Small Wind Turbines & Wind Diesel Systems

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Renewable Generation and Grid Integration

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Dr. Dipl.-Ing. Thomas Ackermann | t.ackermann@energynautics.com

Outline of Lectures

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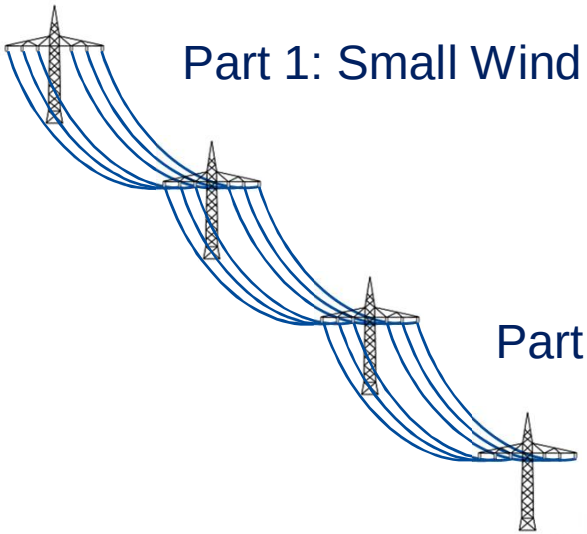
20 July: Part 1: Hybrid Systems
Part 2: Basics on Grid Integration of Renewable Generation

26 July: Part 1: Basics on Grid Integration of Renewable Generation
Part 2: Examples of International High Penetration Studies

27 July: Part 1: Capability of Ancillary Services from RES
Part 2: Outlook- Overall energy systems aspects

Contents



Part 1: Small Wind Turbines

Part 2: Wind-Diesel Systems

Typical Markets for Small Wind Turbines (< 50 kW)

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- Remote Homes
- Telecommunications
- Village/ Rural Electrification
- Water Pumping
- Oil Well Pumping
- Refrigeration
- Desalination

Rural Electrification

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- **World Bank projects in:**
  - Brazil;
  - Russia;
  - Indonesia;
  - China;
  - Mexico ...

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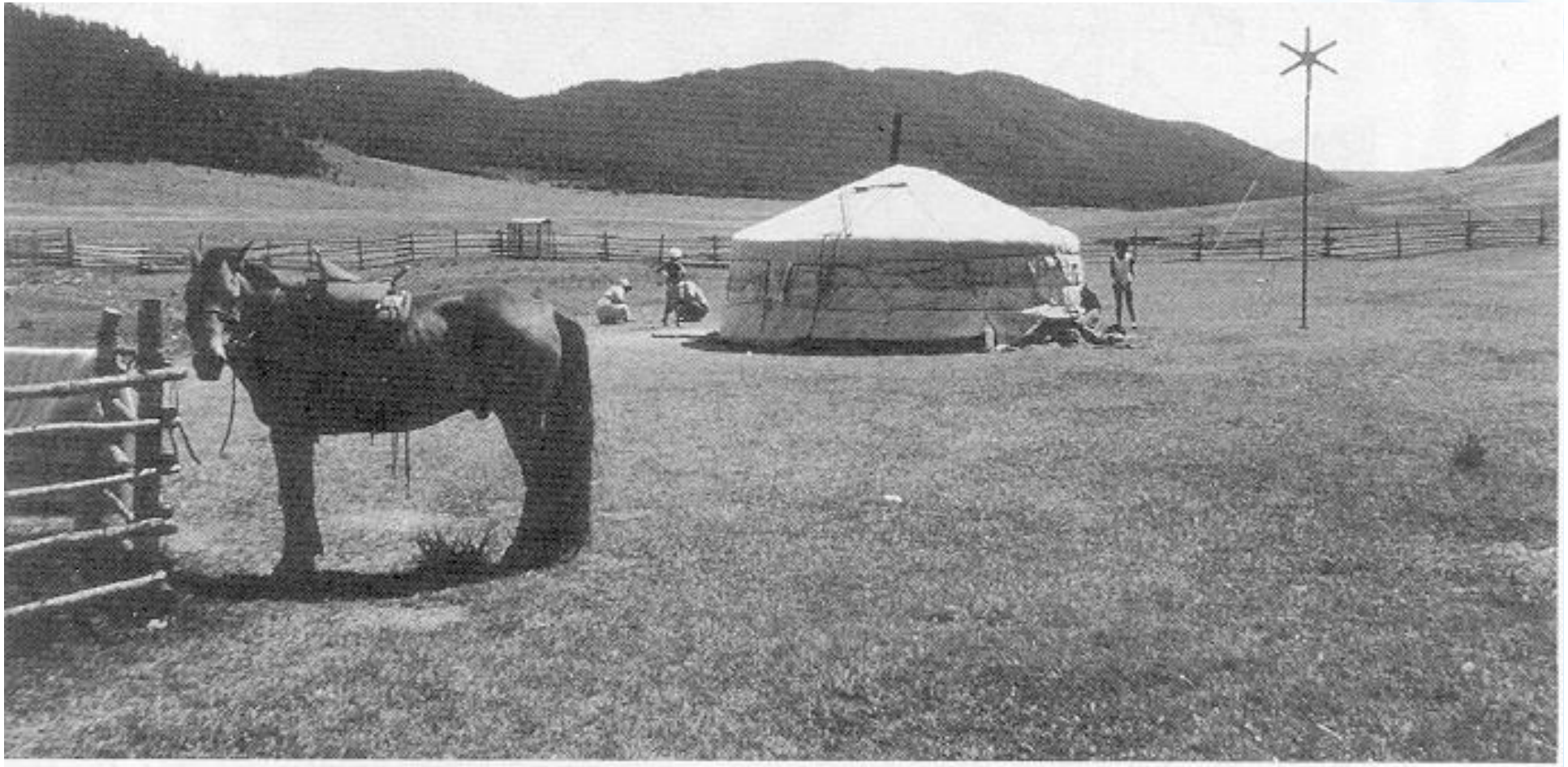

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Features of Small Turbines for Power Generation

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- Larger tower, compared to turbine size;
- Mainly variable speed, direct driven systems (no gearbox) for 2 to 10 kW; direct driven systems are also under development for turbines between 10 to 50 kW (Reason: High rotor speed well suitable for direct driven systems);

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Generators

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- **Low Cost Alternatives:**
  - Alternators are very popular (Advantage: cheaper, long life time);
  - Induction motor (washing machine);
- **Advanced Alternatives:**
  - AC generators (very seldom DC);
  - Permanent magnet generators;

Power regulation

- Yaw (~ 10 %);
- Stall (~ 8 %);
- No Control (~ 14 %);
- Pitch (~ 35 %);
- Tilt (~ 33 %)

