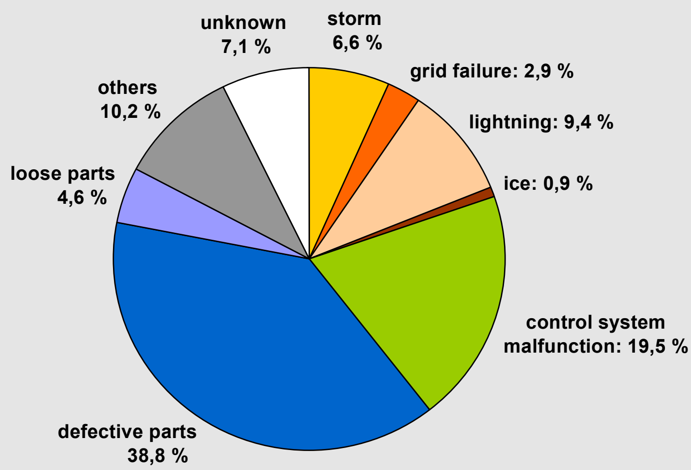
Causes for Failure



Causes for Failure of SWT in the WMEP

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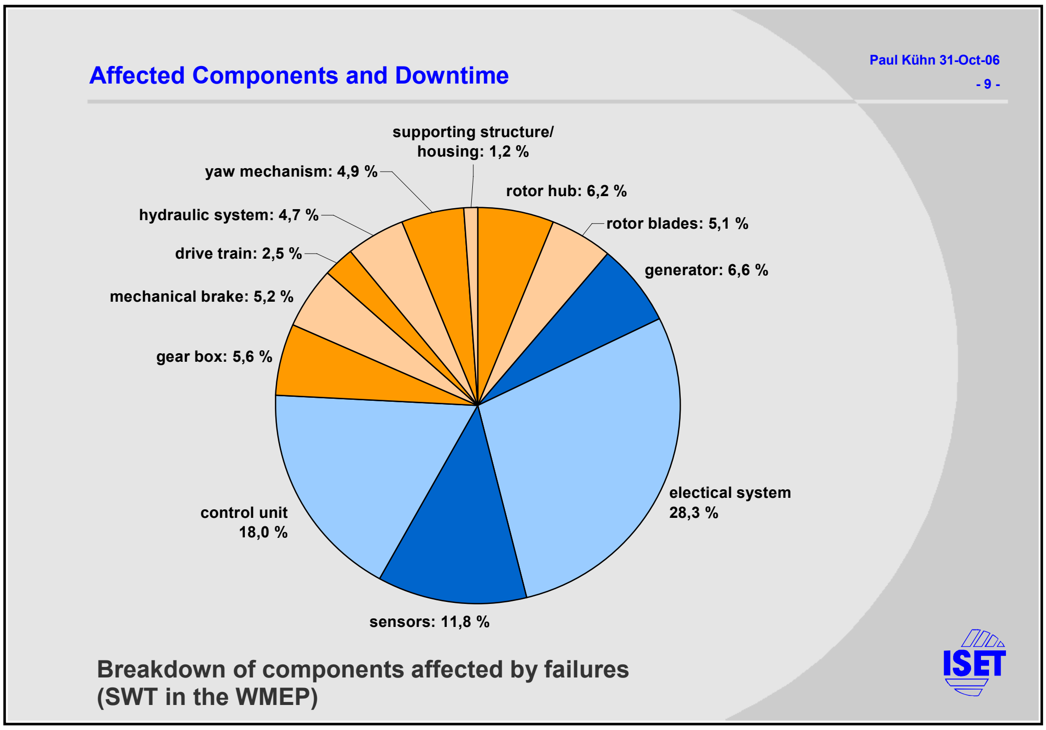
Affected Components and Downtime
Paul Kühn 31-Oct-06
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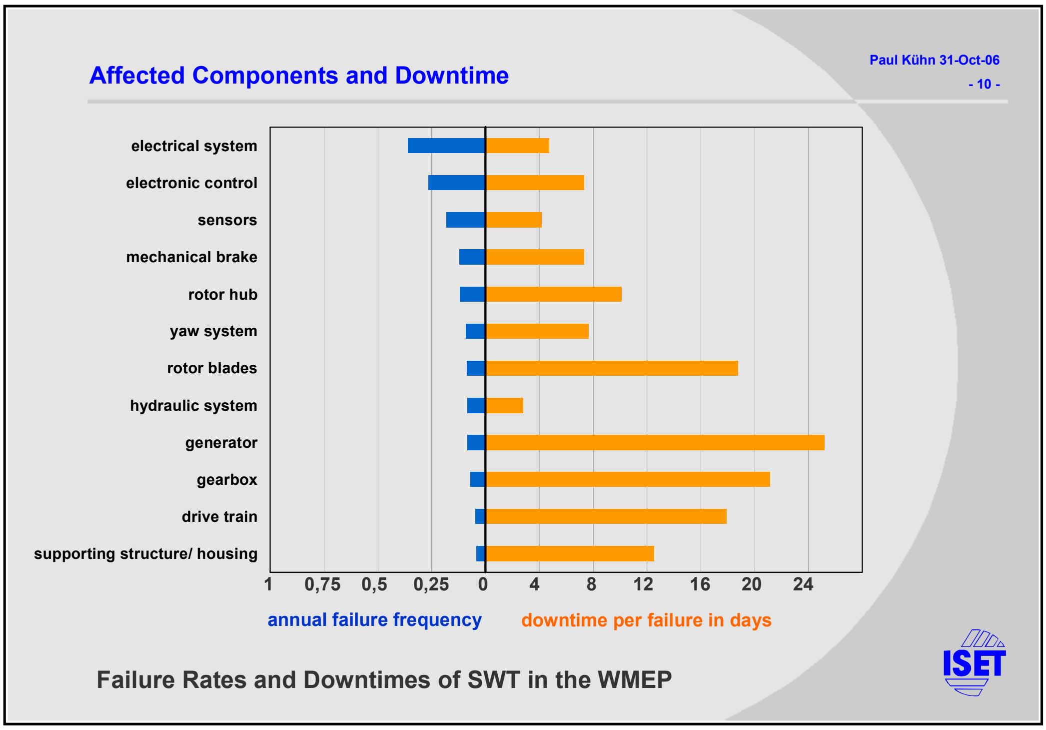
supporting structure/ housing: 1,2 %
yaw mechanism: 4,9 %
rotor hub: 6,2 %
hydraulic system: 4,7 %
rotor blades: 5,1 %
drive train: 2,5 %
generator: 6,6 %
mechanical brake: 5,2 %
gear box: 5,6 %
electical system 28,3 %
control unit 18,0 %
sensors: 11,8 %
Breakdown of components affected by failures (SWT in the WMEP)
ISET


Affected Components and Downtime
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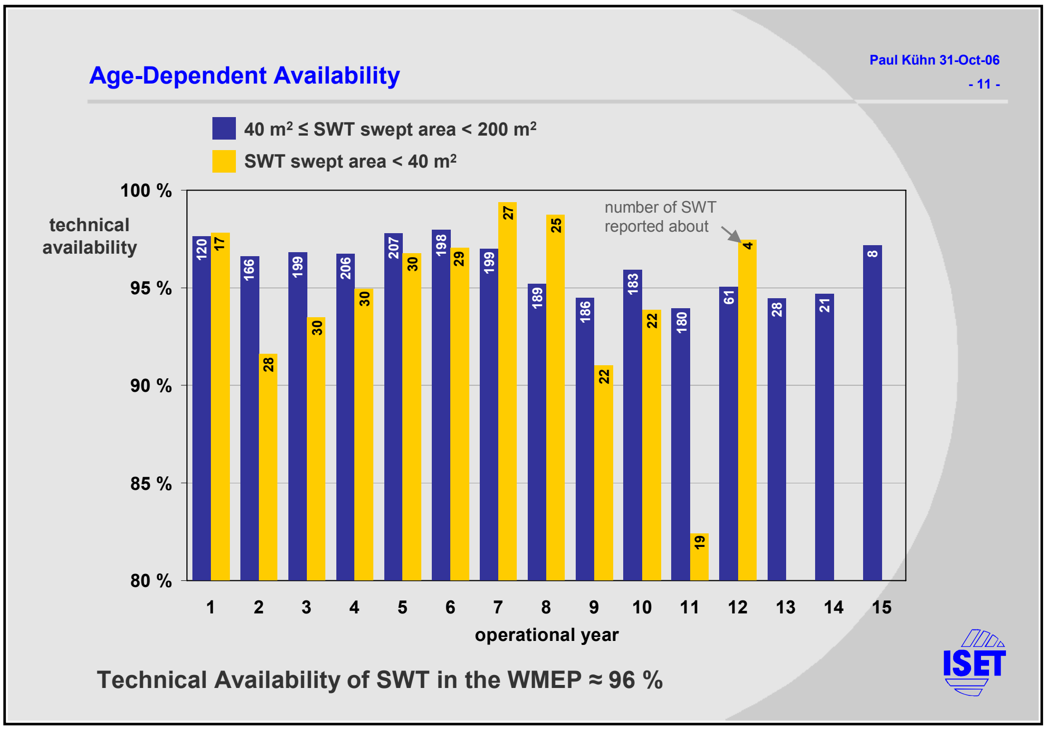
electrical system
electronic control
sensors
mechanical brake
rotor hub
yaw system
rotor blades
hydraulic system
generator
gearbox
drive train
supporting structure/ housing
1
0,75
0,5
0,25
0
4
8
12
16
20
24
annual failure frequency
downtime per failure in days
Failure Rates and Downtimes of SWT in the WMEP
ISET


Age-Dependent Availability
Paul Kühn 31-Oct-06
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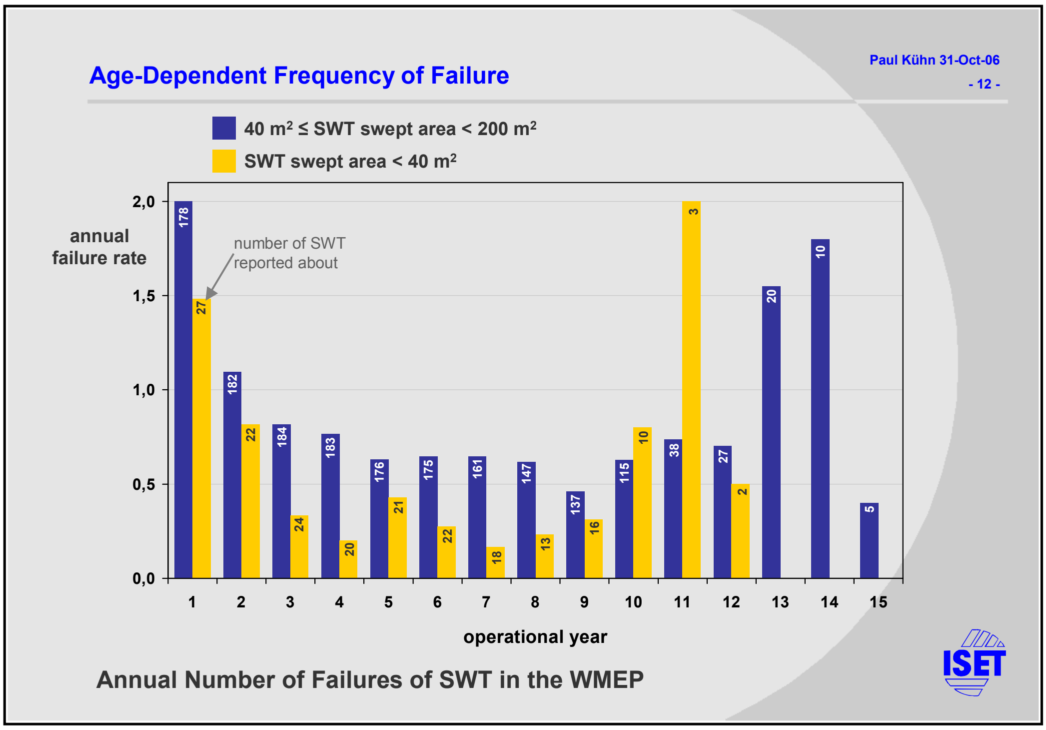
40 m² ≤ SWT swept area < 200 m²
SWT swept area < 40 m²
technical availability
100 %
95 %
90 %
85 %
80 %
number of SWT reported about
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
operational year
Technical Availability of SWT in the WMEP ≈ 96 %


Age-Dependent Frequency of Failure
Paul Kühn 31-Oct-06
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40 m² ≤ SWT swept area < 200 m²
SWT swept area < 40 m²
annual failure rate
2,0
1,5
1,0
0,5
0,0
number of SWT reported about
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
operational year
Annual Number of Failures of SWT in the WMEP

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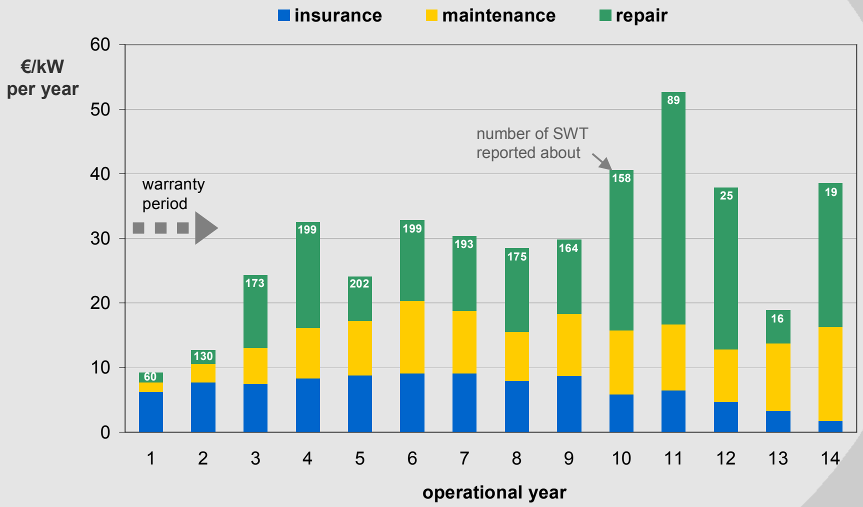
Age-Dependent Costs



Development of Operational Cost of SWT in the WMEP

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Summary

- causes for failure mainly internal problems
- in two third of the cases the failures were based on electrical, in the other third they were based on mechanical components
- relatively long downtimes due to breakdown of components leave room for improvement → optimization of strategies for maintenance and repair i.e. to have spare parts at hand
- 96 % technical availability of SWT is lower than that of large WT, yet still relatively high
- on average each WT suffers from less than one failure per year
- no significant increase in failure frequency up to an operational age of 10 years
- trend of increasing repair costs for older turbines

ISET

Outlook

Paul Kühn 31-Oct-06

- 15 -

ISET´s future R&D activities involving SWT will focus on applications of SWT in autonomous power supply systems:

- investigate specific design- and control requirements of SWT for off-grid applications
- optimize the interaction between SWT and hybrid power systems
- improve technical availability of SWT in remote locations
- expand testing at the ISET test field!!!

ISET

Thank you for your attention!

Paul Kühn 31-Oct-06

- 16 -

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http://reisi.iset.uni-kassel.de

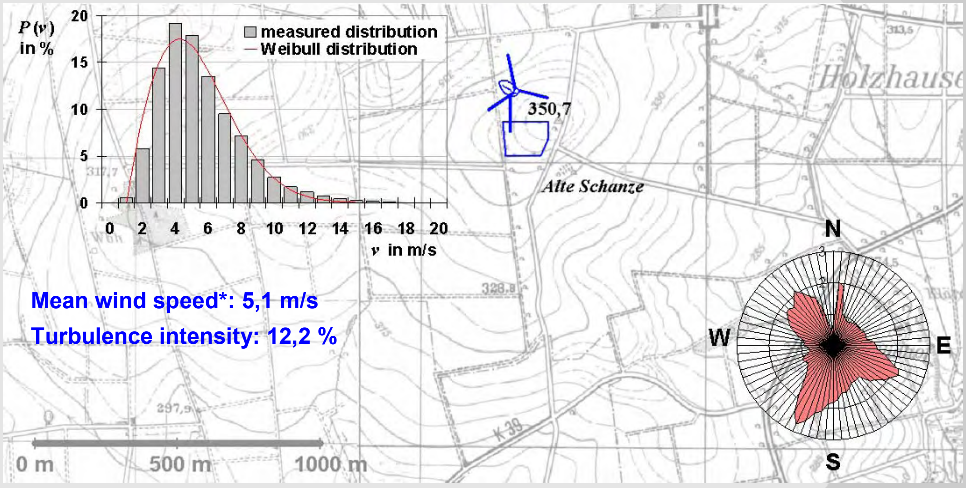
Institut für Solare Energieversorgungstechnik e.V.

