eeeam
ASIA MEETING
ON ENVIRONMENT AND
ELECTRICAL ENGINEERING

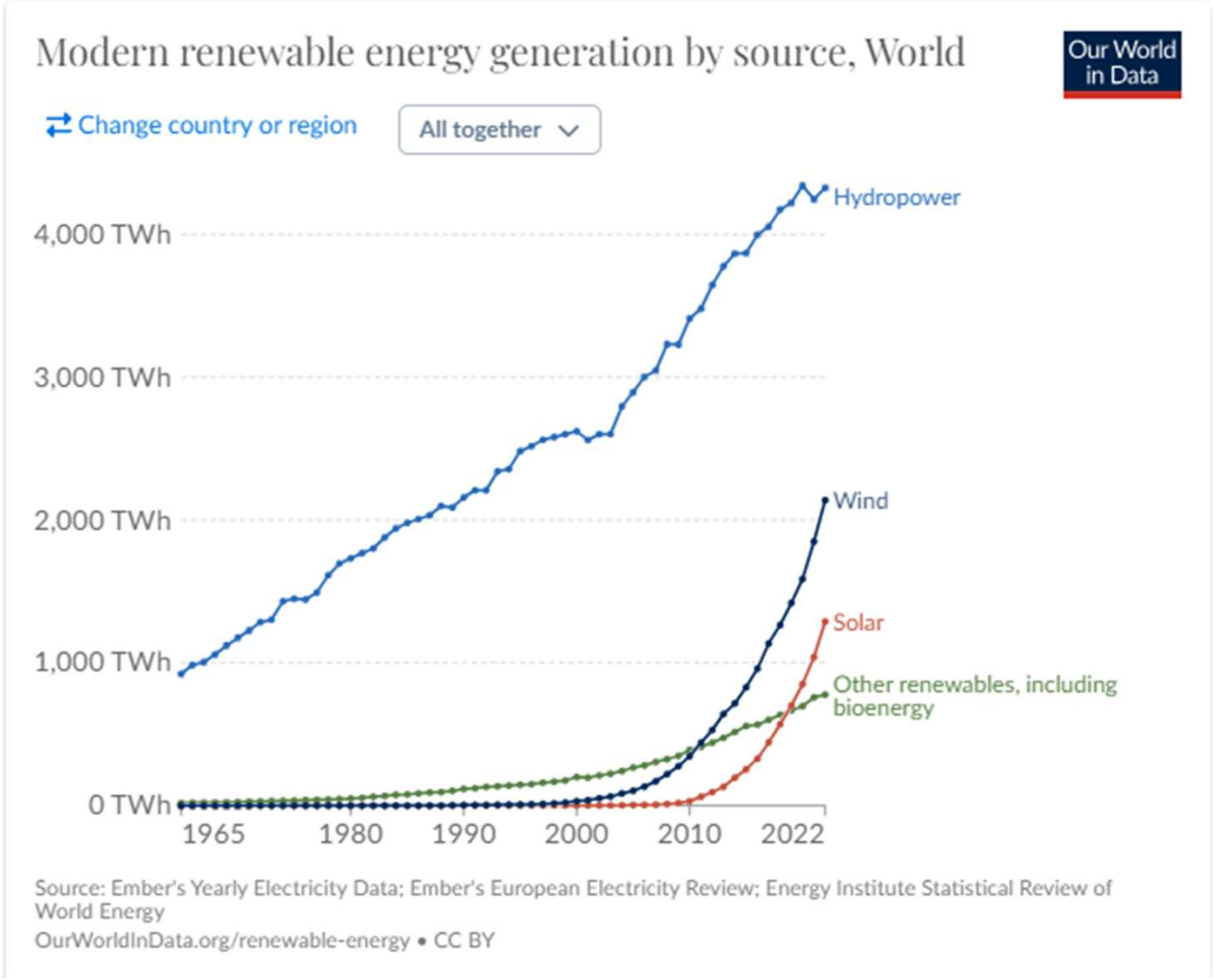
PLENARY SESSION II

"Energy Mix from Technology to Modelling, Operation, and Education"