Yaw/ Horizontal Furling

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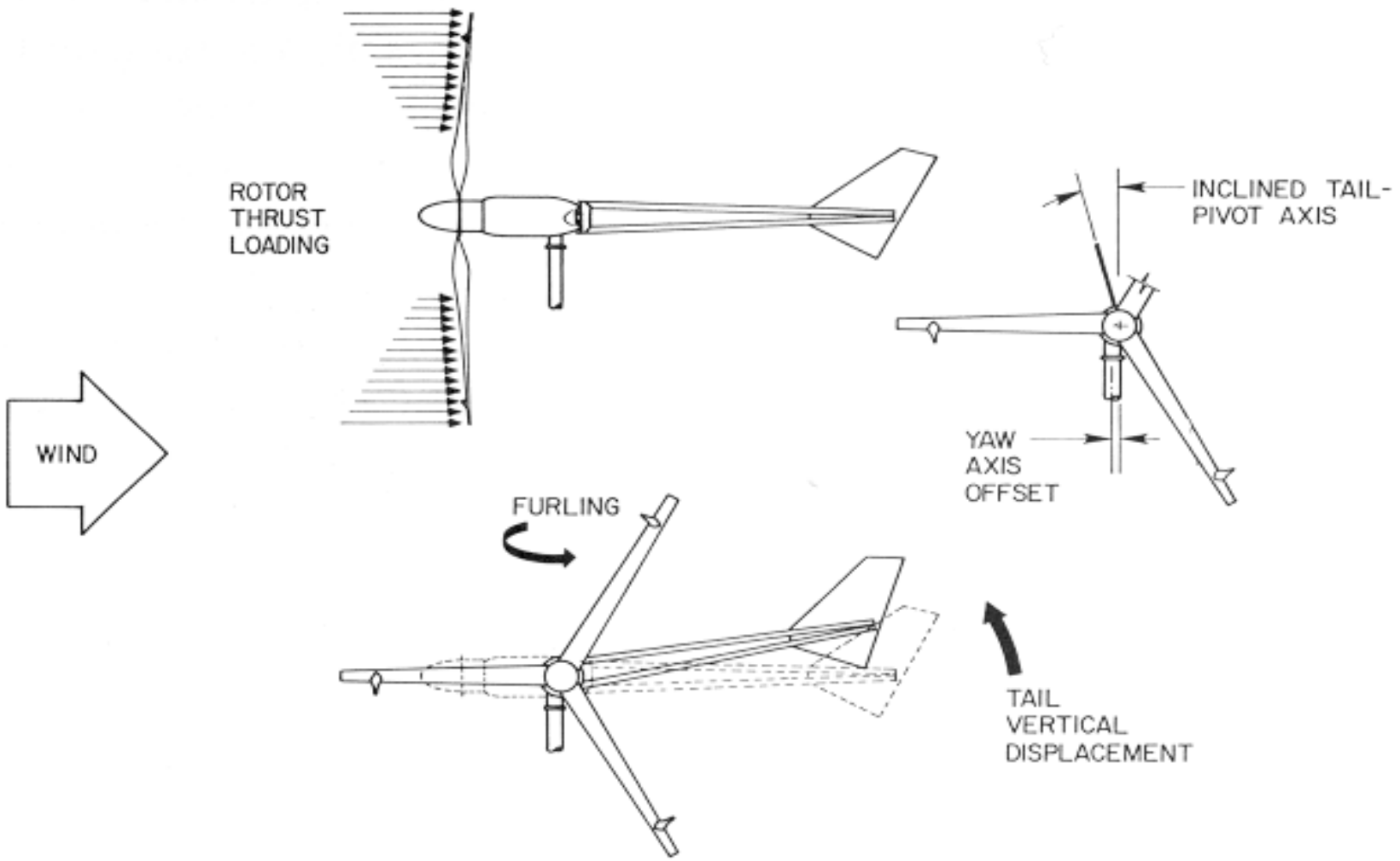