Electrical systems technology for the use of renewable energies and for the decentral power supply

Applications-oriented R&D

- Wind Energy
- Photovoltaics
- Bio Energy
- Hydro Power and Marine Energies
- Energy Conversion and Storage
- Hybrid Systems
- Energy Economy

ISET



* in 30 m, source: Windmessprogramm in Hessen

ISET test field „Alte Schanze“

rotor swept area	SWT model	number	nominal power in kw	rotor diameter in m	total number
< 40 m²	LMW 2500	1	2,5	5	30
	Wenus Inventus 6	18	5	6	
	AEE Peters PG 10	6	10	6,3	
	LMW 10/7	2	10	7	
	Südwind N 710	1	10	7	
	Südwind N 715	2	15	7	
< 200 m²	HAWI 15	2	30	10	205
	HM H-Rotor 60	1	20	10	
	WKZ elektrOmat 20	1	20	10,5	
	Lagerwey LW 11/20	1	20	10,6	
	NEW 100	8	20	11,3	
	HSW 30	11	30 to 33	12,5	
	Südwind N 1230	16	30	12,5	
	Südwind N 1237	15	37	12,5	
	Südwind N 1245	1	45	12,5	
	Tacke TW 45	1	45	12,5	
	Fuhrländer astOs 30	1	30	12,6	
	Aeroman 14.8/33	13	33	14,8	
	DWA 16/55	5	46 to 55	15	
	Krogmann 15/50	49	40 to 50	15	
	Lagerwey LW 15/50	14	30 to 50	15,6	
	Lagerwey LW 15/55	1	55	15,6	
	Lagerwey LW 15/75	42	45 to 75	15,6	
	Kano-Rotor 30	23	30	12,1 to 13,4	
	total/average	235	33,32	12,15	

SWT models in the WMEP

SWT in the WMEP	< 200 m^2	< 40 m^2
number	205	30
with replacement	68	5
nacelle	6	0
set of blades	43	2
hub	22	2
gear box	8	1
generator	42	4
yaw motor	7	0
tower	1	0
control system cabinet	2	1
transformer	1	0

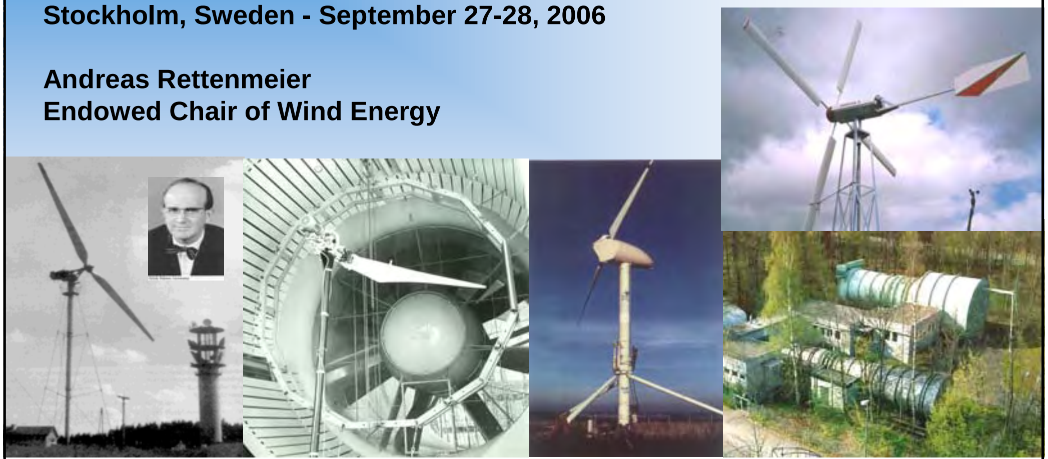
Replacement of main components (SWT in the WMEP)

ISET

Small Wind Turbines
- Research & Teaching at Universität Stuttgart

Stockholm, Sweden - September 27-28, 2006

Andreas Rettenmeier
Endowed Chair of Wind Energy



Contents

- Presentation of the „Endowed Chair of Wind Energy“ (SWE) and „Institute of Aerodynamics and Gas Dynamics (IAG)”
- Facilities at the University of Stuttgart
- Measurements on small wind turbines at the example of the 1,5kW turbine “HAWIAN” in the course „Wind Energy Lab“
- Conclusions

Endowed Chair of Wind Energy (SWE)

- First German wind energy chair
- Director: Prof. Dr. Martin Kühn
- Established in January 2004
  by Public-Private-Partnerships
- Currently 10 employees, growing
- Located at Institute of Aircraft Design

SWE: Research focus

1. Composite structures: Design and manufacturing
2. Load monitoring, control & operation
3. Structural dynamics incl. offshore

2005

Wind energy R&D at Stuttgart pioneering until end of 1980's, spin-off for industrial development in north of Germany and Europe during 1990's

Institute of Aerodynamics and Gas Dynamics (IAG)

- Founded 1946
- Currently 65 employees (wind: 5), 9 branches
- Extensive theoretical and experimental research activities on fluid dynamics, aerodynamics, aeroacoustics and aeroelasticity
- Sustained tradition in airfoil design & testing for wind turbine application
- 11 wind and water tunnels (laminar wind tunnel, gust wind tunnel, large supersonic wind tunnel, ...)

IAG: Research focus

1. Development & application of CFD, CSD and CAA methods
2. Airfoil design & aerodynamic/aeroacoustic verification
3. Basic research on boundary-layer transition and turbulence

Wind turbine test facility at university

Measurements of

- small WEC in gust wind tunnel (IAG), e.g. power curve

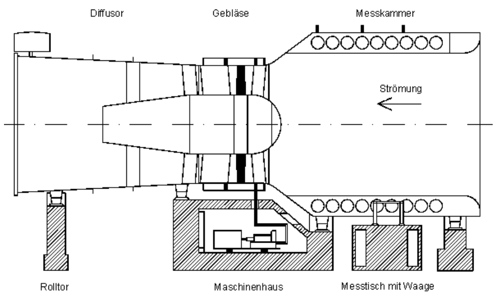
- rotor blade profiles in laminar wind tunnel (IAG)

Development of new rotor blade profiles, especially for low Reynolds number possible, e.g. in history: F.X. Wortmann and D. Althaus
Student course: „profile design“, Thorsten Lutz

gust and laminar wind tunnel

Wind turbine test facility at university

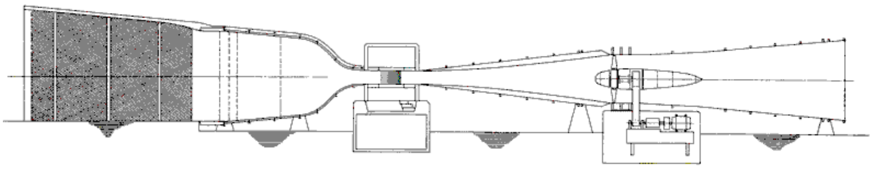
Gust wind tunnel at Institute of Aerodynamics and Gas Dynamics



Max. wind speed:	**17m/s**
Fan:	**Propeller diameter 5.6m, rotational speed up to 190rpm**
Drive:	**AC motor 315kW, hydraulic aggregate, hydraulic motor in the hub**
Total length:	**21.9m**
Metering chamber:	**diameter 6.3m, length approx. 6.5m (at present extension)**

Wind turbine test facility at university

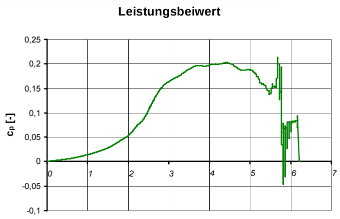
Laminar wind tunnel at Institute of Aerodynamics and Gas Dynamics



Maximum speed:	**90m/s**
Maximal Reynolds number:	**5 x 10^6 (1m chord length of the model)**
Turbulence level:	**2 x 10^{-4} to 5 x 10^{-4}**
Fan:	**8-petalled, diameter 2.7m , rotor blade angle variable**
Mechanical drive:	**DC motor 220kW, thyristor controlled speed control**
Length:	**46m**
Cross section of wind tunnel:	**2.73m x 0.73m = 2m²**
Area of filter pad:	**200m²**
Area of screens:	**40m²**
Contraction ratio:	**100:1**

Speeding-up test in wind tunnel test with students

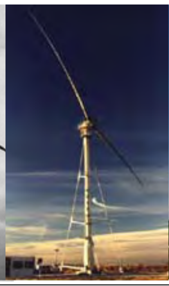
Power curve measurement within 3 minutes



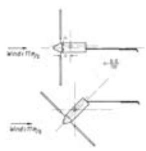
Wind turbine test facility outside university

Schnittlingen, Swabian Alb, 700m above sea level,
70 km from university

- **Existing infrastructure for additional small WEC (e.g. universal foundation)**
- **20m wind met masts**
- **UNIWEX experimental turbine (dismantled, retrofit required)**
- **DEBRA-25 wind turbine (dismantled)**

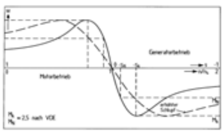


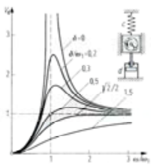
Measurements on small wind turbines at the example of the 1,5kW turbine "HAWIAN" in the course „Wind Energy Lab"



Topics

- **Rotor blade : eigenfrequencies**
- **Generator: speed-torque characteristics**
- **Power limitation and power control**
- **Power curve (Gust Wind Tunnel)**
- **Tower eigenfrequencies**





General information to HAWIAN 4

Horizontal-
Achsige-
WIndenergie-
ANlage

- Power: 1,5kW
- Rotor diameter: 4m
- Eclipse control
- Year of manufacture: 1983

Components of the small WEC HAWIAN 4

Azimuth bearing & rotor hub

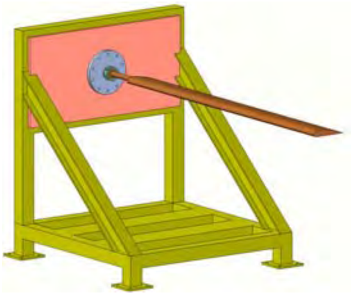
Rotor blades

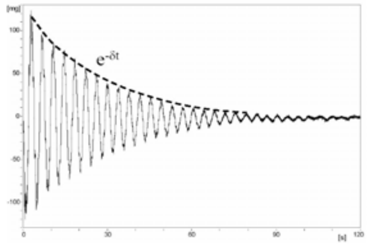
Wind vane

Generator with drive train

El. Circuit

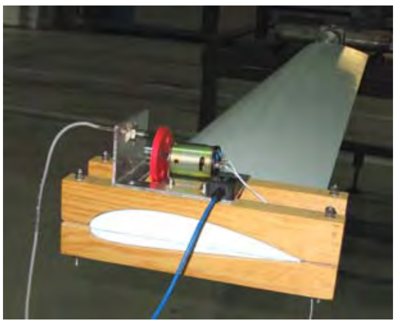
Rotor blade: Determination of 1st eigenfrequency with static bending line



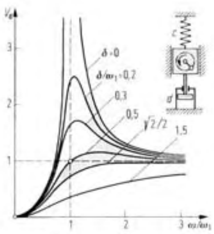


Tasks:
- **Determination of damping coefficient**
- **Static bending line and eigenfrequencies (Petersen)**

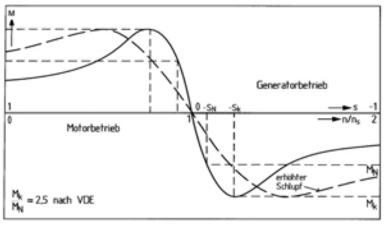
Rotor blade: Determination of eigenfrequencies and transfer function

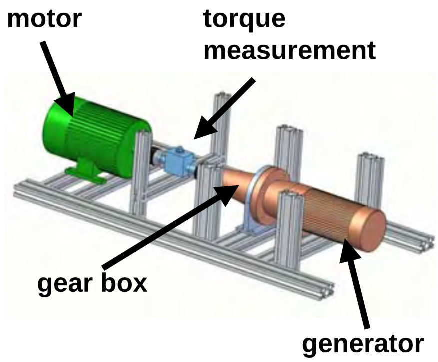


- **Fixed rotor blade**
- **Excentric to bring up dynamic load**
- **Rotational frequency measurement (motor)**
- **Acceleration measurement (blade)**



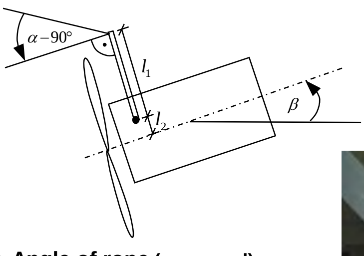
Generator: Torque characteristics





Power limitation and power control

- **Effectiveness of eclipse control**
- **Determination of restoring force of wind vane**
- **Estimation of simulated wind speed**

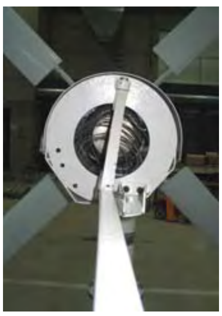


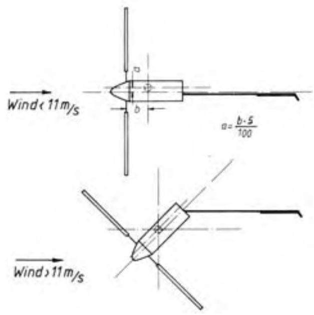
α: **Angle of rope** (measured)

β: **Angle of twist** (measured)

l_1: **Lever arm**

l_2: **Excentricity**





Power curve and tower eigenfrequencies: HAWIAN 4 goes „gust wind tunnel“

1984

Again in 2007 ?

Comparison of measured and simulated values

Simulation Software used

- at SWE: FLEX 5, Simpack, Bladed
- in course: Bladed
  - Rotor blade
    - Eigenfrequencies
    - Damping coefficient
  - Power curve

Conclusions

- **Testing of small WEC possible at Stuttgart University:**
  - **Gust and laminar wind tunnel**
  - **Test site „Schnittlingen“**
- **Simulation and measurement of small WEC like the „big ones“ possible and necessary**

Contact

- **Endowed Chair of Wind Energy**
  http://www.uni-stuttgart.de/windenergie
  Allmandring 5b, 70567 Stuttgart, Germany
  - **Director:** Prof. Dr. Dipl.-Ing. Martin Kühn
  - **Test Site Schnittlingen:** Dipl.-Ing. (FH) Andreas Rettenmeier

- **Institute of of Aerodynamics and Gas Dynamics**
  http://www.iag.uni-stuttgart.de
  Pfaffenwaldring 21, 70569 Stuttgart, Germany
  - **Director:** Prof. Dr.-Ing. Ewald Krämer
  - **Gust / Laminar Wind tunnel:** Dr.-Ing. Werner Würz

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Reliability for Small Wind Turbines

Jim Green
jim_green@nrel.gov

September 27-28, 2006
IEA Topical Expert Meeting
Stockholm, Sweden

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National Wind Technology Center (NWTC)

- National Renewable Energy Laboratory
- U.S. Department of Energy, Wind Technology Program
  - Research, analysis, modeling, component testing, system testing, applications

Reliable Long Life

"Technical failures and excessive maintenance should be reduced."