The Development of Wind Turbine Electrical Systems and Ancillary Services

Prof. Ola Carlson
Division of Electric Power Engineering
Chalmers University of Technology
Gothenburg, Sweden
Email: ola.carlson@chalmers.se

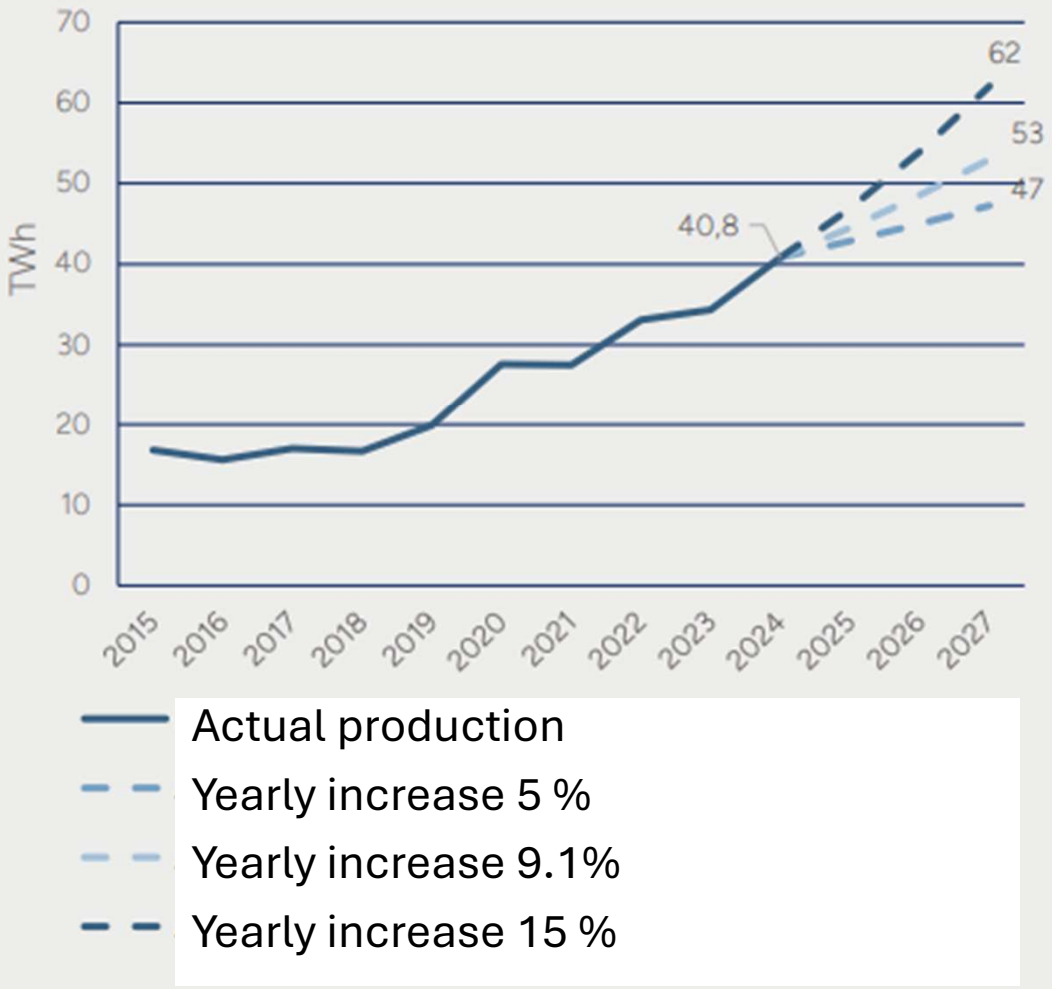
2024 - Total power production worldwide: 30,000 TWh