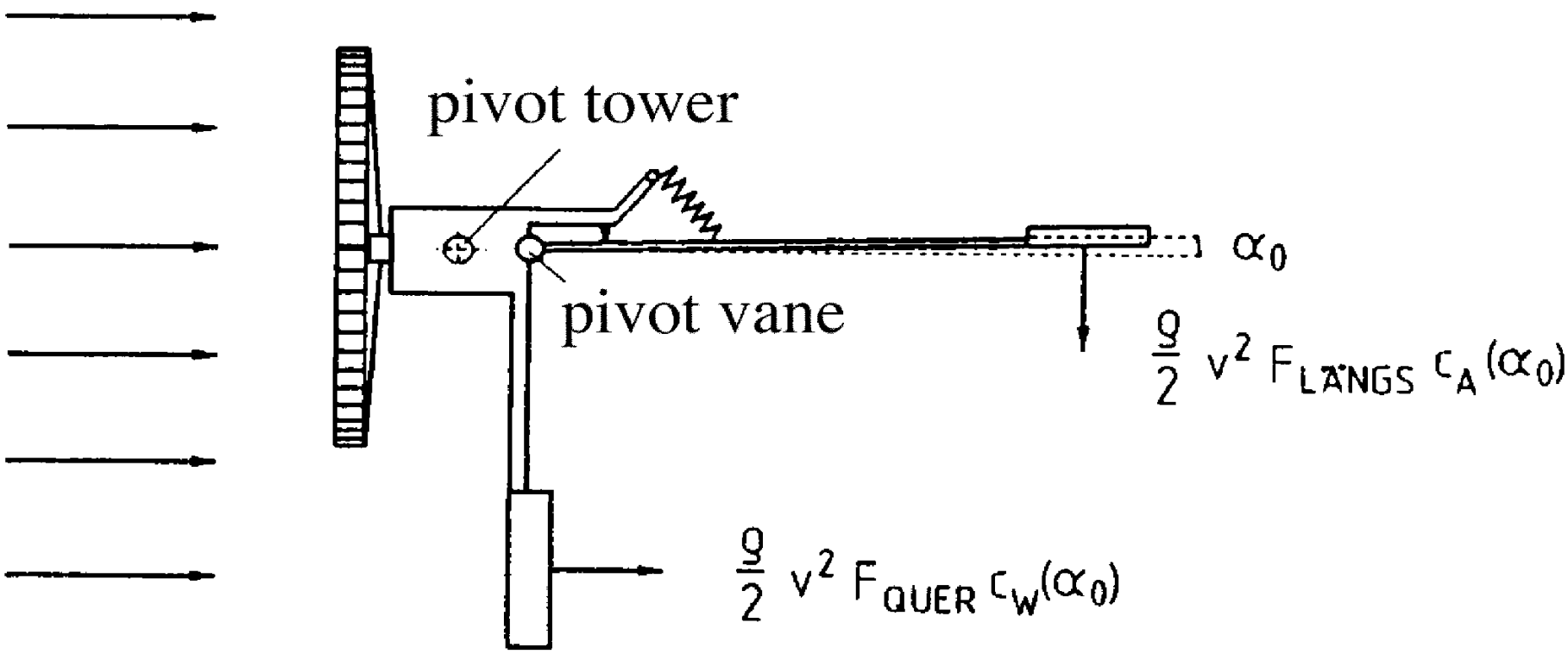
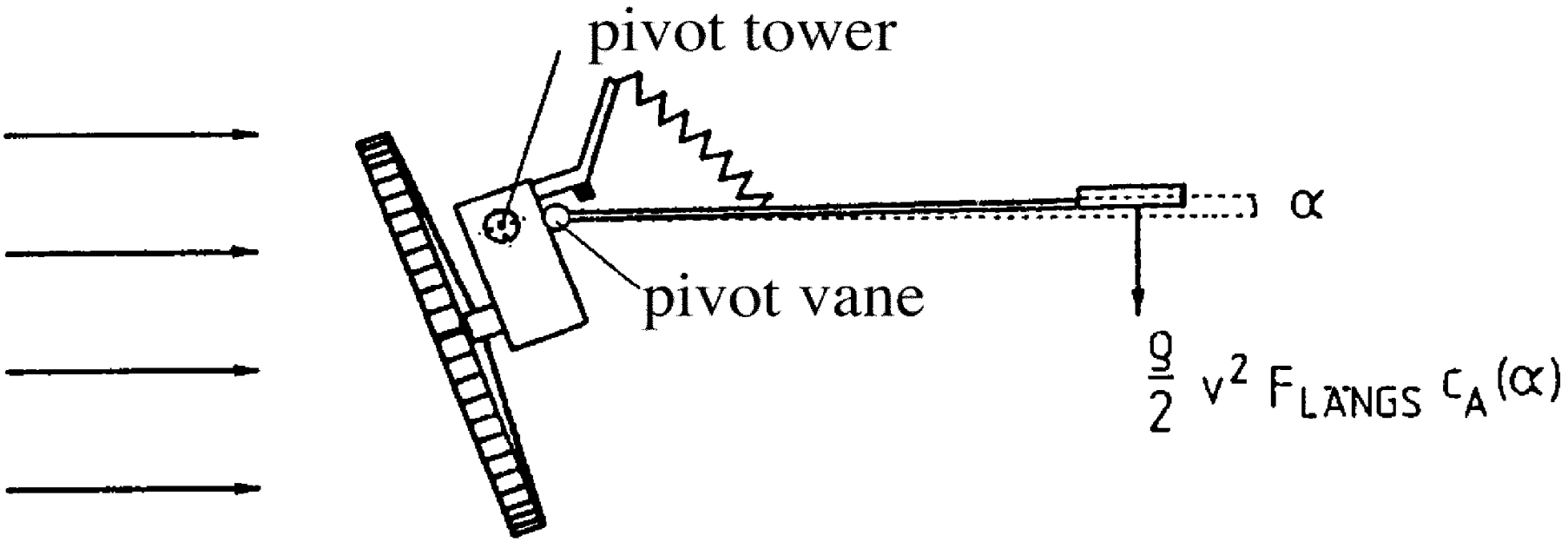
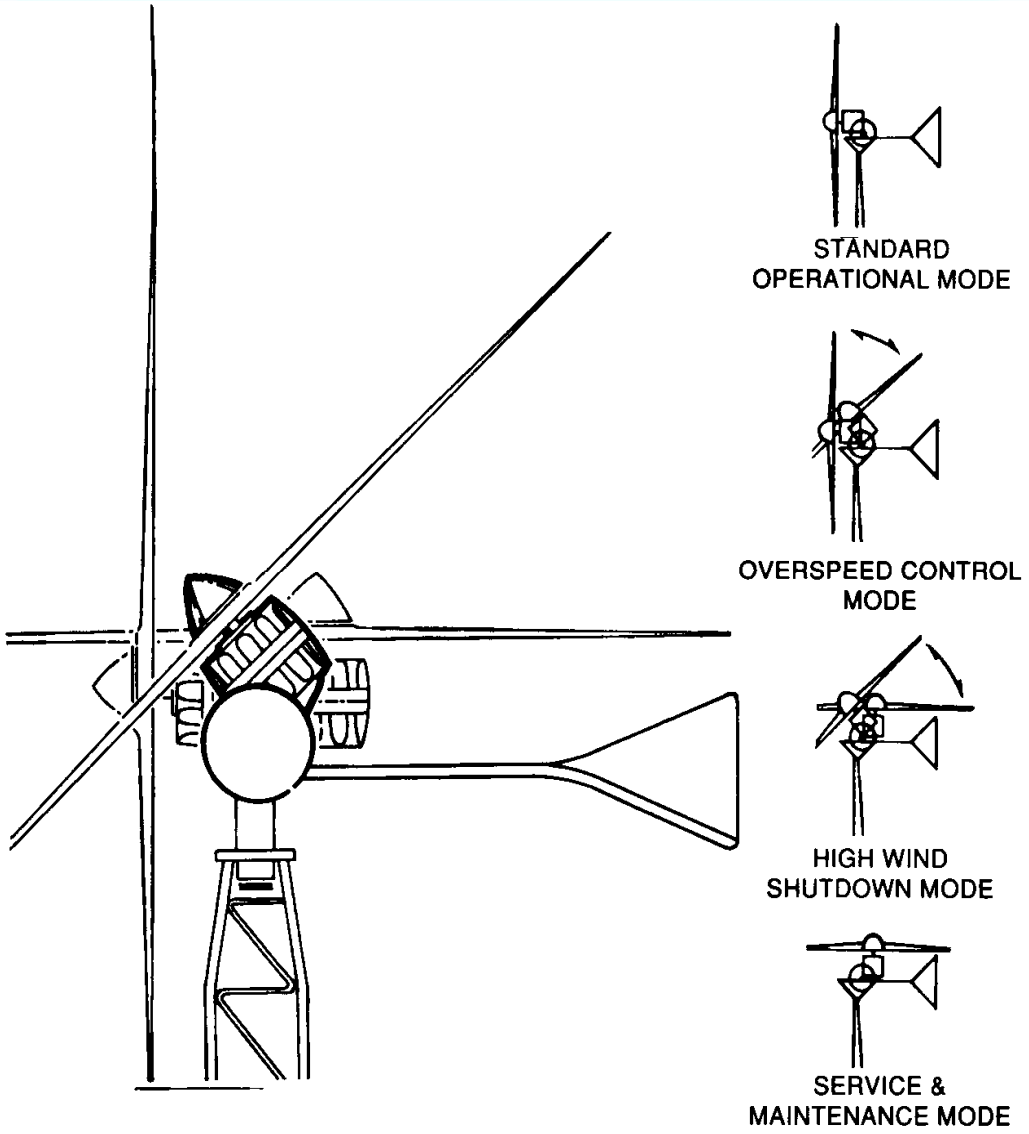