- Relevant test capabilities at the NWTC
  - Dynamometer testing
  - Thermal imaging
  - Blade ultimate strength testing
  - Blade fatigue testing

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NWTC 225-kW DYNAMOMETER

- ~ 25 year old facility upgraded with 225 kW drive motor in 2006
- Electric services available:
  - 480 VAC, 3-phase, 60 Hz, 250 kVA
  - 120/240 VAC, 1-phase, 60 Hz, 50 kVA
  - Battery bank simulation, 20 kVA (voltage-controlled DC bus)
- Testing of generators/alternators, gearboxes, power electronics, control systems, & software
- *225-kW Dynamometer for Testing Small Wind Turbine Components* (June 2006, Green) *http://www.nrel.gov/docs/fy06osti/40070.pdf*

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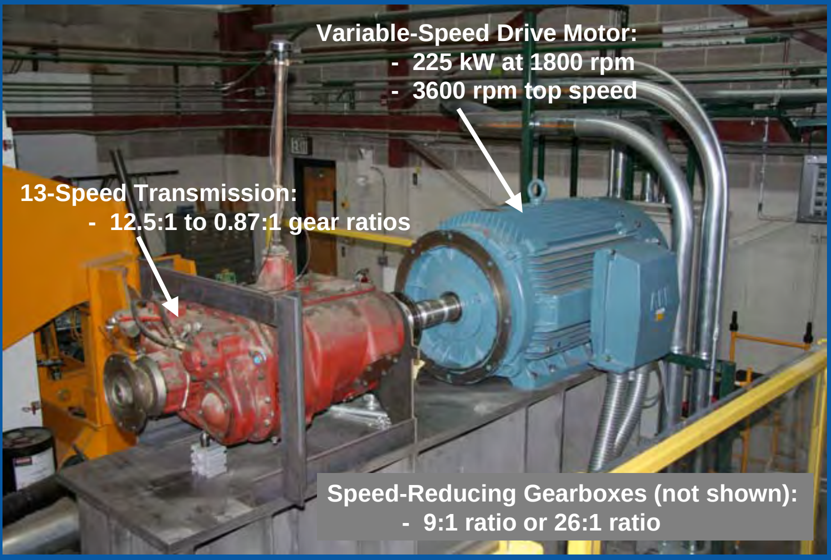
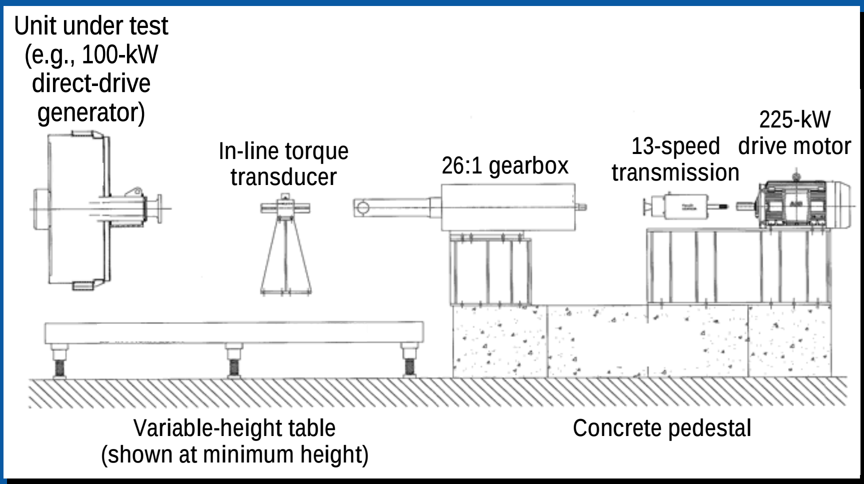
NWTC Dynamometer Components

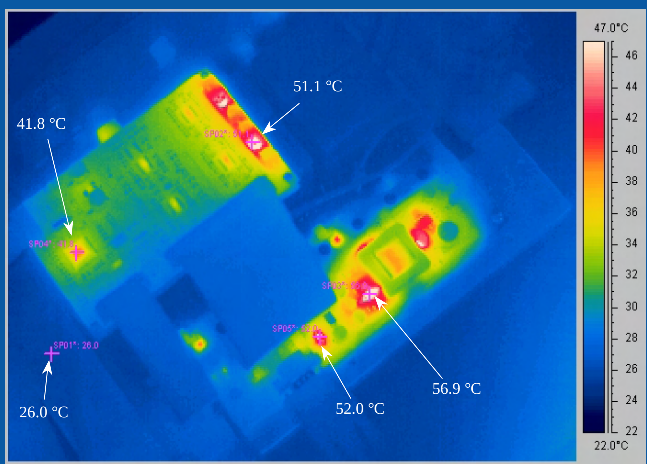


NWTC Dynamometer: Example Configuration



IR Thermal Imaging

Thermal image of prototype small wind turbine inverter



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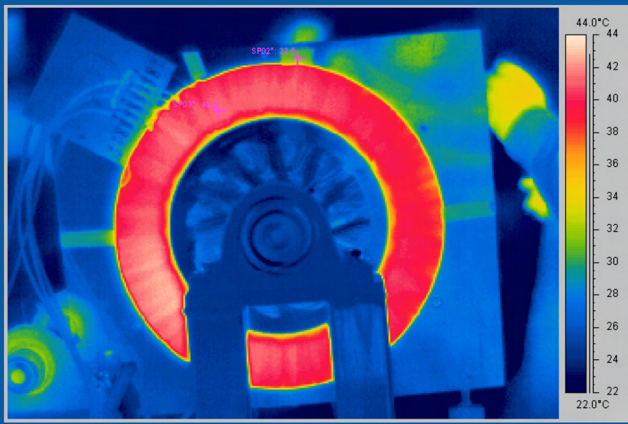
IR Thermal Imaging

Thermal image of prototype small wind turbine alternator



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IEC Testing at the NWTC

- The NWTC is accredited per ISO 17025 to conduct IEC-compliant testing:
  - Mechanical Loads, IEC 61400-13
  - Static Blade, IEC 61400-23

ACCREDITED
Certificate Number 1239-01

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Blade Ultimate Strength Testing

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Blade Fatigue Testing

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Questions/Issues

- How can dynamometer testing be used more effectively to improve reliability?
  - Accelerated life testing for components analogous to blade fatigue testing?
  - How can we test for 20-year life of alternators, gearboxes, power electronics, bearings, etc.
- Should we be doing ultimate strength and/or fatigue testing of towers? of foundations?

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Reliable Performance

"Published power curve, production and noise data should be reliable."

- Manufacturer's performance data has been unreliable, may be based on:
  - analytical predictions, extrapolations from other turbine models, wind tunnel data, self-testing with small data sets, etc.
- Wind turbine ratings are arbitrary
  - Incentives programs are often structured to encourage higher values of rated power
  - Competition with PV, priced as $/kW, has similar effect

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IEC Testing at the NWTC

- The NWTC is accredited per ISO 17025 to conduct IEC-compliant testing:
  - Power Performance, IEC 61400-12
  - Acoustic Noise, IEC 61400-11
  - Power Quality, IEC 61400-21

ACCREDITED
Certificate Number 1239-01

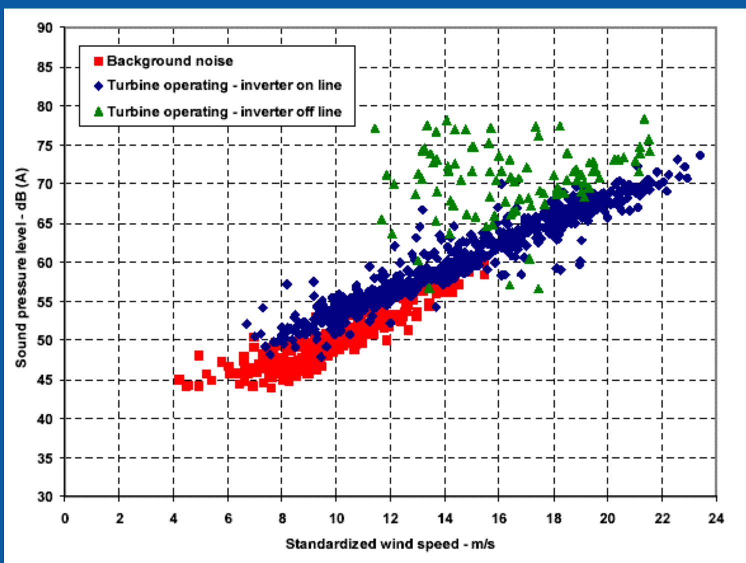
Power Performance, IEC 61400-12

- IEC 61400-12, Power Performance, includes Annex H on “Power Performance Testing of Small Wind Turbines”
  - Averaging time (1 min in place of 10 min)
  - Prescribed battery voltage for testing battery charging wind turbines

Acoustic Emissions

- IEC working group MT11 is currently making revisions to IEC 61400-11, Acoustic Emissions.
- MT11 is considering a new annex to address measurements for small turbines, may include:
  - Shorter averaging periods (10 sec in place of 1 min)
  - Measured wind speed (in place of power)
  - Binned data analysis (in place of regression)
  - Data at winds speeds >10 m/s where power/speed control functions are active

Bergey Excel-S Noise



Proposed AWEA Standard

- A draft standard has been proposed to AWEA: “AWEA Small Wind Turbine Performance and Safety Standard”
- “…to provide consumers with realistic and comparable performance ratings…”
  - Rated power at 11 m/s per IEC power curve
  - Rated annual energy at 5 m/s per IEC power curve (hub height, sea level, etc.)
  - Rated sound level at 60 m distance, not exceeded 95% of the time
  - Does not require 3rd party testing, only review of test reports

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Site Assessments?

- State of Wisconsin has a “Renewable Energy Site Assessment” program to evaluate suitability of specific sites for renewable energy applications:
  - Apply using on-line form
  - Preliminary screening via phone interview
  - Site visit by certified, professional assessor who delivers written report
  - Cost is $300-400, subsidized 60% by the state
  - Assessors report required for state 25% incentive program
- http://www.focusonenergy.com/page.jsp?pageId=1712

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Questions/Issues

- Need for a standard, widely-accepted method for specifying “rated power”
- How to make acoustic data more user-friendly?
- How to make wind turbine performance claims credible and reliable without imposing an unreasonable cost burden on manufacturers?
- Importance of site-specific factors on wind turbine performance?
- Future of proposed AWEA standard?

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Reliable Safety

“Appropriate safety standards followed and accidents avoided.”

- IEC 61400-2 is the best available means for documenting safe design of small wind turbines
- No IEC certification agent in the U.S.
  - UL was preparing to do this, then backed away
- U.S. marketplace is not yet requiring certification
- Cost of the IEC certification process remains a significant concern
- Various UL standards are used to verify electrical safety

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Proposed AWEA Standard

- A draft standard has been proposed to AWEA: "AWEA Small Wind Turbine Performance and Safety Standard"
- "…to provide consumers with a measure of confidence in the quality of small wind turbine products…"
  - Invokes a subset of the requirements in IEC 61400-2 (unstated goal to reduce cost of compliance)
  - Both design evaluation and duration test required
  - Tower designs are not evaluated, defer to building permit process
  - IEC-certified turbines would be considered compliant with this standard?

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Questions/Issues

- Lack of U.S.-based IEC certification agent
- High cost of IEC-compliant certification
- Future of proposed AWEA standard?

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Reliability: Legal to Use

"The buyer should not have to face the risk of buying a product that is illegal to operate."

- Zoning
- Construction permits
- Interconnection

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U.S. Zoning Basics

- Zoning is one form of land use law
- Laws in each of the 50 states delegate zoning authority to local jurisdictions: "Home Rule"
  - counties, parishes, boroughs, municipalities, townships, cities, villages, etc.
- *Zoning for Distributed Wind Power: Breaking Down Barriers* (August 2005, Green and Sagrillo)
  - *http://www.nrel.gov/docs/fy05osti/38167.pdf*

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How Many Local Jurisdictions?

- 3,034 counties (National Association of Counties)
- 16,504 townships
- 19,429 municipalities (National League of Cities)

Total: 38,967

Estimated # of local zoning jurisdictions:
15,000-20,000

Zoning

- Limits on heights of structures (35 ft, 11 m) are common
  - Obtain a "Variance" or a "Special Use Permit" (permission to violate the zoning code on <u>one</u> property)
  - Public hearing process can cost thousands of dollars and take several months
- The primary opportunity for small wind turbines will be in rural and less-densely-populated areas
  - Favorable zoning
  - Wind resource
  - Larger properties
- Cost, delay, and antiquated zoning rules are ongoing problems in some locations

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Construction Permits

- Permitting is done locally, every jurisdiction is unique
- Two primary types of permits:
  - <u>Building Permit</u>: evaluation of structural safety of the tower and foundation, often based on the International Building Code
  - <u>Electrical Permit</u>: evaluation of electrical safety, usually based on the *National Electric Code* (National Fire Protection Association)

Interconnection to the Utility Grid

- Compliance with nationally accepted standards to ensure safety and acceptable power quality
- 1547-2003, *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*
  - Response to abnormal conditions or grid outages, synchronization, grounding, power quality, etc.
- UL 1741, *Inverters, Converters, and Controllers for Use in Independent Power Systems*
  - Test protocol to verify compliance with 1547-2003
- *National Electric Code* (National Fire Protection Association)
  - Electrical safety of the installation

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Questions/Issues

- How best to alleviate zoning barriers to small wind turbines on a state or national basis?

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The Dynamic Wind Power Captureability of a High Performance SHWT : Zephyr’s “Airdolphin”

Hikaru Matsumiya
Prof., Department of Mechanical Engineering Science, Kyushu University, Japan*
Ryosuke Ito
President, Zephyr Corporation, Japan**
Chuichi Arakawa
Prof., Department of Mechanical Engineering, The University of Tokyo, Japan***
Makoto Iida
Dr. Eng, The University of Tokyo, Japan****
Junko Nakayama
President, Zephyr Corporation, Japan**

IEA TASK XI 2006.SEP Sweden “Challenges of Introducing Reliable Small Wind Turbines”

Contents

- High Performance
  = High “*Captureability*”
- “*Airdolphin*”, a high performance SHWT, developed

Introduction

Small wind turbines are considered
- **Low performance**
- **Unreliable**
- **High cost (per kW)**

But,they have huge potential for wind power generation !

IEA TASK XI 2006.SEP Sweden “Challenges of Introducing Reliable Small Wind Turbines”

Project Team

- Zephyr :

⇒ “Unless small wind turbines could offer performance far exceeding current standards, they would never be a future chance to be a viable alternative energy source.”

- AIST Wind Energy Group :

⇒ “A small wind turbine is not only for a small remote island or for domestic use, but also for huge worldwide lands, just because it produces clean energy without any emission such as CO2 without any fuel.”

- Started Project Team in 2002

⇒ AIST, Kyushu Univ., Univ. Tokyo, Zephyr, ・・・・・・・

Airdolphin

Item	Feature
Type	3-bladed, upwind-type HAWT
Rotor diameter	1.8 m
Blade material and mass	Full carbon fiber and 380 g per blade
Cut-in / Cut-out wind speed	2.5 m/s(with power assist function) / 50 m/s
Rated / Maximum power	1 kW (12.5 m/s) / 3.2 kW (20 m/s)
Generator	Permanent magnetic, 3-phase induction type
Brake	Stall regulation and electro-magnetic blake
Yaw control	Swing rudder system

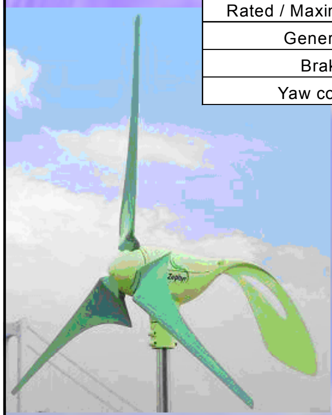
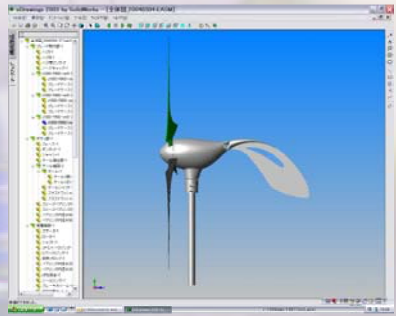
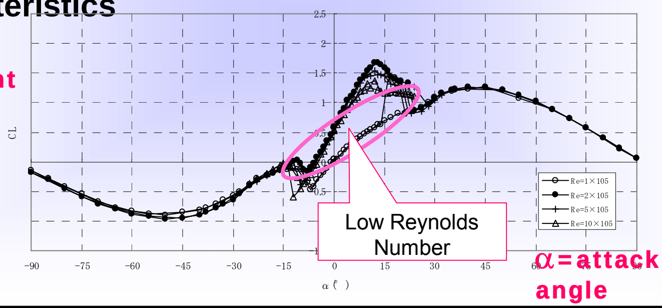


Fig.1 1kW SHWT Airdolphin



Aerodynamic characteristics:
High Performance Rotor

- **Multi-stagger design to achieve high start-up at low wind speed region**
- **Light and strong full-carbon blades to attain high reponse**
- **Thin aerofoil sections to reduce the aerodynamic problem of low Reynolds number**
- **Power assist function to improve start-up characteristics**



Brake system

Without reliable brake system, no high operation mode above 30 m/s up to 50 m/s is possible.