Renewables are
32 % of
Global Power
Production in 2024

According to IEA
43 % in 2030

Swedish wind power production



Swedish Electrical Power Production 2024

Consumption- 136 TWh
Production -169 TWh

Hydro power in the north, 39 %

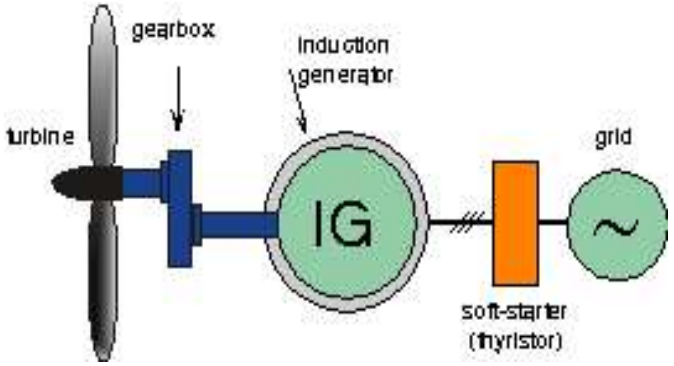
Nuclear in the south, 29 %

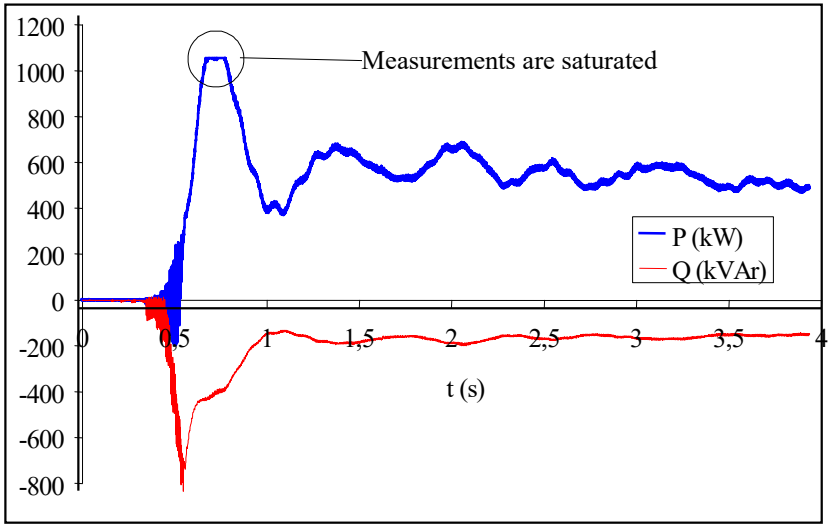
Combined heat and power production, 7%

Wind Power, 25 %

Export 20 %

Induction generator with soft-starter (thyristor)





- Robust generator
- Low maintenance
- Simple system
- High mechanical forces
- Dominating system during 1980-1990
- Not so common on large machines > 1.5 MW

Grid connection of stall-controlled wind turbine

Chalmers 1978, industry 1980

Wind power with variable speed

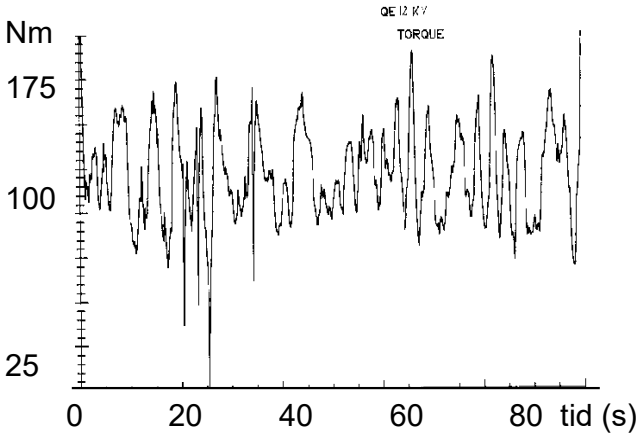
Why use variable speed?

mechanical	+ Less noise
	+ Structural constitution
	+ Control of drive train torque
electric	+ Less power pulsations
	+ Possible to connect to a weak grid
	− More expensive electric system
	• About the same efficiency