pivot tower
pivot vane
α_0
$\frac{\varrho}{2} v^2 F_{LÄNGS} c_A(\alpha_0)$
$\frac{\varrho}{2} v^2 F_{QUER} c_W(\alpha_0)$


pivot tower
pivot vane
α
$\frac{\rho}{2} v^2 F_{LÄNGS} c_A(\alpha)$


1500

Tilt/ Vertical Furling



Pitch Control

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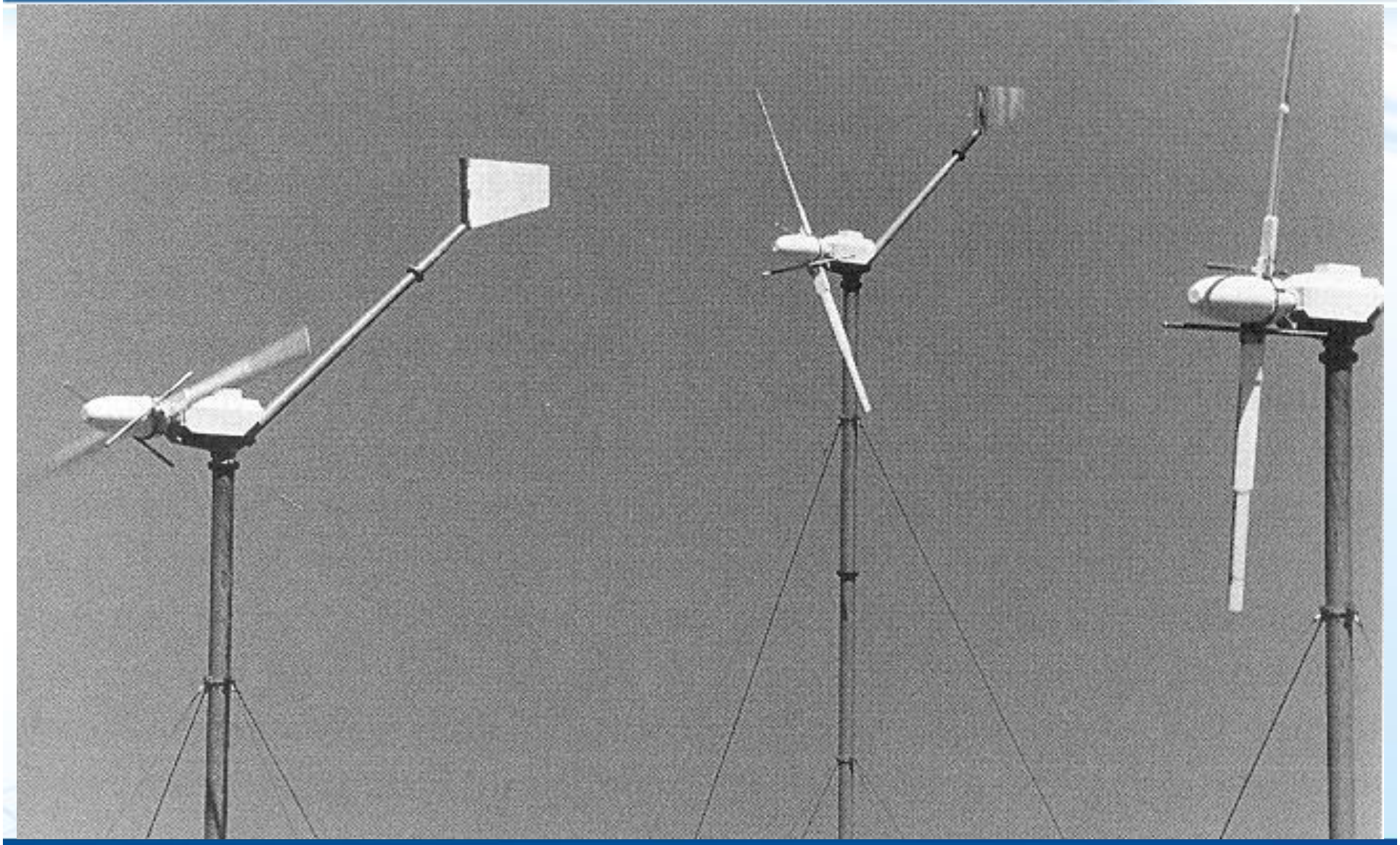
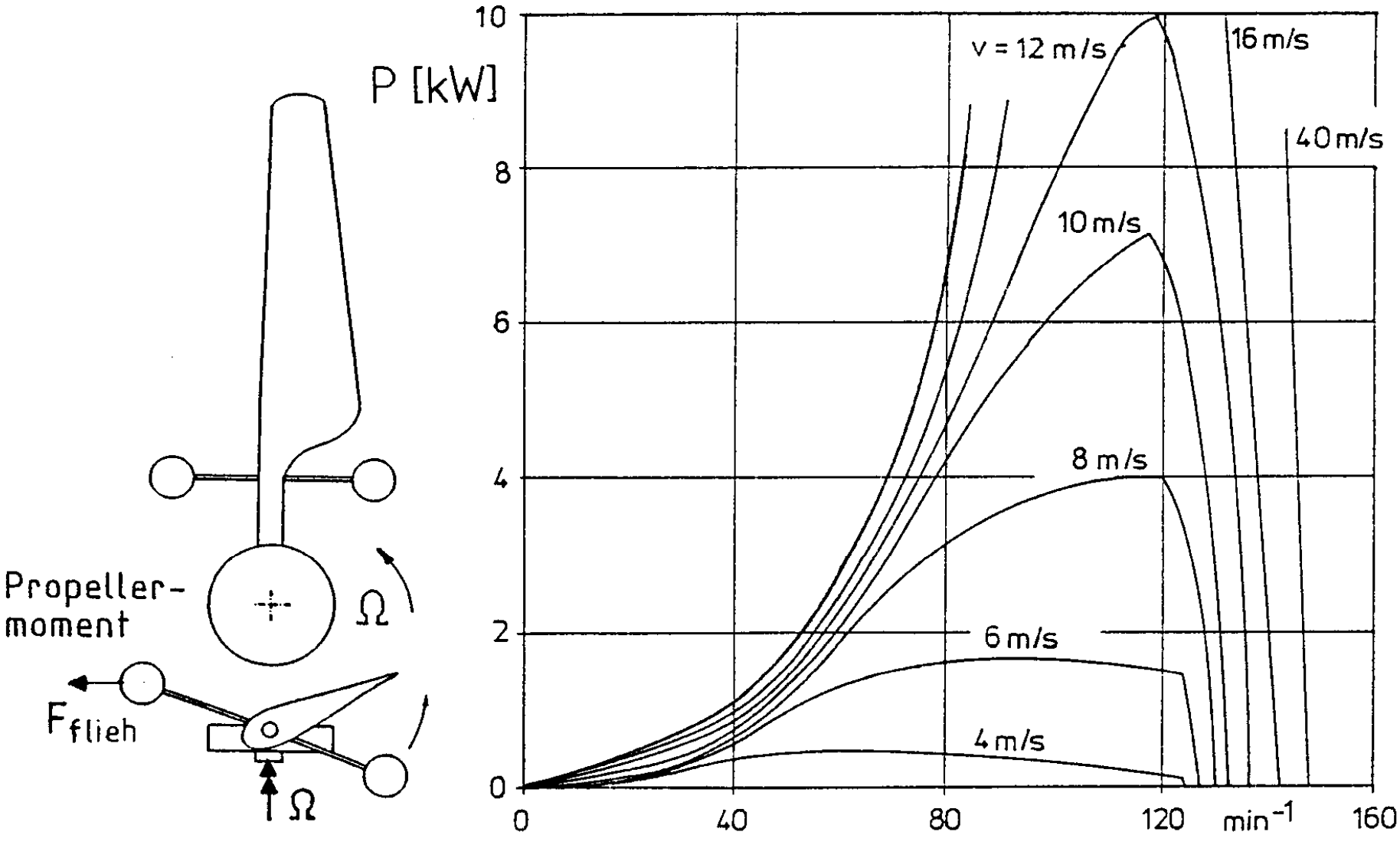
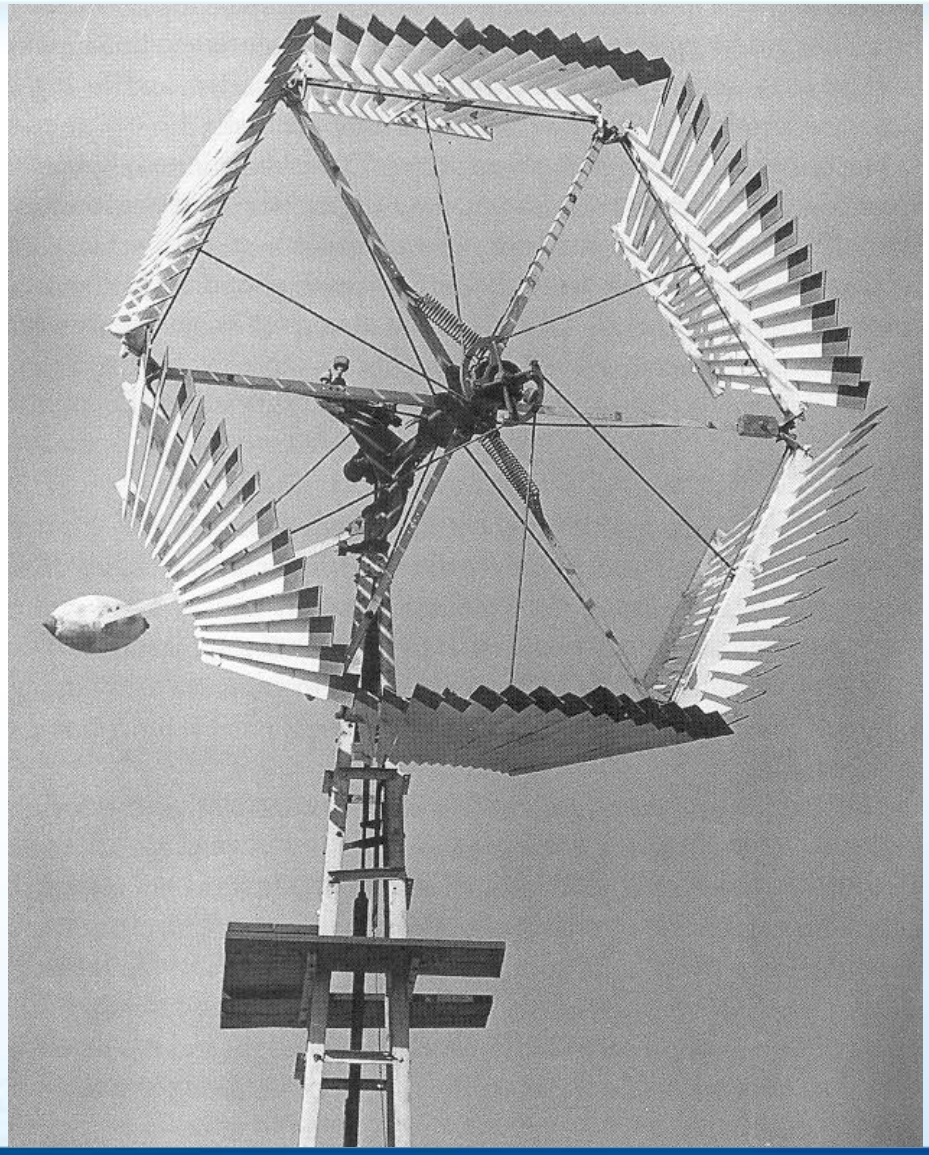