Thanks to the rigid carbon blades, the rotor has no cut-out speed, which means Airdolphin may work under storms.

However, the rotor and the generator shall be prevented from over speed and over current.

This was attained by dual measures; aerodynamic stall regulation and electro-magnetic braking function, both of which keep the operation active, producing power under high wind speed range without shutdown action.

Control systems

- *Power assist function for start-up*
- *Aerodynamic stall regulation and electro-magnetic braking function for power control*
- *swing rudder system for yaw control*

The tail wing is hinged free to swing flexible under random wind direction change.

This was experimentally shown to work quite smart.

Truck Tests

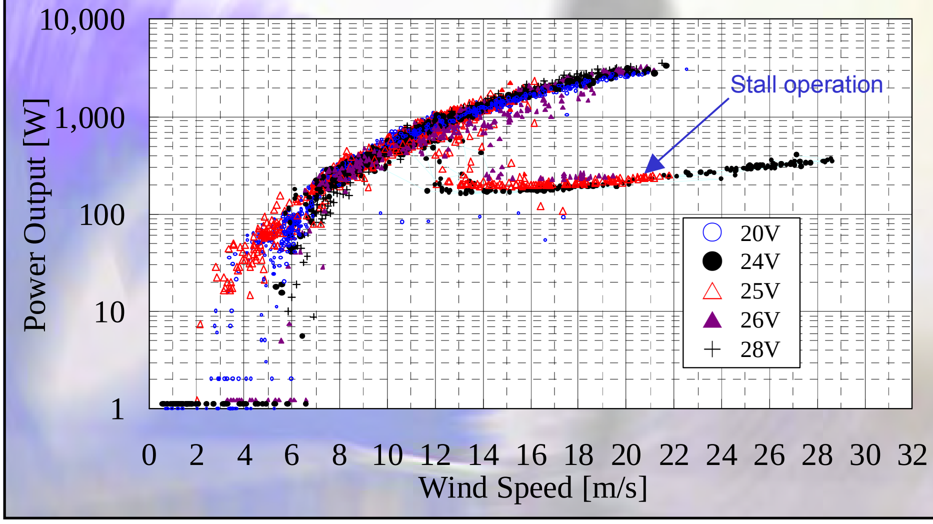
Fig.3 Track test

The performance is obtained by track tests.

The vehicle can run up to 30 m/s which is the relative wind speed that flow into the wind turbine on the vehicle.

A data acquisition system on the vehicle collects all the operational data of the wind turbine.

Power Curve by Truck Test



Capacity Factor and Captureability

Capacity Factor (CF):

$$CF \equiv \frac{G}{G_R} \qquad (1)$$

$$G = T\int_0^{\infty} \frac{1}{2}\rho V^3 \cdot C_P(V) \cdot A \cdot f(V)\, dV$$

$$G_R = P_R \times T = \frac{1}{2}\rho V_R{}^3 \cdot C_P(V_R) \cdot A \cdot T$$

$$CF = \int_0^{\infty} \left(\frac{V}{V_R}\right)^3 \cdot \frac{C_P(V)}{C_P(V_R)} \cdot f(V)\, dV$$

CP is not absolute index of wind turbine performance, because CP can be increased if a low-speed wind turbine (low V_R) is installed at high wind speed site.

Captureability

Captureability (CPT) is an another index that represents ability how much ratio a wind turbine can capture energy from the wind.

$$CPT \equiv \frac{G}{E}$$

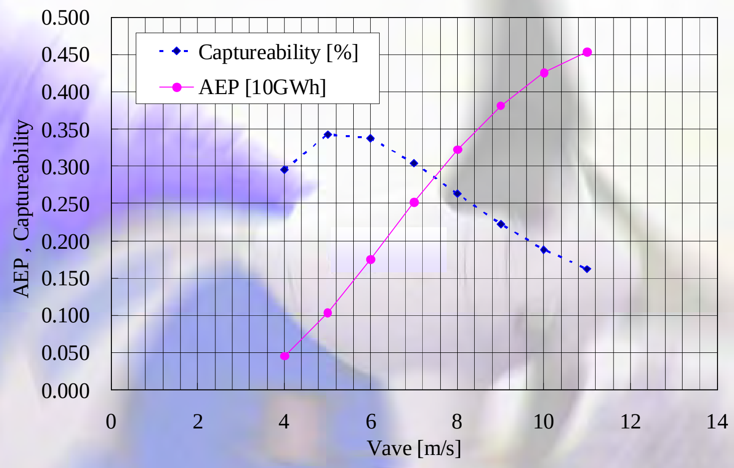
$$G = T\int_0^{\infty} \frac{1}{2}\rho V^3 \cdot C_P(V) \cdot A \cdot f(V)\, dV$$

$$E = T\int_0^{\infty} \frac{1}{2}\rho V^3 \cdot A \cdot f(V) dV$$

$$CPT = \frac{\int_0^{\infty} V^3 \cdot C_P(V) \cdot f(V) dV}{\int_0^{\infty} V^3 \cdot f(V)\, dV} \qquad (7)$$

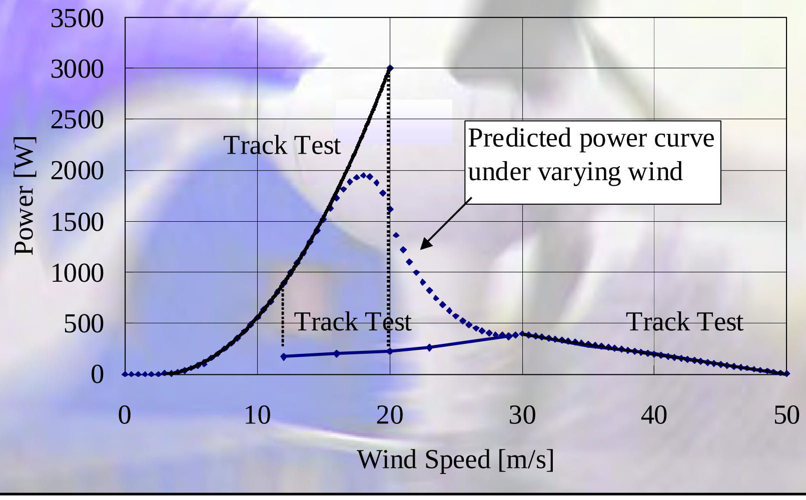
“Captureability” will give more direct and concrete evaluation of the performance of a wind turbine than Capacity factor.

Sample Data of Captureability



Sample data of captureability for a 1-MW turbine given in IEC 61400-12-1. Max CPT is 0.35 at the site of V_{ave}=5.5 m/s. Rayleigh distribution is assumed.

Predicted Power Curve under natural wind



IEA TASK XI 2006.SEP Sweden "Challenges of Introducing Reliable Small Wind Turbines"

Captureability of Airdolphin

Vave	Airdo phin Mark-Zero	Airdolphin-Conservative	Reference from IEC
4	0.323	0.322	0.296
5	0.340	0.336	0.343
6	0.334	0.319	0.337
7	0.315	0.284	0.305
8	0.286	0.245	0.263
9	0.252	0.206	0.223
10	0.217	0.171	0.189
11	0.183	0.140	0.162

Captureability of Airdolphin Mark-Zero, Airdolphin conservative and Reference data from IEC Document under Rayleigh distribution

Operation Mode of Airdolphin Conservative : Cut-in/rated/cut-out wind speeds are given as 2.5 /s, 12.5 m/s and 25 m/s, respectively. Also 1 kW max. power is assumed.

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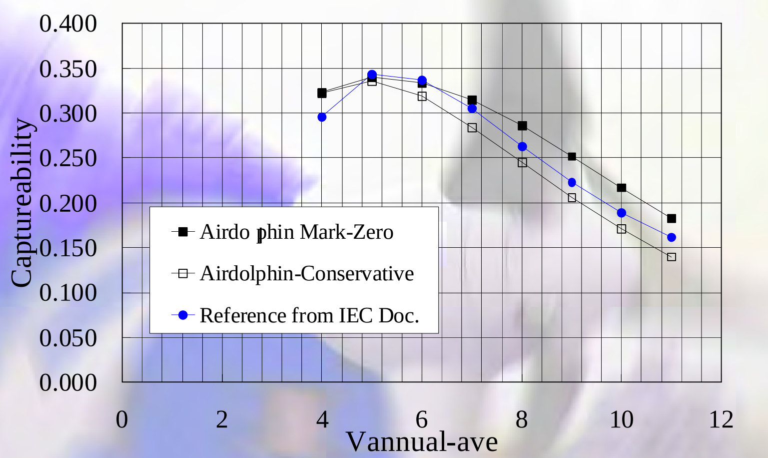
Captureability of Airdolphin



Captureability of Airdolphin Mark-Zero is superior than other two as V_{ave}incleases. At a site of Vave=9 m/s, its AEP is 22 % higher than the conservative and 13 % than the Reference machine.

Dynamic Captureability

“Dynamic” Captureability means the ability to capture energy from turbulent wind by daynamic response of the turbine.

Let , $V(t) = \overline{V} + v(t),\ \overline{V} = \text{mean wind speed}$

a simple statistical calculation will give the following formula:

$$E[V^3(t)] = \overline{V}^3 (1 + 3 \cdot TI^2),\ TI = \text{turbulence intensity}$$

The statistically expected value of $E[V^3(t)]$ will capture more by $3 \cdot TI^2$ %.

If TI=0.248 (V=7 m/s, category A, IEC): 18.5 % incraease of AEP.

This will compensate the energy loss by yaw error. (Dynamic captureability)

Round Robin Testing

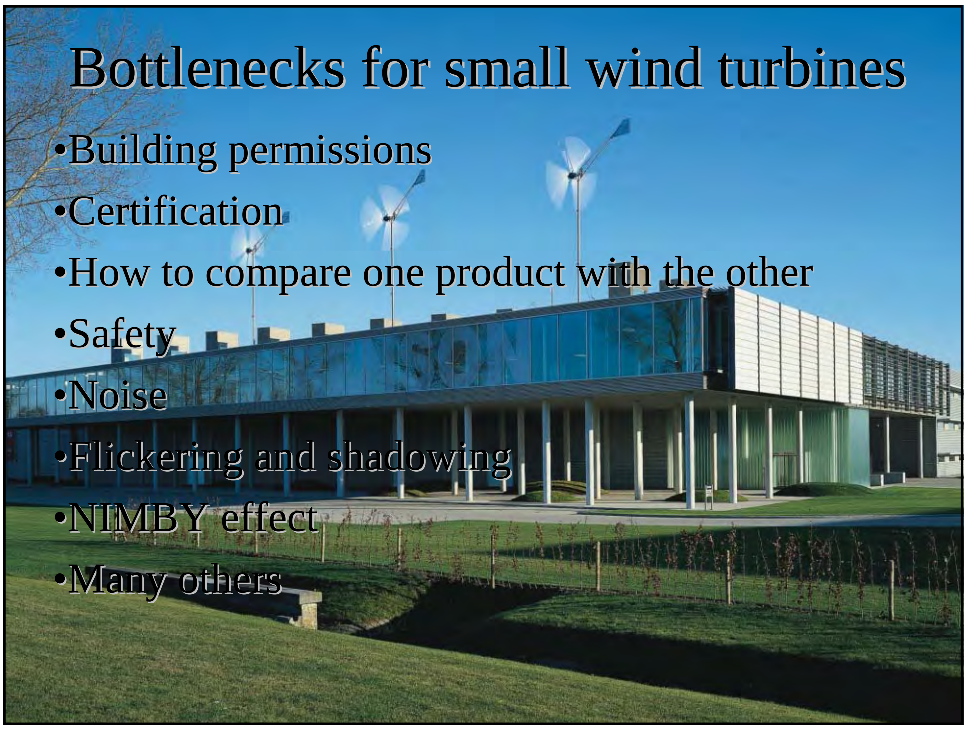
- Demo. sites:
  - Spain, China, Bulgaria,Scotland, Italy, Japan
- Zephryr’s Web Page:
  - Live camera
- Round Robin Testing
  - CIEMAT
  - Kyushu University
  - University of Tokyo
  - Zephyr Corporation
- Purpose;
  - Field tests, Demonstration

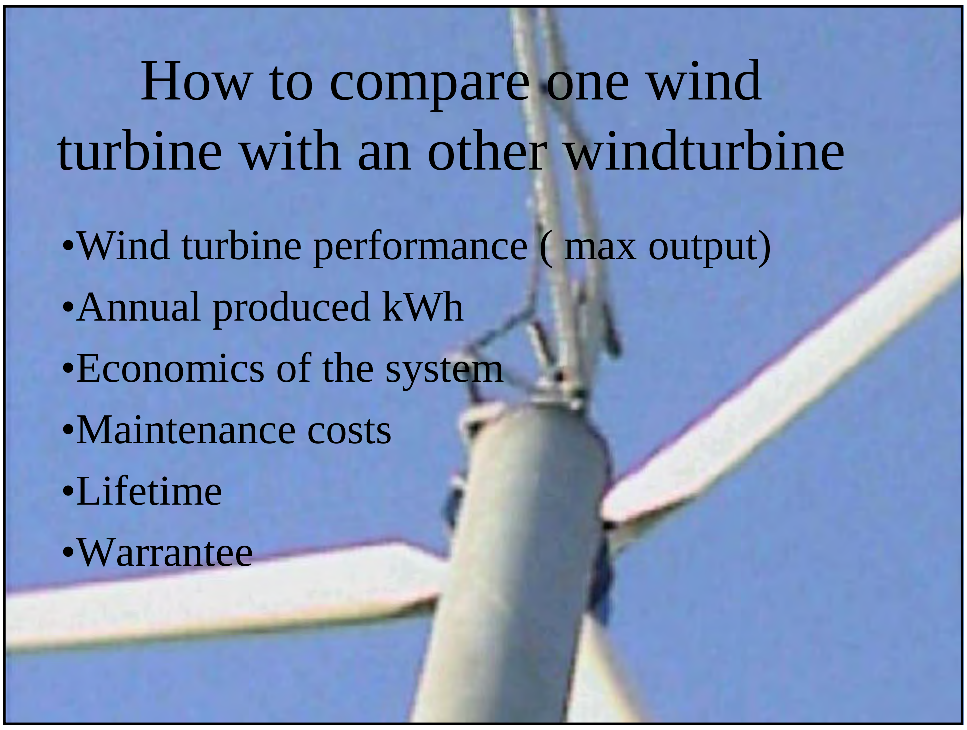
Conclusion

- Captureability proposed:
  A direct and simple index of WT performance
- High-performance SHWT developed:
  "Airdolphin" 1kW,1.8m
- Truck test performed:
  High captureability expected
- International Round Robin Test Program soon start

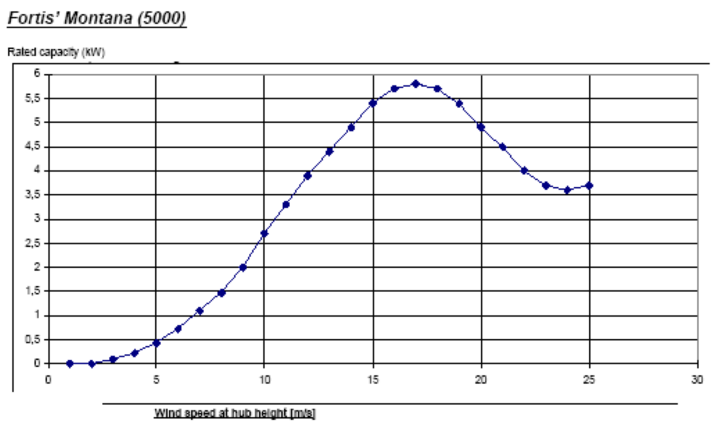

Micro generation
*Private generation with a.o. windturbine
*Rooftop wind turbines
*Stand alone systems
*Urban wind turbines


Fortis windenergy Netherlands
* Production of small wind turbines between 0,8 kW and 10 kW
* 30 years of experience
* Over 6000 units produced and installed world wide
* 5 years warrantee
* Applications as: stand alone, grid connected, water pumping, wind/diesel and wind/PV systems, telecom, a.o.