Torque measurements with constant and variable speed

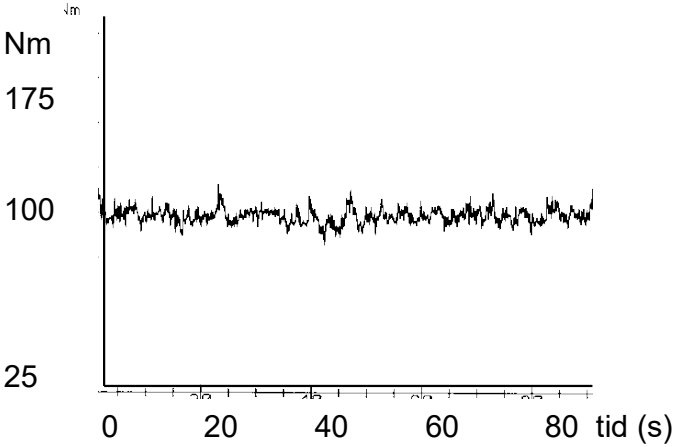
Measurements from Chalmers test wind turbine 1986

Constant speed



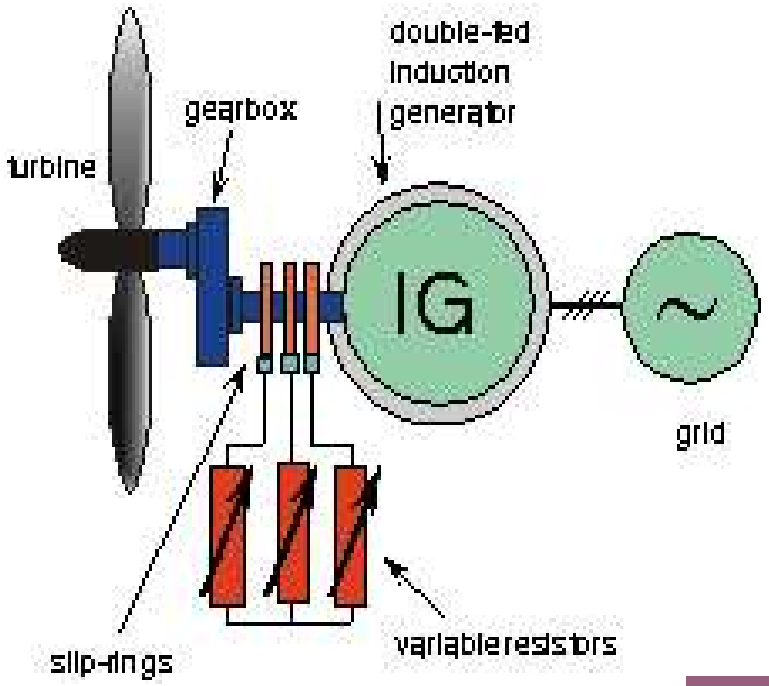
- Large torque rippel
- High mechanical forces