P [kW]
10
8
6
4
2
0
0
40
80
120
160
min⁻¹
v = 12 m/s
16 m/s
40 m/s
10 m/s
8 m/s
6 m/s
4 m/s
Propeller-
moment
Ω
F flieh
Ω



Blades

- **Often very bad aerodynamic design for small blades, e.g.**
  - 455 kW/ m2 for Bonus 600 kW
  - 260 kW/ m2 for Bergey 10 kW;

Good research in this area is done by the University of New South Wales, Newcastle, Australia

Maintenance

- Low maintenance costs is the key, however, it is often very difficult ton achieve;
- Also, very difficult and risky to climb up a large tower to repair/ maintain a small wind turbine;

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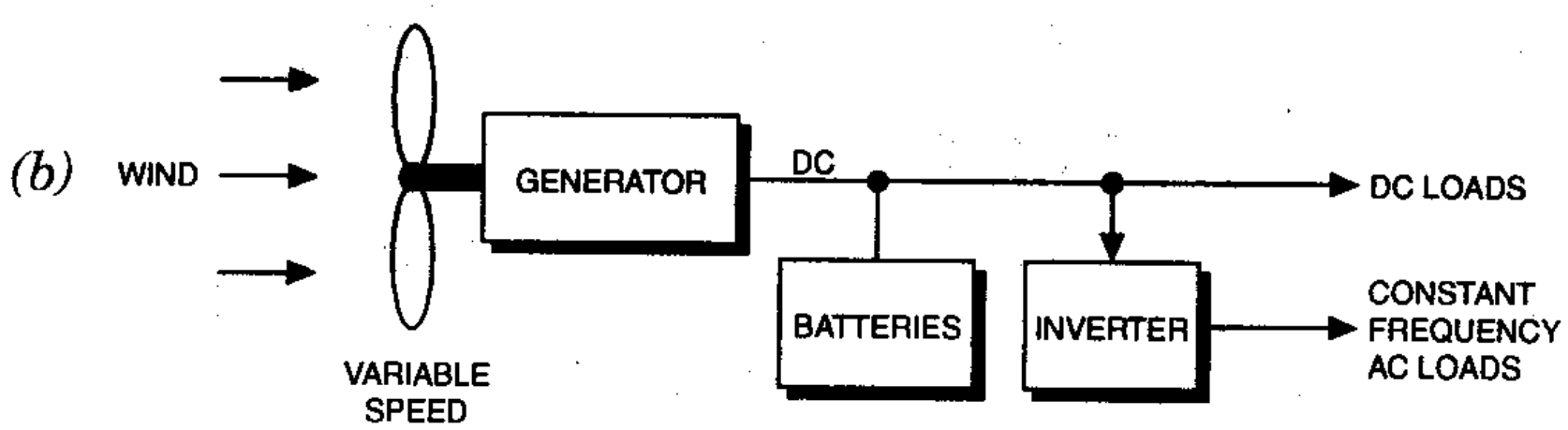
Grid Connection I



Induction Generator

- Easy to synchronize with the network;
- Cheap and easy;
- BUT: Requires reactive power, hence a reactive power source needed!
- Voltage different to regulate;

Synchronous Generator

- Reactive power generation possible;
- Easy to control;
- BUT: Must be synchronized in frequency, phase and current;

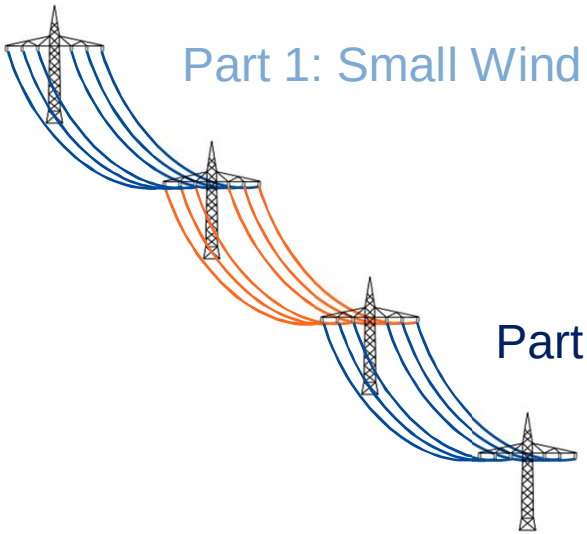
DC Generator

- Direct connection to battery possible (Battery charger);
- No synchronisation required;
- Low efficiency;
- Repair of DC generator can get very expensive;

Battery & Inverter

- Power output can be regulated;
- Easy to synchronize;
- Can supply reactive power;
- Expensive;
- Control might be difficult;
- Lifetime of Battery limited.