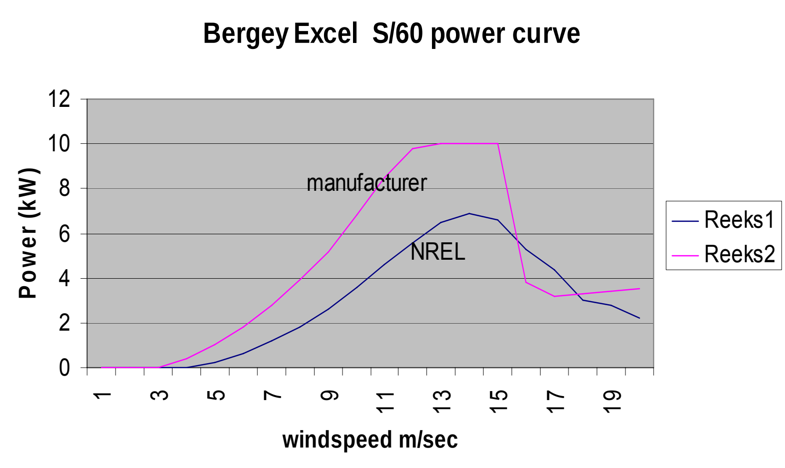

Bottlenecks for small wind turbines
•Building permissions
•Certification
•How to compare one product with the other
•Safety
•Noise
•Flickering and shadowing
•NIMBY effect
•Many others

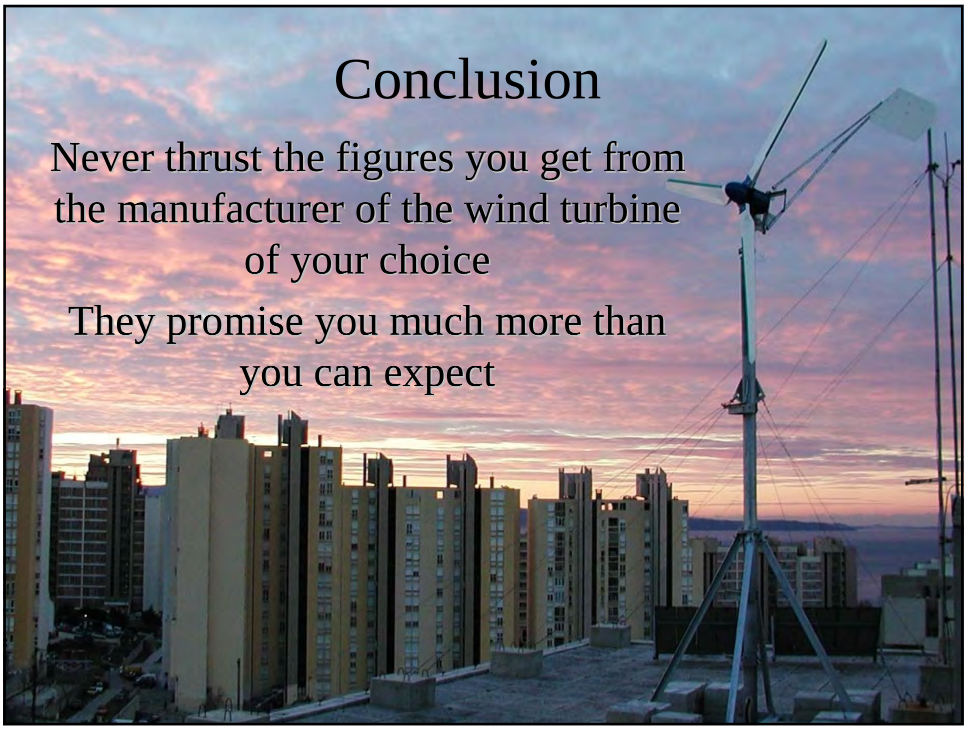

How to compare one wind turbine with an other windturbine
•Wind turbine performance (max output)
•Annual produced kWh
•Economics of the system
•Maintenance costs
•Lifetime
•Warrantee

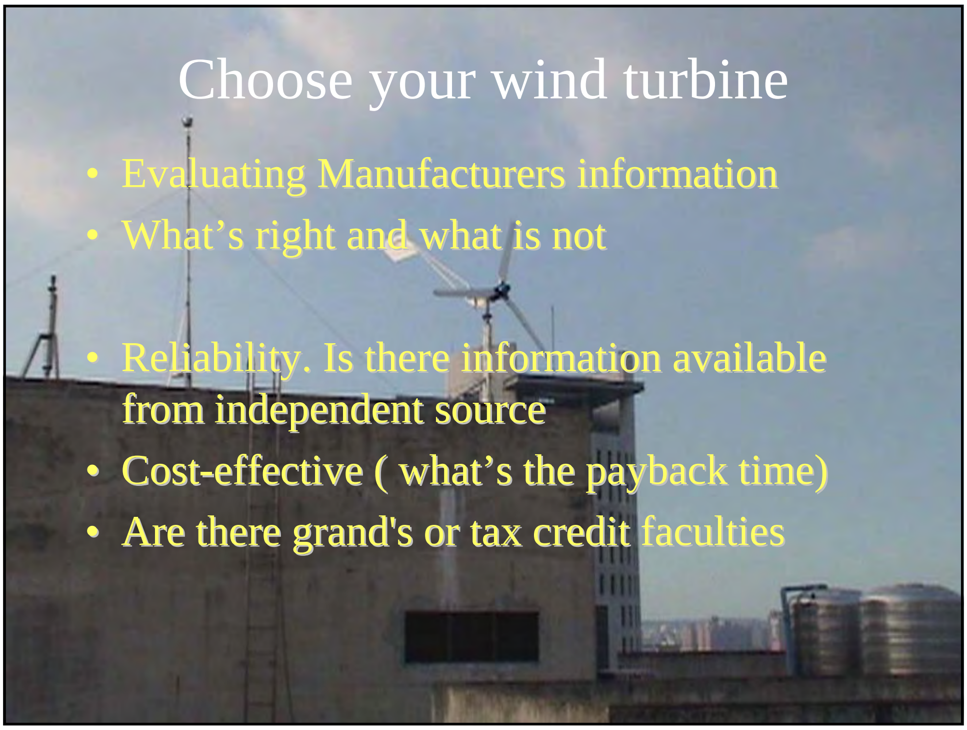
Wind turbine performance

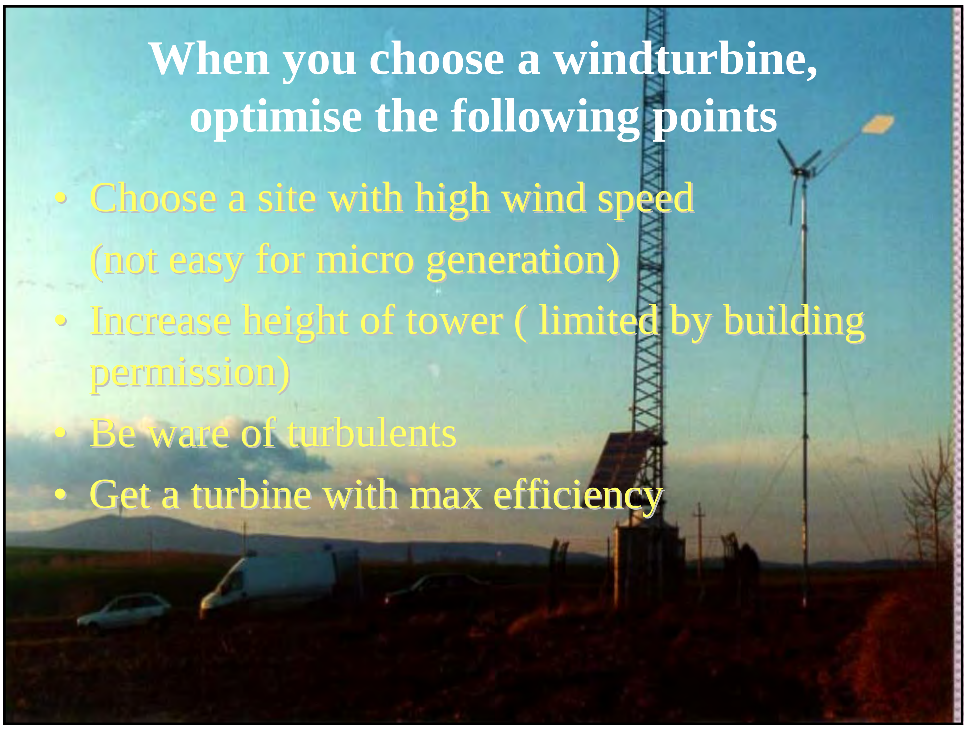


$P = Cp \cdot 0{,}5 \cdot rho \cdot V^3 \cdot A$




Conclusion
Never thrust the figures you get from the manufacturer of the wind turbine of your choice
They promise you much more than you can expect


Choose your wind turbine
• Evaluating Manufacturers information
• What’s right and what is not
• Reliability. Is there information available from independent source
• Cost-effective (what’s the payback time)
• Are there grand's or tax credit faculties



Different concepts of wind turbines

Fortis Montana

Horizontal axis windturbine

5 m rotor diameter

Different concepts of wind turbines

Provane

Horizontal axis windturbine

5 m rotor diameter

Different concepts of wind turbines

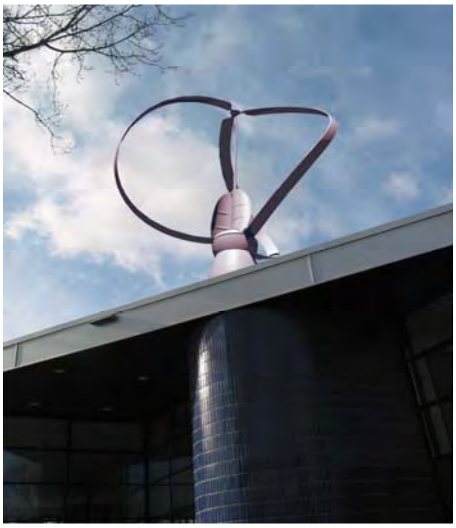
Turby

Vertical axis wind turbine

Darrieus rotor type

Annual output 5000 kWh/y

Different concepts of wind turbines



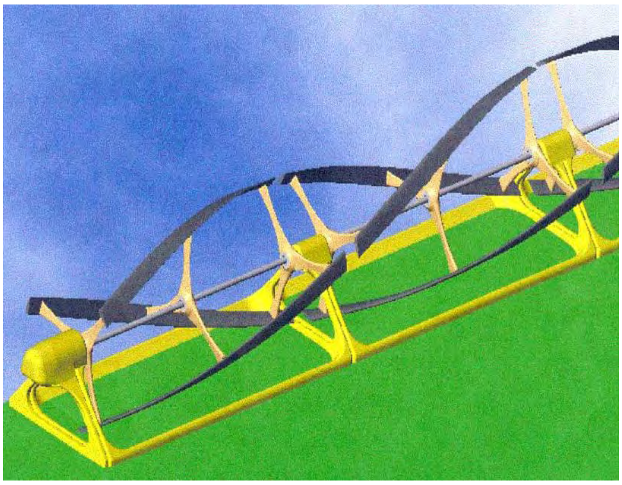
NEOGA Ecofys

Vertical axis wind turbine

Darrieus rotor

3 m diameter

Different concepts of wind turbines



Windwall

Horizontal axis Windturbine

Darrieus rotor

Different concepts of wind turbines

Windside
Turbines
Vertical axis
Savonius
type

Performance overview

	power	diameter	surface	Power/m^2
Montana	5,6 kW	5,0 m	19,6 m^3	285 W/m^2
Provane	2 kW	5,0 m	19,6	102
Tulipo	2,5 kW	5,0 m	19,6	127
Turby	1,5 kW	2,65 x 2,0	5,3	283
Neoga	2,0 kW	3,0 m	5,4	370
Windwall	4,0 kW	1,2 x 14,4	17,3	231
Windside	0,2 kW	1,02 x 2m	2,04	83

More figures

Compare with other wind turbine and PV

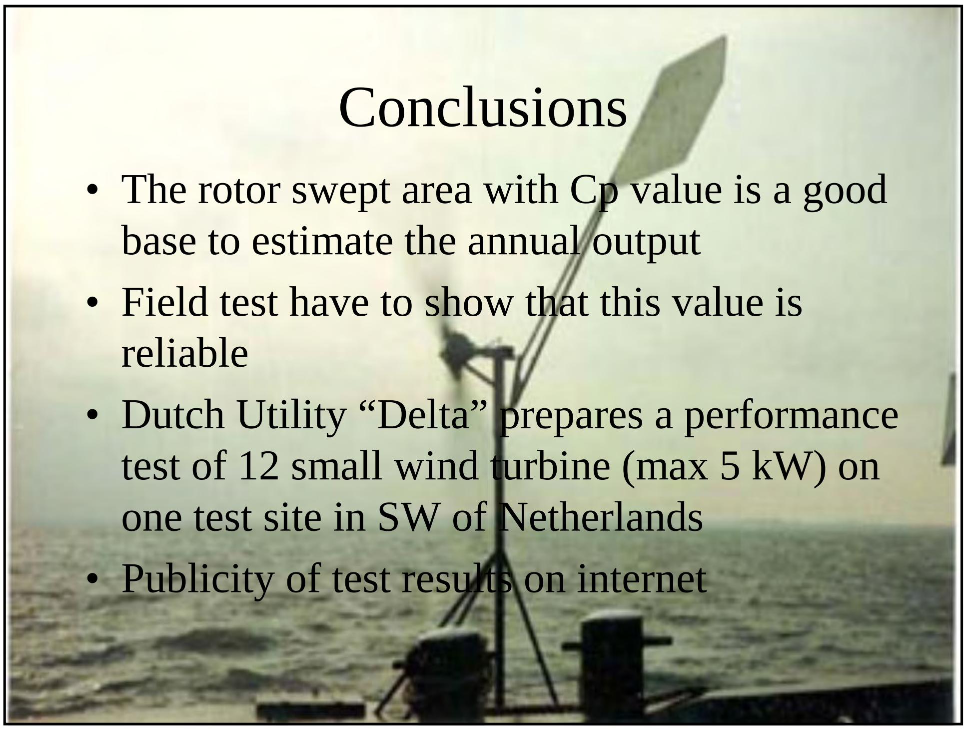
Vestas	V66-1.65	3.422 m^2	1650 kW	482 W/m^2
Lagerwey	LW18/80	255 m^2	80 kW	314 W/m^2
PVmodul		1 m^2	115W	115W/m^2

Annual energy production

Windturbine type	**Rotor surface m^2**	**Max Cp value**	**Annual energy production kWh**	**Annual energy kWh/m2**
Montana	19,6	0,4	3000-9800	153 - 500
Provane	19,6	0,4	3000-9800	153 - 500
Tulipo	19,6	0,4	3000-9800	153 - 500
Turby	5,3	0,3	600-1980	110 - 375
Neoga	5,4	0,3	600-2025	110 - 375
Windwall	17,3	0,3	1550-5200	90 - 300
Windside	2,04	0,1	20 -30	10 - 15

More figures

Windturbine type	**Rotor surface m^2**	**Max Cp value**	**Annual energy production kWh**	**Annual energy kWh/m2**
Vestas V66-1.65	3422	0,5	$1{,}7 – 3{,}4.10^6$	500 - 1000
Lagerweij LW18/80	255	0,4- 0,5	$75 – 180.10^3$	295 - 700
PV modul	1	0,12-0,18	60 -80	60 -80



Conclusions

- The rotor swept area with Cp value is a good base to estimate the annual output
- Field test have to show that this value is reliable
- Dutch Utility “Delta” prepares a performance test of 12 small wind turbine (max 5 kW) on one test site in SW of Netherlands
- Publicity of test results on internet

Small wind in Ireland

L. D. Staudt

Centre for Renewable Energy at Dundalk Institute of Technology

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"Experiences in the field"

- 1200 small wind systems in the 1980s with Enertech (USA)
- Small wind R&D
- Wind autoproduction (Vestas V52 on campus)
- Electricity storage R&D
- Consultancy (small and large wind)
- MSc in Renewable Energy Systems
- "Installer academy" for small RE systems

Small wind in Ireland

- Only battery charging systems until very recently
- Grid connection previously not allowed
- Massive wind resource, great interest in small grid-connected wind systems
- <10 grid-connected systems at present
- Planning guidelines under development

Small wind in Ireland

- Less than 16 amps per phase (= “micro”)
  - <3.7kVA for single phase
  - <11kVA for three phase
- No payment for energy export, and meter does not reverse, i.e. no net metering
- favours “undersized” machines
- Must conform to Draft EN 50438
- But only <u>electrical</u> safety considered…

Small wind in Ireland

- Still very early days
- No government incentives for microgeneration yet (incentives for heat pumps, solar hot water and wood heat exist)
- Small wind may become very common in windy Ireland, as small wind systems decrease in price, incentives are put in place, and electricity prices rise

Concerns

- Ambitious power ratings fool the purchaser
- Unrealistic production estimates by over-enthusiastic/ignorant suppliers and installers
- Especially some “rooftop” systems
  - a very attractive marketing concept…
  - giving small wind a questionable reputation?
- No mechanical safety or installation standard

Recommendations

- IEC 61400-2 for product safety…
- “Installer academy” training and certification for small wind installers for installation safety
- “Quality stamp” (not mandatory, but desirable) validating production claims, by recognised test facility

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Small Scale Wind Power from Hannevind Vindkraft AB

Topical expert meeting: The Challenges of Introducing Reliable Small Wind Turbines

September 2006

Brian Coughlan
(BrianCoughlan@hannevind.com)

Hannevind Vindkraft Confidential

Outline

http://www.hannevind.com/

- Hannevind: The Company.
- Hannevind: The Turbines.
- The big issues of small-scale wind power.
- Challenges/Solutions.
- Position regarding IEC 61400-2: Wind turbines - Part 2: Design requirements for small wind turbines.
- What can we as a community do to promote small-scale wind energy?

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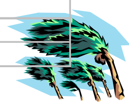
The Company

http://www.hannevind.com/

- Hannevind, the brainchild of Sven-Åke Hannevind, was founded 6 years ago as a response to the disappointing state of the Swedish wind turbine industry.
  - The home user was basically ignored.
  - Even modest wind power generators were disproportionatley expensive.
- Hannevind has set out to deliver reliable and high-energy wind power at a price affordable to most middle class households in Sweden, installable even in urban areas. This is in effect the company mission statement.
- Currently the Hannevind 2,2 kWh unit, delivering 2 – 3,000 kWh per year is priced at €3,500 - €5,000 fully installed. This investment is typically recouped within 10 years.
- Hannevind produce wind turbines with a swept area ranging from 5 to 314 m^2.

Rating	Rotor Diameter (meters)	Swept Area Meters Squared	Annual Power Output at 6 m/s
2,2 kWh	2.3	4.15	2,500 kWh
5,5 kWh	5	19.63	13,000 kWh
11 kWh	11	95.03	50,000 kWh
22 kWh	14	153.94	90,000 kWh
45 kWh	20	314.16	200,000 kWh



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Hannevind: The Turbines

http://www.hannevind.com/

- Control unit – our secret sauce!!!
  - Makes maximal use of prevailing wind conditions.
  - Ensures energy is not lost in intermittent and disturbed wind.
  - Keeps generating power all the way up to winds of 20 m/s.
  - Automatically shuts down in wind speeds exceeding 20 m/s.
  - Eliminates the need for a tail and related engineering.
- Blade design
  - We have designed the blades with turbine software to complement the commercial generator and gearbox combinations we have chosen to use.
- Blade Materials
  - The right balance of light and strong. No wood, plastic or aluminium.
  - Only galvanised steel or fibreglass.
- Number of Blades
  - Using the same turbine engineering software, we have settled on a three-blade fibreglass turbine for our larger devices. For the smaller, galvanised steel is used.
- Generator
  - Safety and efficiency being key, an asynchronous generator is the only unit used in all Hannevind wind turbines. All the devices operate with an efficiency of 80%+, for the larger turbines, we include a reactive power capacitor that pushes efficiency to 90%+.

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The big issues of Wind Power

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http://www.hannevind.com/

- **Is it reliable?**
  - Key components are purchased from established sources with good reputations, and all rated for an operating life of 20 years plus.
  - We highlight to consumers, that small-scale home turbines should **complement** grid power, and not be seen as a complete replacement.
- **Is it economical?**
  - Pays for itself of within 5 – 10 years at today's prices, depending on the turbine, the bigger the better!!
  - Energy is not getting cheaper, thus ROI is likely to be sooner rather than later.
- **Is it noisy?**
  - Testing conducted by the relevant Swedish environmental authority has rated the larger turbines to less than 39 dB(a) within 70 meters during normal operation.
  - The 2,2 kWh, which is generally attached to the house can typically not be heard above normal ambient noise, and no vibration can be detected inside the house.
- **Is it safe?**
  - The smaller turbines use galvanised steel vanes, which are over engineered for safety. The larger turbines are constructed of fibreglass.
  - The rotors have been tested up to 31 m/s in operation.
  - Additionally, when wind speeds consistently exceed 20 m/s the control unit gradually slows the turbine to a stop, locks it in position, and turns it 90 degrees to the wind.
  - Because we use only asynchronous generators, the device must be connected to a secondary source of power, typically grid power. In the event of a power outage, turbine shutdown is immediate. This is a critical safety feature for those turbines supplying electricity to local utilities.

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Challenges/Solutions

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- Sourcing and programming the control unit.
  - This had to be done from scratch, and there were no readily available guidelines.
  - Sourced a Siemens module as the core device for the control unit.
  - Allows programming and sensing for various parameters such as wind speed and direction, generator temperature, oil level, turbine revolutions, power levels, and physical stability.
  - The interaction of these parameters can be amended and programmed to cater for specific local conditions.
- Onboard alert system.
  - Integrated a GSM phone into the unit.
  - SMS's sent to control centre when parameters exceed operational norms.
- Procuring Funding
  - Hannevind is a small operation, with limited resources to devote to searching for money and backers; our experiences to date have been disappointing.
- Assisting prospective buyers through the maze of bureaucracy
  - Sweden is pretty good about renewables, but planning permission and related complications can still be a significant hurdle.
  - We have intervened with government offices on behalf of customers in the past.
- Managing growth
  - We have done no marketing other than the website.
  - It is a classic case of "build it and they will come".
  - However, we are now running at capacity+, simply delivering the systems we currently have on order, and this is impeding our ability to grow.

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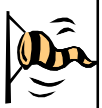
Position regarding IEC 61400-2 : Wind turbines - Part 2: Design requirements for small wind turbines

http://www.hannevind.com/

- We would like to see regulation addressing:
  - How small wind turbines are marketed.
  - Accelerated planning permission.
  - Standard specification for installation with no planning permission.
  - Specific safety requirements and standards.
  - Net Metering
  - Provision for accreditation and ***companies limited to selling those products that have been accredited***.



What should we do as a community to promote small-scale wind energy?

http://www.hannevind.com/

- We are competitors … lets get that out of the way.
  - Only in principle
  - Mass Small Scale wind power will be more TV's of the 1950's than video recorders of the 1990's.
  - Production and sales will be regional, proprietary and require a significant after sales operation for maintenance, repairs and upgrades.

- Therefore, co-operation is beneficial
- Share technical knowledge
- Share breakthroughs
- Share business ideas
- Share political ideas

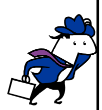
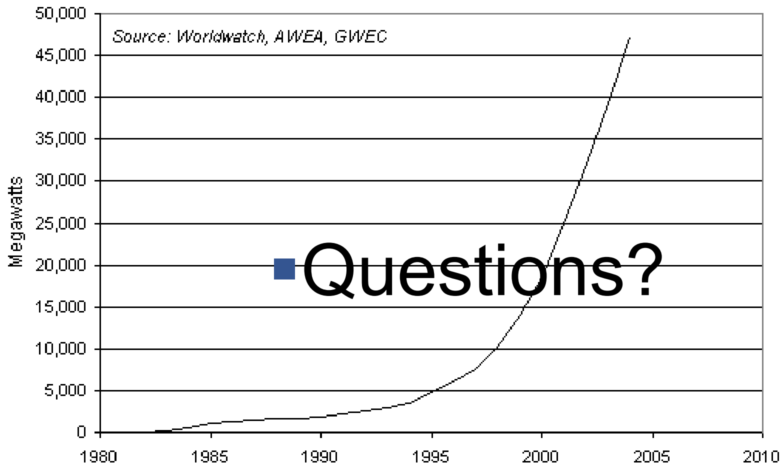


Figure 10-1. World Wind Energy Generating Capacity, 1980-2004



- Questions?

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SWT reliability analysis. Spanish case.

Ignacio Cruz CIEMAT Spain
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Layout of the presentation

- Current situation.
- Spanish case
- Action: Soria Test Site
- Some results:
  - Results: Wind turbine performance.
  - Results: Wind turbine noise emissions.
  - Results: Generator Test.
  - Results: control & power conditioning system.
    - Off-grid SWT. Battery charge system
    - Grid connected SWT
- Future Work.
- Expected difficulties
- Conclusions

IEA Topical Expert Meeting on Challenges of Introducing Reliable Small Wind Turbines
27th- 28th of September 2006 Stockholm, Sweden

MINISTERIO DE EDUCACIÓN Y CIENCIA — Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Current Situation

- SWT Technology is immature
- The design procedure is generally not evaluated. Lack of adequate design codes
- Low requirements on controllability of SWT. (Control equipment is nowadays major cause for maintenance & repair actions).
- Lack of databases for reliability of components.
- Low requirements on condition monitoring and lack of SWT available data.
- Power converters and control specifications must be on higher level.
- Poor maintenance and operation procedures.

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Spanish case

- SWT Buy down subsidy: The level of investment subsidy depend on the region where the SWT will be installed, but there are any requirement about quality or certification.
- For grid connection cases, similar regulation and feed-in-tariff to larger wind farms is applied. Only the environmental impact study is less severe.
- Only customer can ask for reliability studies or certifications. There are customers with some technical knowledge (some times is worst if they are not well trained)
- In case of failure, the manufacturer usually change free of charge the component or the complete SWT.
- Only CIEMAT (Public research centre is working on the certification of SWT(Power performance, noise emissions,)

IEA Topical Expert Meeting on Challenges of Introducing Reliable Small Wind Turbines
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Action: Test Site in CEDER-Soria

- Two general areas of research: one is focused on the characterization of small wind turbines
  - Power Performance Tests. (IEC 61400-12)
  - Noise Emission Measurement (IEC 61400-11)
  - Safety and Function Tests (IEC WT 01)
  - Duration Tests (IEC WT 01)
  - Measurements of grid connected SWT (IEC 61400-21)
  - Other Tests
    - Generator performance
    - Blade Test

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Action: Test Site in CEDER-Soria

- The other area of interest deals with research and development on autonomous wind energy systems
  - SEDUCTOR Project (Wind-diesel system)
  - Wind Electric Pumping System Test Rig
  - CICLOPS Project (Wind-PV-Diesel system)
  - Wind to Hydrogen Project (Wind – Electrolyser integration)

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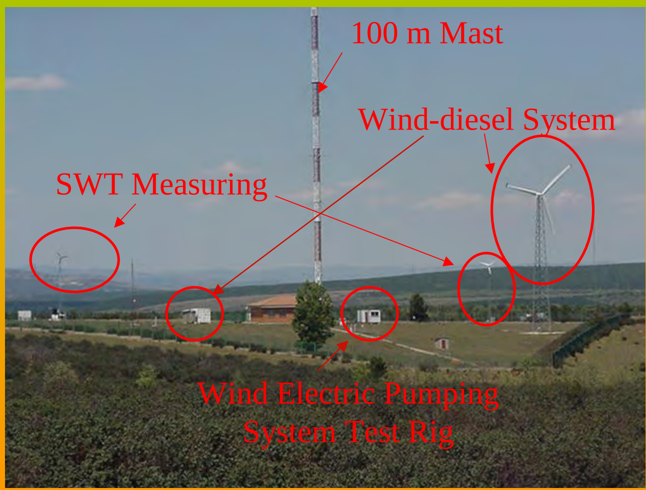
Action: Test Site in CEDER-Soria Phase I



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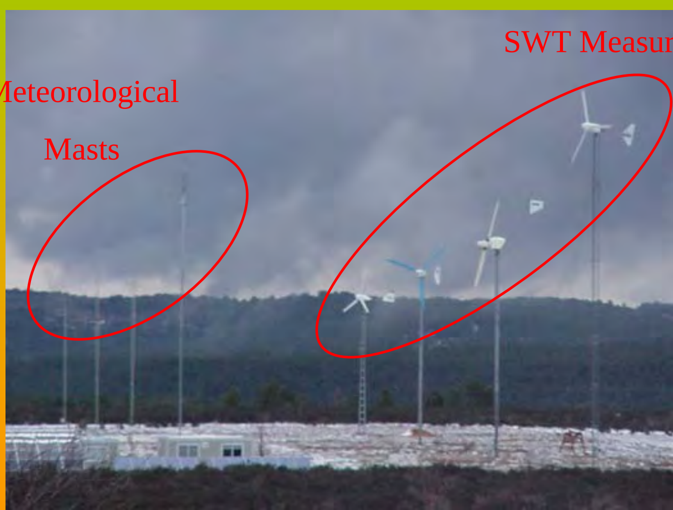
Action: Test Site in CEDER-Soria Phase II



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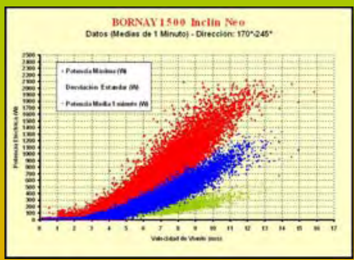
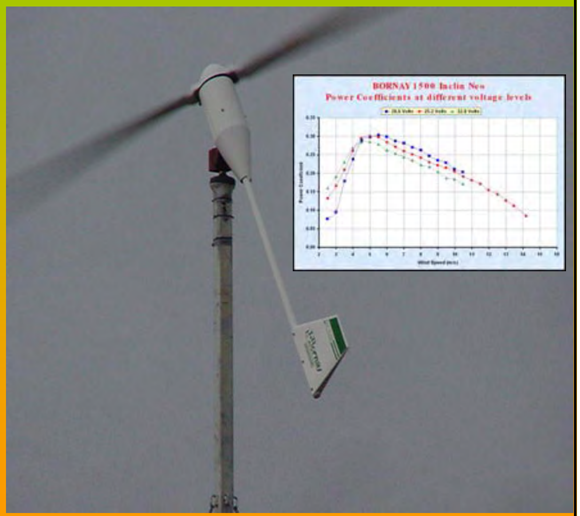
Results: Wind Turbine performance





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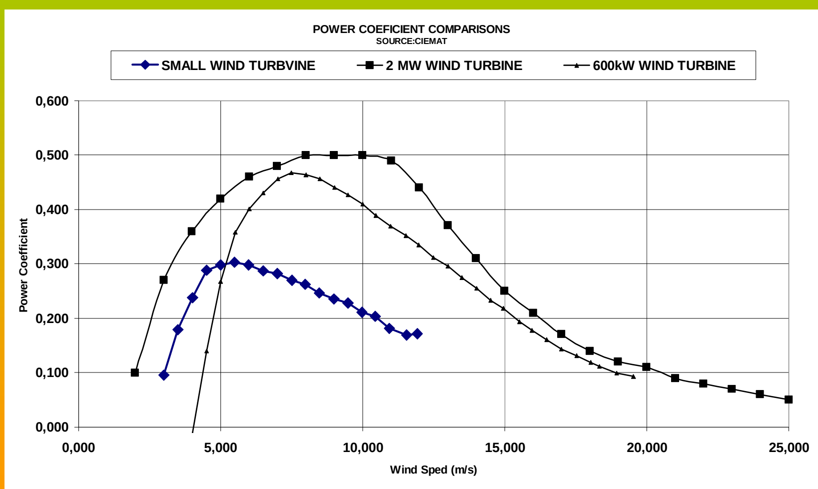
Results: Wind Turbine performance