Contents



Wind Diesel Systems

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- In many remote locations in the world, power generation with diesel generators is the common;
- Fuel prices, however, are often very expensive: In Australia/China, fuel costs per kWh can reach up to 20 Uscents;
- Wind power can be used as fuel saver!

Wind Diesel Systems

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- Different design concepts possible, from very basic to extremely complicated;
- Costs versus reliability, power quality, lifetime of diesel generator & battery, redundancy of equipment.
- Larger number of different concept are in use.

Diesel/ Battery

- Diesel: Cascade Design;
- Battery: Short term storage up to 5-10 minutes;
  Short lifetime due to large number of cycles,
  Extra building, Air-condition ?, Environmental
  problematic;

Practical Steps

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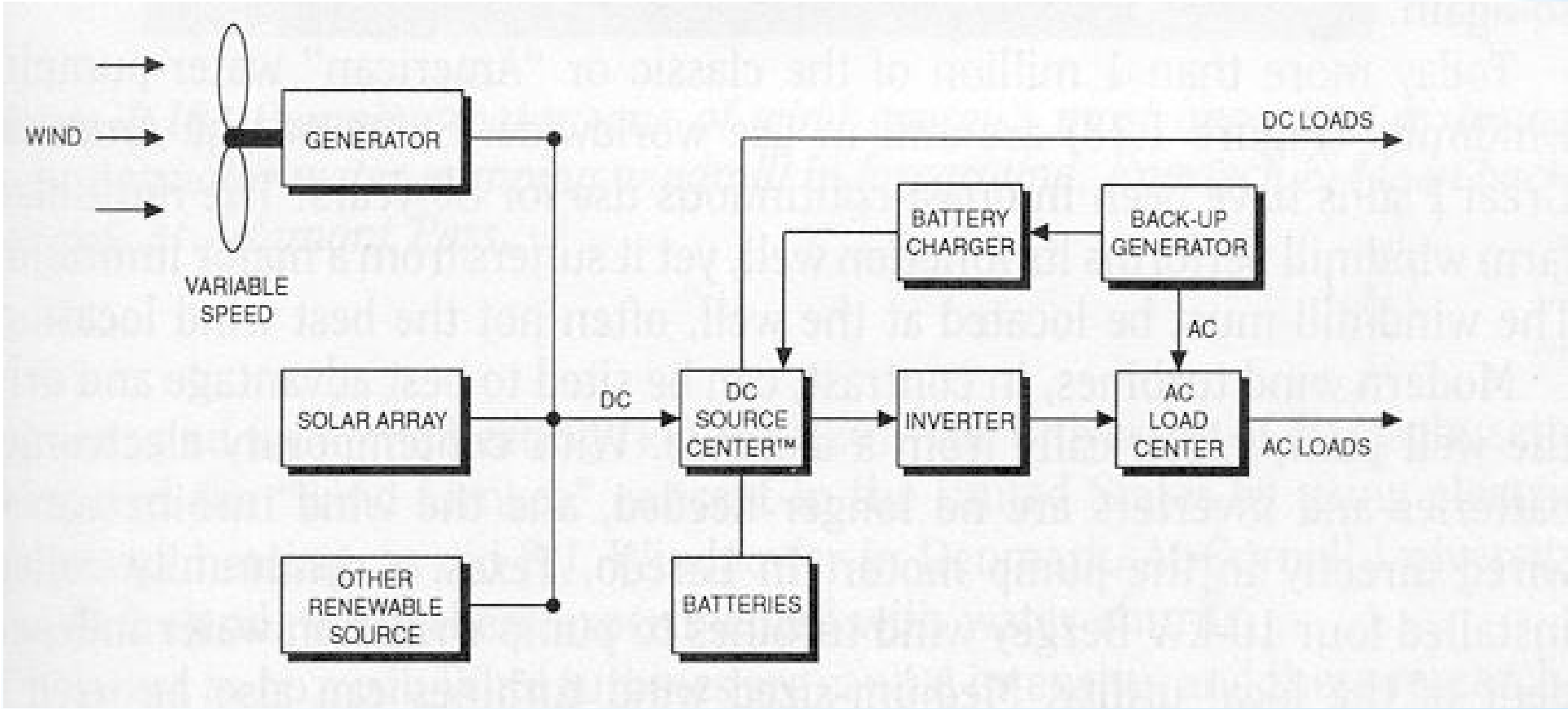
Important: Define Max, Min and average load

Wind-Diesel-Battery Systems



System 1: Wind / Diesel Controlled by Frequency (Droop Mode)

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- The grid frequency is used as a measure for loadsharing between the WTG and the diesel genset;
- If the load increases, speed of diesel drops and frequency decreases;
- If diesel power output is less than 50 % than wind turbine would sense a rise and would start to pitch (reduce output), hence increase load on the diesel generator

System 1

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- **Advantages**
  - WTG can be installed without communication link;
  - Minimum load on diesel genset is ensured;
- **Disadvantages**
  - Wind speed fluctuations affect grid frequency
  - Need to provide spinning reserve to balance wind speed fluctuations;
  - Control dynamic problems occur during low load periods when the WTG power output must be decreased;

System II: Wind/ Diesel/ Battery System controlled by Frequency

- Battery as short term energy buffer;
- Oversupply of WTG used to recharge the battery;

System II

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Advantages

- Higher Penetration possible
- Less use of diesel/ reduced diesel costs/ longer lifetime
- WTG can be installed without communication link;
- Increased stability in the network

Disadvantages

- Higher investment and maintenance costs (Battery/ Inverter)
- Wind speed fluctuations affect grid frequency (but less)
- Control dynamic problems can occur during due to “Tower Shadow effect” and governor system and low load situations

System III: W/D/B with WTG Setpoint Control

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- Diesel gensets are equipped with load share and speed control. The engine speed controller together with the engine governor control the speed of the engine to a setpoint of 50 HZ. Supported by load share system;

- The load share system distributes the load to the diesel gensets and the wind farm, WTG must except setpoints (Pitch), communication required

System III

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- **Advantages**
  - Increased power quality
  - Increased stability in the network
- **Disadvantages**
  - Higher investment and maintenance costs (Communication link)
  - Wind speed fluctuations affect grid frequency (but less less)

System IV: W/ D (B/ Flywheel) with Variable Speed WTG

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- Wind Turbine as Flywheel;
- Converter (Battery) as short term energy buffer;
- Power Factor control;
- Better Integration into Control System