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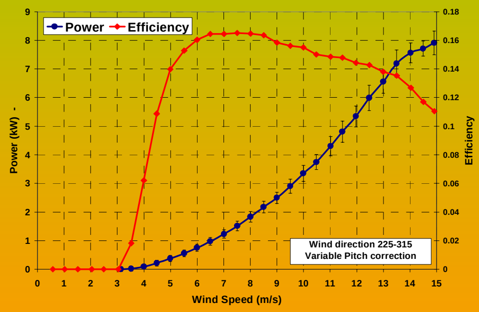
Results: Wind Turbine performance



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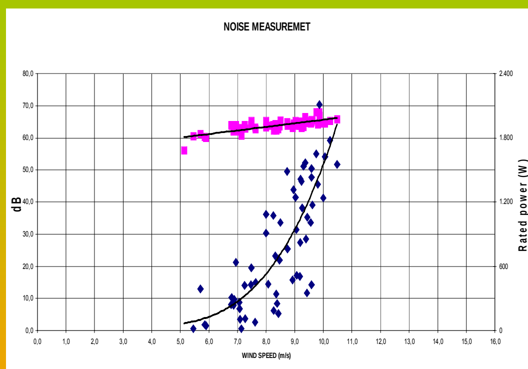
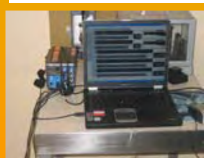
Results: Wind Turbine noise emissions





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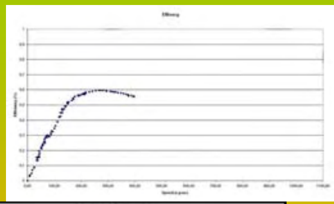
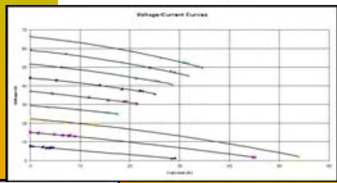
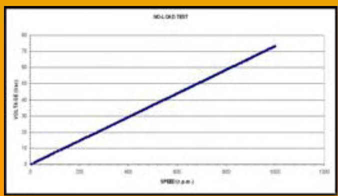
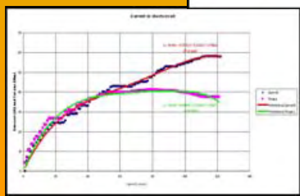
Results: Generator Test









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Results: Control & Power Conditioning Units. Charge controllers

- Most innovative components.
- Increasing reliability

- Chargers topology dependence:
  - A rectifier (when AC input),
  - a controlled DC/DC chopper (step-down converter)
  - MPPT, microprocessor-based control.

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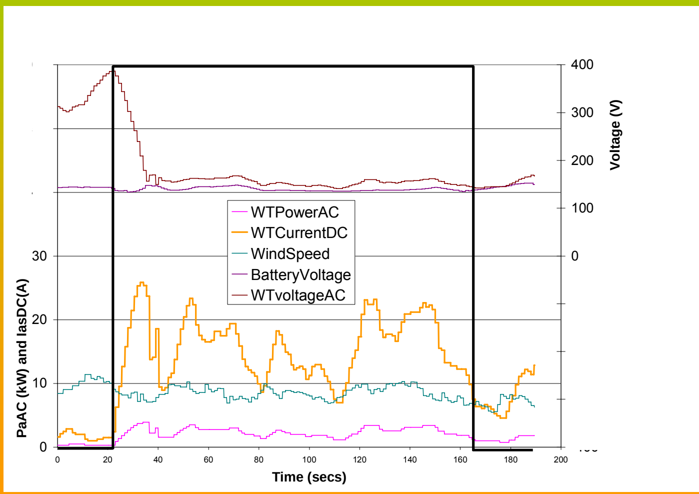
Reliability of the Wind turbine Battery Charge Controller. Dynamic Response



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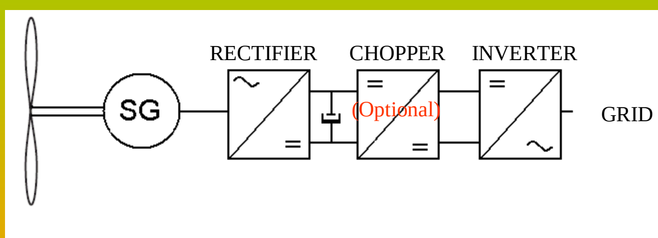
Reliability of SWT connected to the grid: Dependence on the power electronics topology applied and adaptation level

1



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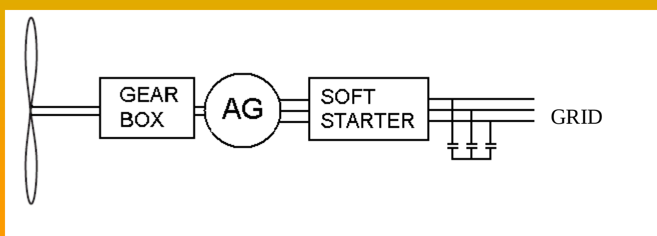

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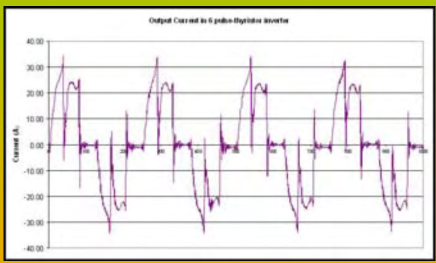
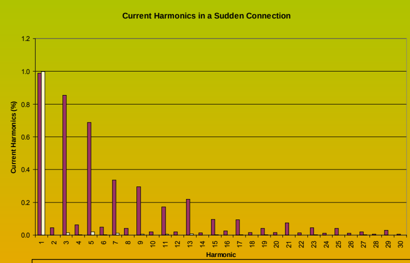
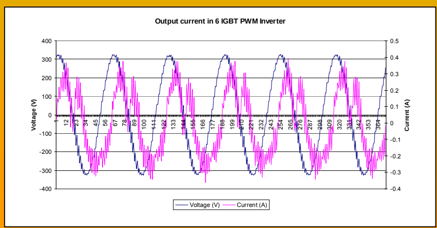
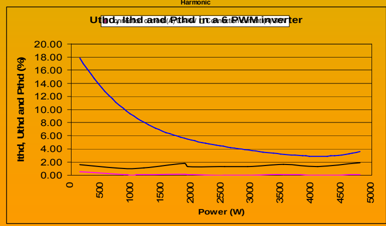
Reliability of SWT connected to the grid: Dependence on the power electronics topology applied and adaptation level.









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Future Work

- Development of adequate design codes and validation of engineering rules.
  - Design certification according to the IEC 61400-2 Ed 2
  - More detailed design process (structural reliability methods, probabilistic methods, monitoring and maintenance driving design
- Significant improvement of reliability and controllability of SWT.
  - Introduction of controlled flexibility (active systems instead of passive).
- Lower loads & stable behaviour.
  - Fatigue and vibration analysis.
  - Control techniques more sophisticated to add stability and alleviate loads.
- Lower weights and less structural components.
- Close cooperation for training in operation and maintenance activities at two levels (professionals (installers) and non professionals (customers).

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Expected difficulties

- In general, this strategy means increasing SWT specific costs but lower O&M cost because of the higher reliability.
- IEC Wind Turbine standards not always valid for small ones:
  - Very expensive implementation.
  - Reports not friendly for the end users.
  - Standard doesn't represent the complexity of the SWT behaviour.
- Customers and end users in general are not experts. High reliability must be guarantied by government programs.
- Big market for SWT is in developing countries, so high reliability is crucial. Future high cost of energy force high penetration in industrialised countries.

Conclusions

- Reliability of SWT has a strong dependence on the application. (grid connected, stand-alone, water pumping…) and the site conditions. Adequate design codes for adaptation are required.
- Certification is crucial for high reliability operation but an adequate operation and maintenance procedure has to be developed. The problem is who does this activity? End user or professionals?
- Standards have to be simple, realistic and useful.
- High reliable design is expensive. Certification is every day a much more complex and expensive activity. A good operation and maintenance is a costly activity. Possible subsidies must be associated to quality? Rules have to be mandatory, but with public support for testing and certification activities.
- There is a lack of appropriate international R&D programmes for SWT evaluation in operating conditions.

Advise for improving reliability of small wind turbines

Presentation by Sven Ruin, TEROC AB, consultant specialized in wind energy and hybrid power systems

Background: How can you compare wind turbines?

• For off-grid and grid backup systems, I normally compare the complete wind systems, for example using HOMER. Key figures are e.g. total net present cost or cost of energy ($/kWh).

• For pure grid-connection, small wind turbines can be compared using the same methods as for medium or large wind turbines. For a potential buyer, it is also relevant to compare the investment in a small wind turbine or PV system with buying a share of a medium or large wind turbine, such as a wind co-operative (this can sometimes give you 10 times more renewable energy for your money, but can normally not be a backup in case of a power outage).

Comparison of wind turbines, continued:

- **However, all comparisons are based on that you have correct input data. This is a problem with small wind turbines. Reliable data on performance, maintenance requirements, lifetime etc is difficult to find.**

For policymakers and other organizations:

- **Link incentives to requirements on the products, e.g. on compliance with international standards, 3rd party type approval, independent measurements and making operating statistics public (follow the successful example of fostering the market for medium and large wind turbines).**

- **Provide relevant consumer information regarding small wind turbines, showing both good examples and warning for the pitfalls.**

- **Check the fulfillment of legal requirements. Stop the worst unsafe products from being sold.**

For buyers:

• Ask for compliance with international standards, 3rd party type approval, independent measurements and public operating statistics.

• If the above is not available: Inspect the manufacturer yourself, if possible. If it is a larger procurement, you may want to hire a specialist to review the manufacturers strength calculations etc.

• If the power curve has not been properly measured, comparing swept area may be better.

• Check references, if possible in an area with similar conditions. What works at a less demanding place may not work at your place.

For all:

• Don't forget the tower – it should be treated as part of the wind turbine in strength calculations etc! Normally, only the wind turbine designer has all the information needed to properly determine the suitability of a tower. Dynamics and fatigue are involved. If local tower manufacturing is desired, do it according to drawings from the wind turbine designer. Make sure that the wind turbine manufacturer's warranty is valid with the tower used.

• Turbulence an fatigue are very important, but especially if the site is in an area where high extreme wind speeds can be expected (e.g. with tropical hurricanes), survival wind speed of the entire wind turbine is very important too.

Are the safety related systems really fail-safe? They should be, but sometimes they are not.

Example: In one case with a passive-pitch controlled small wind turbine, a small single-point failure in blade synchronization can lead to thrown blades – a self-destroying instead of fail-safe wind turbine!

The need for a test center making test results public has long been recognized, or would a website publishing/linking the results be sufficient? There are already many test centers around the world, also in non IEA countries, such as France.

Thank you NREL, Klemen and others who have made results public! You have made a very important contribution to the entire small wind community.

Where else are public test reports available?

A test center or test website could publish information regarding all goals of this meeting:

1. Reliable long life: Report technical failures and all maintenance needed. What where the external conditions during the test?

2. Reliable performance: Report independently measured power curve, production and noise data.

3. Reliable safety: What external conditions and standards are stated by the manufacturer? Report if any independent review, 3rd party type approval etc is available.

4. Reliable from a legal point of view: CE mark and associated documentation is relevant in Europe.

Contact information:

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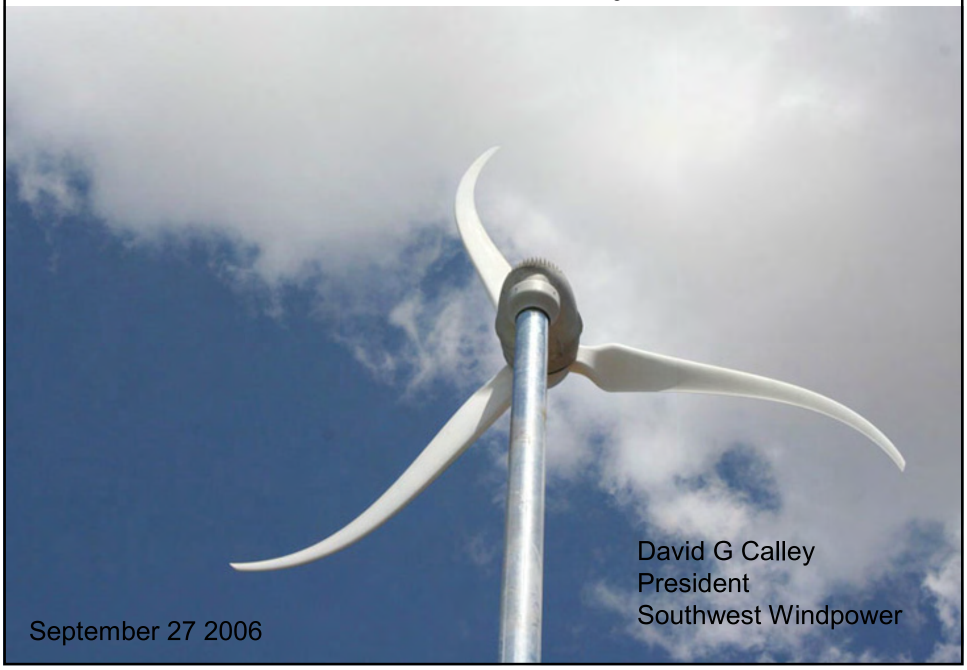
A brief Review of SkyStream



David G Calley
President
Southwest Windpower

September 27 2006

Company background

Southwest Windpower is located in Flagstaff Arizona. We have been designing, manufacturing and selling wind turbines worldwide since 1987. (I have been doing this much longer)

Sales for 2006 are about $10 million and are projected to be $17 million for 2007.

We employee 86 full time employees in 3 facilities totaling approximately 30,000 sq ft.

Mongolia 2002 – Rod Robinson

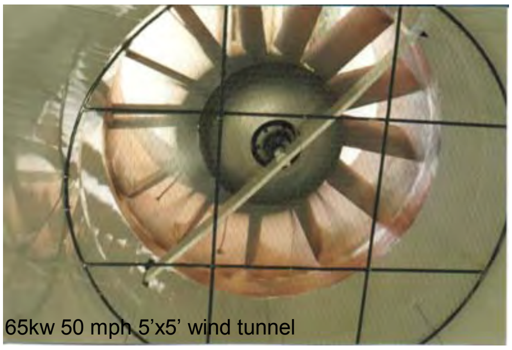
Company

Engineering consists of 8 research and development staff and 5 production engineering.

Production is approximately 1,600 turbines per month (almost 2200 in a good month) approximately 6 Mw (MW) per year.

Distribution in 60 countries.

The product line ranges from wind turbines of 400 watts peak to 3,000 watts peak.



65kw 50 mph 5'x5' wind tunnel

AIR Marine 400 watt wind turbine

•In 2002 "Exporter of the Year"

•Outstanding partnership of the year DOE

•ISO 9000 listed manufacturer

Current Products

- Air-X Series – Land and Marine
- Whisper 40/80 series
- Whisper 175

Design for a New Residential Wind Turbine

Integrated “appliance” concept
- Integrated inverter
- Integrated tower conforming to local zoning
- Rapid installation with existing infrastructure

Designed to integrate in to urban environments
- Silent operation
- “Light pole” tower using little space
- Strong emphasis on clean aesthetic design

Rear Silent operation, not noticable

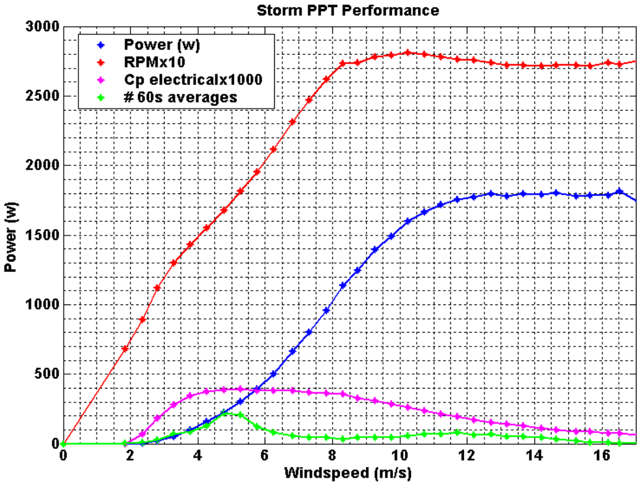
High volume manufacturing

Designed for very low wind speed areas
- New airfoils designed for low wind
- New slotless alternator, the subject of this presentation

The prototype was delivered to NREL, the National Renewable Energy Laboratories for testing and the final design review was held in July. Though much work remains, the design is now about 16 months from market.