System IV

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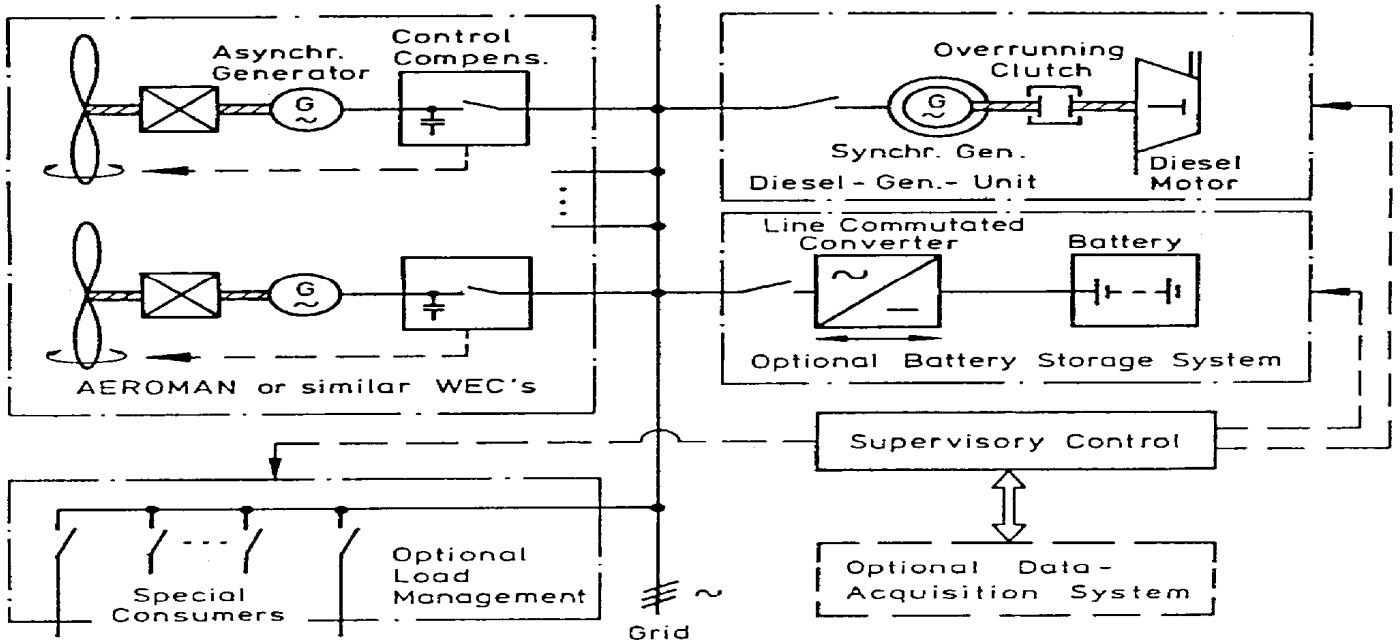
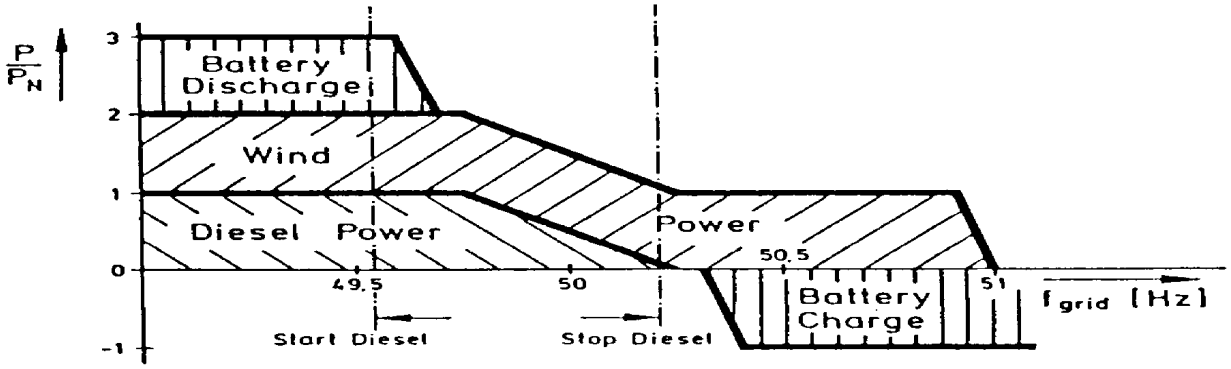
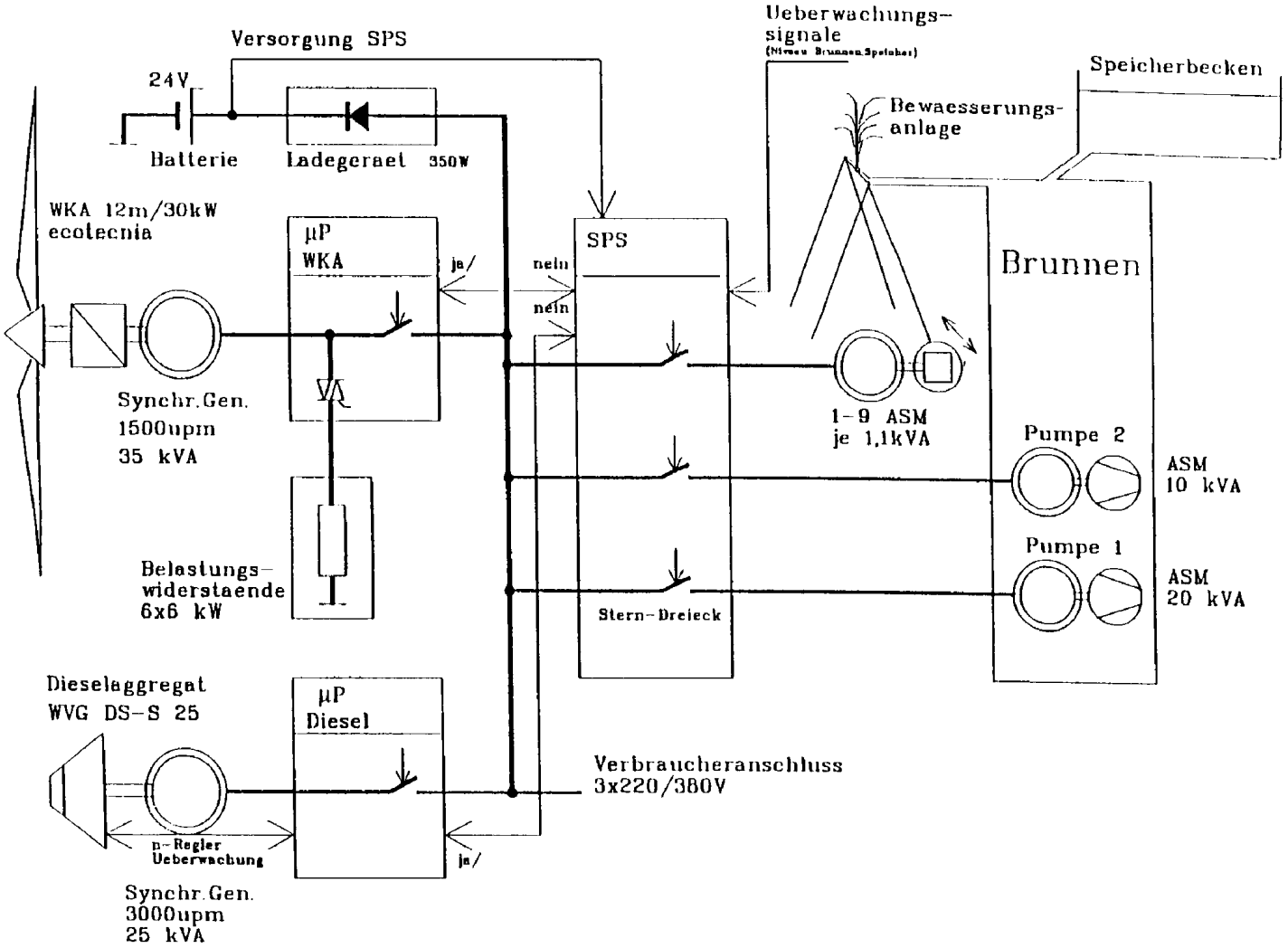
- **Advantages**
  - Very Higher Penetration possible (even 100%)
  - Much better power quality;
  - Log lifetime of diesel genset
  - High stability in the network
- **Disadvantages**
  - Communication Link Required
  - Price!

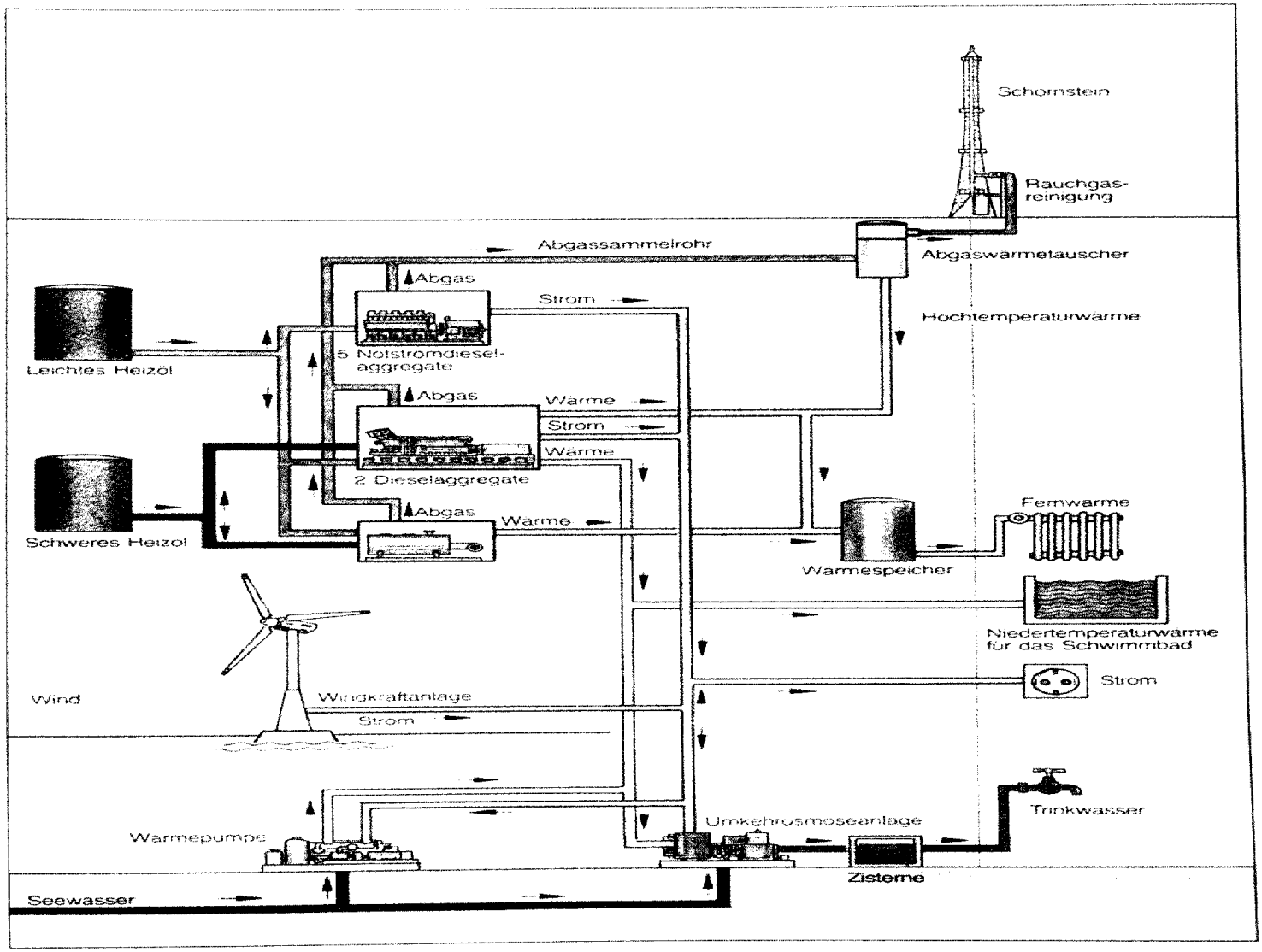
Other Systems

- “Our system in Mongolia”
- Pitchwind/ ÅF (no Battery)
- “Australia System”: Battery at each house


Asynchr. Generator
Control Compens.
G
AEROMAN or similar WEC's
Overrunning Clutch
Synchr. Gen.
Diesel - Gen.- Unit
Diesel Motor
Line Commutated Converter
Battery
Optional Battery Storage System
Supervisory Control
Optional Data - Acquisition System
Special Consumers
Optional Load Management
Grid


P/P_N
3
2
1
0
-1
Battery Discharge
Wind
Diesel Power
Power
49.5
50
50.5
51
Battery Charge
Start Diesel
Stop Diesel
f grid [Hz]


Versorgung SPS
24V
Batterie
Ladegeraet 350W
Ueberwachungs-
signale
Speicherbecken
Bewaesserungs-
anlage
WKA 12m/30kW
ecotecnia
µP
WKA
ja/
nein
nein
SPS
Brunnen
Synchr.Gen.
1500upm
35 kVA
1-9 ASM
je 1,1kVA
Pumpe 2
ASM
10 kVA
Belastungs-
widerstaende
6x6 kW
Pumpe 1
ASM
20 kVA
Stern-Dreieck
Dieselaggregat
WVG DS-S 25
µP
Diesel
Verbraucheranschluss
3x220/380V
n-Regler
Ueberwachung
ja/
Synchr.Gen.
3000upm
25 kVA


Schornstein
Rauchgas-reinigung
Abgassammelrohr
Abgaswärmetauscher
Abgas
Strom
Hochtemperaturwärme
5 Notstromdiesel-aggregate
Leichtes Heizöl
Abgas
Wärme
Strom
Wärme
2 Dieselaggregate
Abgas
Wärme
Schweres Heizöl
Fernwärme
Wärmespeicher
Niedertemperaturwärme für das Schwimmbad
Strom
Wind
Windkraftanlage
Strom
Trinkwasser
Umkehrosmoseanlage
Wärmepumps
Zisterne
Seewasser

Esperance/ Australia

- 14 MW Diesel,
- 2.4 MW Wind Farm;
- During low load and high wind periods wind power penetration of up to 75 %

Exmouth/ Australia

- Three 20/ 25 kW wind turbines (can be removed very fast);
- Generates about 200,000 kWh per year;
- Saves about 50,000 Liters (one liter about 0.5 US$)

Denham/ Australia

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- 800 people,
- 1. Step: 1 E30 (230 kW, supplies 20 % of the local electricity, saves 175.000 liter of diesel)

Denham/ Australia

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- 2. Step:
- two more E30 (230 kW);
- aim: 70 % of electricity;

- **3. Step:**
- **Short term supply: Two Flywheels (5 kWh, can supply up to 300 kW);**
- **Aim: 100 % supply out of wind/ flywheel system!**

King Island/ Australia

- 4 x 1200 kW Diesel;
- Load: 850 kW - 2700 kW;
- 3 x 250 kW (Nordex, stall);
- Dump Load, four elements: 35-70-140-280 kW (0-525 kW);
- Nordex argues that dump load is faster than pitch;
- 85 % wind power penetration possible;
- Fuel cost savings per year: 250.000 US$

King Island/ Australia

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http://www.kingislandrenewableenergy.com.au/