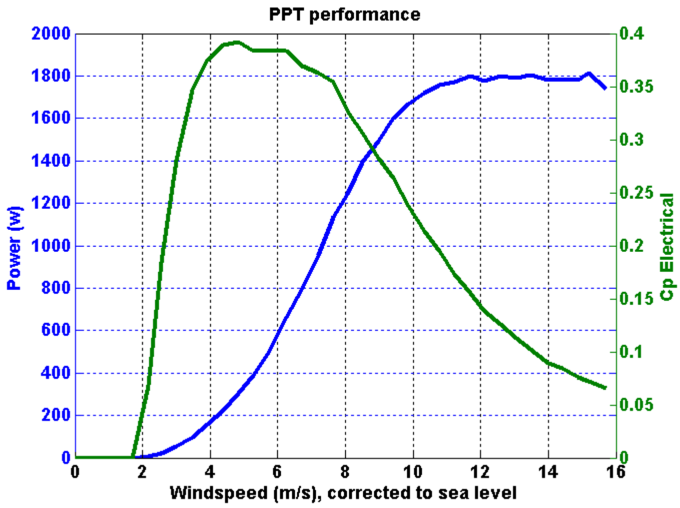
Only the alternator design will be addressed in this presentation.

Power, efficiency and rpm



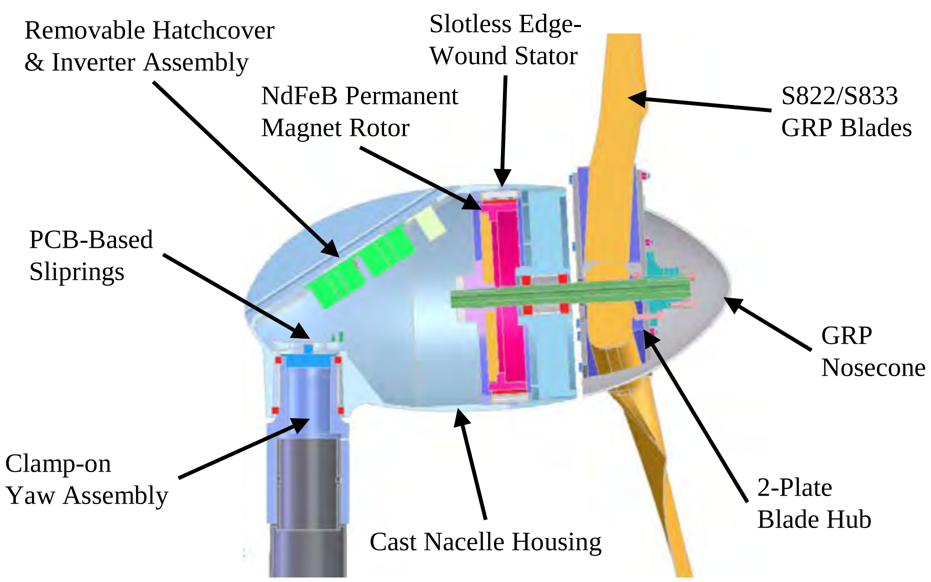
Uncorrected data at 6,800 ft

Corrected Data



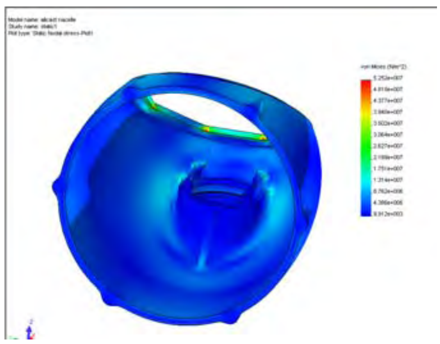
- 300 PRM max
- Now 9 m/s rating (improved from this curve)
- Near .4 net electrical Cp
- 160 max tip speed
- Flat power at 1800 rpm (programmed)

Construction



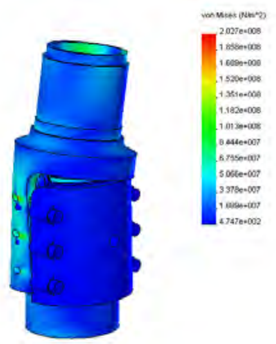
Nacelle

- Designed for Die cast aluminum
- Excellent heat flow
- EMI shielding
- Sealed



Yaw Assembly

- Production design likely different
- Universal “AIR” style clamp
- Molded high volume production design
- Integrated sliprings



Blades

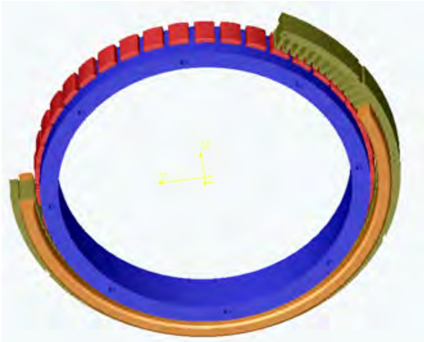
- S822, S823 NREL airfoils
- Low noise and high performance
- Consistent quality, high volume production
- Prototype test units of fiberglass, production will be injection molded
- Multi-part injection mold blade

Inverter

Wind Turbine Alternator Design

Standard Considerations

- High efficiency,
- Low cost,
- High reliability,
- Long life,
- No maintenance,
- Low noise and
- High torque (for stalling)
- High volume manufacturability

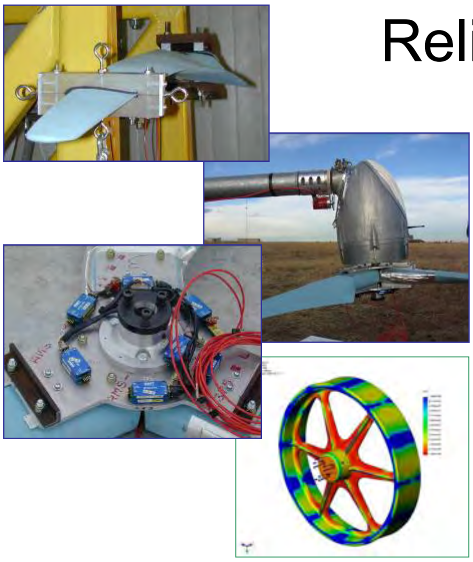


Original prototype “conventional”

Wind turbines are also concerned with compact design and light weight, but these are largely secondary concerns driven by a link to the cost of the structure to support the system and material costs.

These requirements generally preclude anything but brushless, high strength permanent magnet designs.

Reliability Testing



- Extensive field, computer modeled and laboratory work has resulted in the most tested small wind turbine in history.

Beta test program

- 26 beta test sites
- Wireless connected
- IEC standard data (Wind speed at hub 2.5-4 diameters, air density (pressure and temperature), wind direction
- 6 months or so period

Wind Alternator Design Issues

Wind turbines have fairly specific design problems. One of the most significant of these is the requirement for extremely low detent or cogging torque. This design problem arises from the aerodynamics of the wind turbine at start up. A brief explanation may assist in understanding this sensitivity.

- At startup, the airfoils are deep in stall (They are so deep in stall that no airfoils are tested in this angle of attack range)
- In this range, torque is produced by transfer of momentum, and not by lift in the classical sense
- The power in the wind is proportional the cube of the wind speed

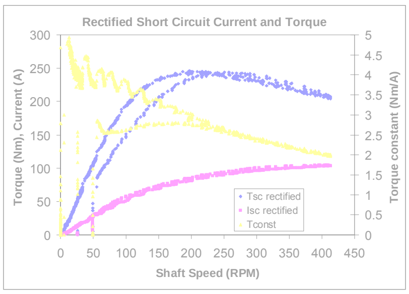
These combine to make starting at very low wind speeds very difficult with permanent magnet wind turbines.

Alternator Design Approach

The requirement for low cogging and noise leads us to slotless designs.

The requirement for high volume manufacturing at low cost lead us to an unusual if not unique approach.

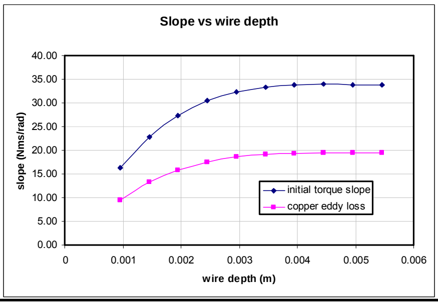
Rather than winding coils and placing them in or up against the gap, we tried sliding coils on a slotless torroidal core.



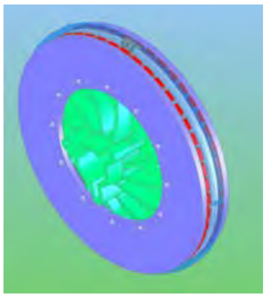
Optimizing the design

Cost performance model developed to optimize key variables

- Configurations, i.e. Conventional, vs axial slotless, vs radial slotless
- Torroidal vs conventional coil orientation
- Wire depth
- Wire width (max voltage, eddy current losses in wire, difficulty of mfg.)
- Frequency (pole count)
- Aspect ratio (diameter to length)
- Magnet power/ thickness



Axial slotless



Work for Peace

RENEWABLE ENERGY MADE SIMPLE

Southwest Windpower

www.windenergy.com

Thank you!

Summary of IEA RD&D Wind – 49th Topical Expert Meeting on

CHALLENGES OF INTRODUCING RELIABLE SMALL WIND TURBINES

September 2006, Stockholm, Sweden

Sven Ruin and Sven-Erik Thor

Background

Small wind turbines have great potential to provide electric power, especially in remote locations. Market studies indicate a quickly growing demand for small wind turbines and hybrid power systems, which combine wind and some other generation technology. However, it is known that many small wind turbines:

- do not live long because of technical failures and/or excessive maintenance requirements,
- have misleading or non-existent power curves, production and noise data,
- are not designed according to existing safety standards and have caused accidents,
- are illegal to use, because they do not fulfil legal product requirements.

While government programs in the early days fostered the manufacturers of medium-sized wind turbines to produce good products, this was not the case for small wind turbines.

Contributing to the problems with small wind turbines, is also the fact that they are often purchased by private individuals, without the professional competence and procurement practices normally used when buying medium and large wind turbines.

Objective

The objective of the 49th Topical Expert Meeting was to find ways to ensure that small wind turbines are reliable in the following sense:

- reliable long life: technical failures and excessive maintenance reduced,
- reliable performance: published power curve, production and noise data should be reliable,
- reliable safety: appropriate safety standards followed and accidents avoided,
- reliable from a legal point of view: the buyer should not face the risk of buying a product that is illegal to operate.

Participants/Presentations

A total of 17 participants attended this meeting with representatives from Canada, Germany, Ireland, Japan, Spain, Sweden, the Netherlands and USA. The participants represented National Research Organizations, Manufacturers and Developers as well as representatives from national energy agencies.

A total of 12 presentations were given on the following topics:

1. Introductory note to meeting
2. Small Wind Energy Technology in Canada
3. Big Experience with Small Wind Turbines (SWT)
4. Small Wind Turbines - Research & Teaching at Universität Stuttgart
5. Reliability for Small Wind Turbines

6. The Dynamic Wind Power Captureability of a High Performance SHWT Zephyr's "Airdolphin"
7. Fortis windenergy
8. Small wind in Ireland
9. Small Scale Wind Power from Hannevind Vindkraft AB
10. SWT reliability analysis. Spanish case
11. Advise for improving reliability of small wind turbines
12. A brief Review of SkyStream Development

Discussion

At the end of the meeting a discussion was held on the following three topics:

- Cost
- Standardisation / Certification
- Test Centers

Cost

The opinion was that the costs of small wind turbines could be lowered with larger production volumes, i.e. economy of scale. But cost is not only associated with the wind turbine itself. Costs and time for getting a building permission etc can also be crucial for small wind turbines.

Irresponsible actors on the market were considered to be a threat to the market. There are some very doubtful small wind turbines coming into the European market, and the risk is that they will undermine the market for the legitimate manufacturers.

David Calley: Look at the costs per kg for e.g. car and washer manufacturers. As small wind turbine manufacturers we should be able to come down to their numbers. We need to invest to do that. Cost reduction is part of his vision for a better future for small wind turbines.

Johan Kuikman mentioned that the European Wind Energy Association works also to promote small wind turbines, not just with large wind turbines.

The operational costs, for small wind turbines must also come down, not only the investment costs. According to ISET investigation in Germany, the operational costs are on average:

- 16 Eurocents/kWh for small wind turbines with less than 40 m^2 swept area
- 3.5 Eurocents/kWh for those with 40-200 m^2 swept area

Johan Kuikman: From the industry side, I think that if there is a good market, the investors will come. For that to be possible, I want the bottlenecks to disappear for small wind turbines.

Standardisation / Certification

David Calley: AWEA's objective with the proposed AWEA standard for certification of small wind turbines is to lower the cost of certification.

Jim Green: Cost of certification is one barrier for small wind turbine manufacturers. However, he doubted that large simplifications can be done while safety requirements are upheld. A standardized, simple performance rating seems viable though.

David Calley: It is less costly to measure performance well than to certify the safety of a small wind turbine – learning and using IEC 61400-12 is much easier and less costly than IEC 61400-1 or IEC 61400-2. Let us make that a recommendation: Manufacturers should publish one energy rating summarizing the performance. He suggested that the annual energy production at 5 m/s annual average wind speed should be presented. This should be measured according to IEC 61400-12 by a third party.

John Quinn: A simplified noise rating would also be very helpful.

David Calley: The maximum noise level measured at all reasonable conditions could be a good summary.

John Quinn: Certain countries have ratings at specific wind speeds. We should work towards basic requirements that can be used everywhere. A label showing that the product is legal and safe would be a good start. Let's creage e.g. a manufacturers organization for this. The industry could self-destruct without it. Everyone who wants to sell a product on the European market should contact a lawyer with the relevant knowledge first. If they sell an illegal product, they may end up in court and lose their shirt.

Hikaru Matsumiya: One thing that the IEA could do is to issue a guideline or recommended practice.

Test Centers

Ignacio Cruz: The cost to measure or certify a small wind turbine is an issue. We at CIEMAT are members of MEASNET and to carry such costs is difficult for the small wind turbine industry. MEASNET has higher quality standards for performance measurements than IEC.

Johan Kuikman: One of the major wind energy organizations could be an organizer of a web site with public test information.

Continuation

The participants were in favour of promoting further work in the area. The most important thing is a label stating that a product is legal and safe, this will block the worst unsafe products from being sold. One such opportunity would be to develop a recommended practice for labelling of small wind turbines.

Other initiatives related to such a proposal is the EU-funded study on small wind prepared by a group from France and the Netherlands. John Kuikman has more details. Hikaru Matsumiya (vice chair of GWEC) mentioned that The Global Wind Energy Council would probably support an initiative like this. The American Wind Energy Association is presently working in this area, especially on standardization. Jim Green knows more about this.

The participants agreed to write a proposal for the development of a Recommended Practice on methods for labelling of small wind turbines. An AdHoc group was set up with the responsibility to prepare such a proposal. The following participants volunteered for this work:

Brian Coughlan
Ignacio Cruz
John Quinn
Sven Ruin
Lawrence Staudt

The roadmap for the coming activities could look like this:

1. A summary of this meeting will be written and circulated (*this text*).
2. Sven-Erik Thor will contact the IEA ExCo Planning Committee in order to inform about the proposal to start preparation of a new task and check preliminary interest.
3. Participants in this meeting should contact their national IEA representatives and explain the importance of an IEA recommended practice for consumer labelling of small wind turbines, to gain their support for this idea.
4. Develop a draft proposal for starting a new task with the aim to develop a Recommended Practice on methods for labelling of small wind turbines

List of participants

IEA RD&D Wind Task 11, Topical Expert Meeting
Challenges of Introducing Reliable Small Wind Turbines
Stockholm
27-28 September 2006

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