Variabel speed



- Long lifetime of gearbox
- Small influence on power quality

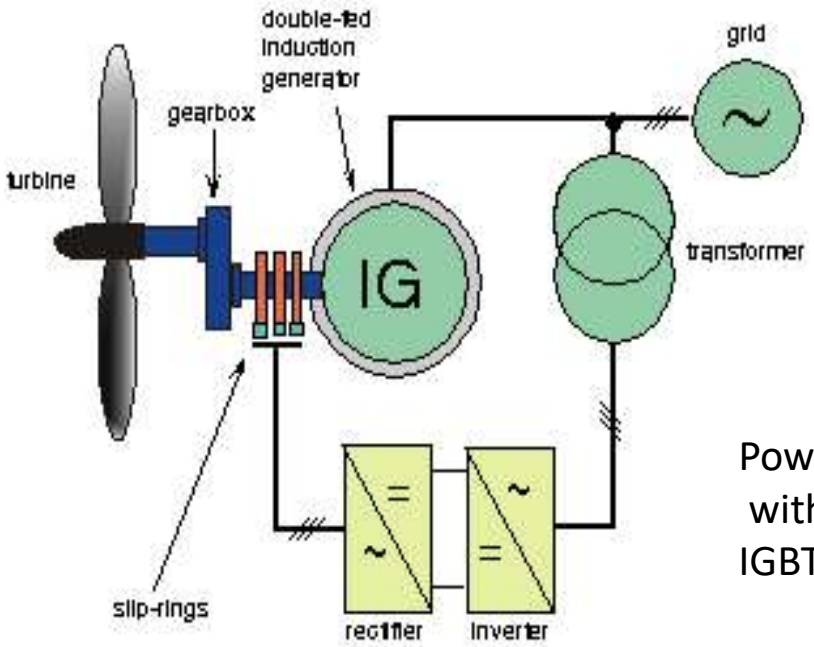
Induction generator with controlled rotor resistances



- Optislip (name by Vestas)
- Small speed variations
- Limited torque control
- Speed increase = power in the resistor

Chalmers 1984, industrin 1994

Double-fed induction generator, DFIG



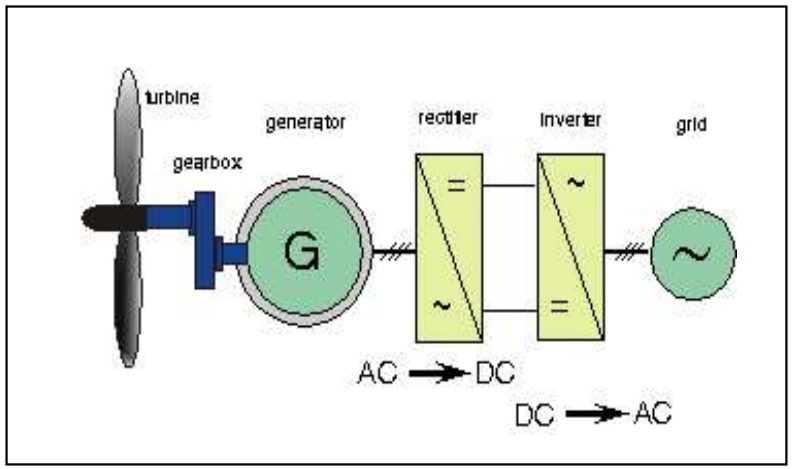
- Limited speed variation
- Limited power of the converter
- Good efficiency
- Good control of P, Q
- Slip rings = maintenance

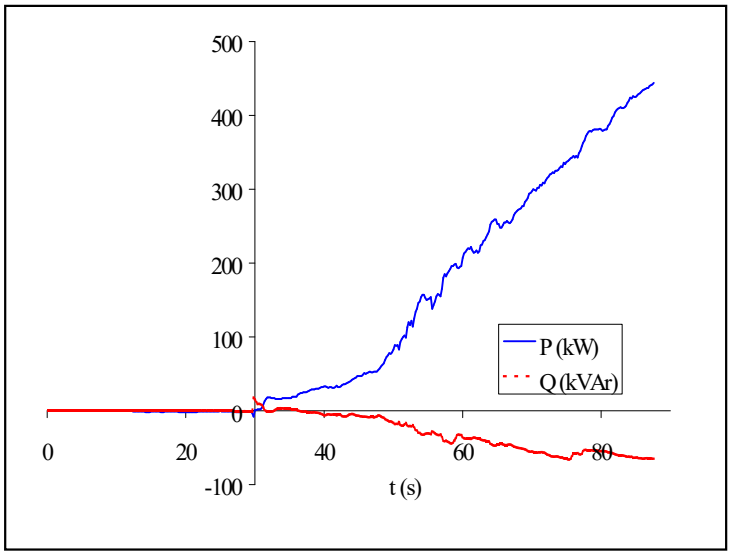
Power package with 6 IGBT-transistor

50 cm

Chalmers 1986, 2002, industry 1995

Full Power Converter



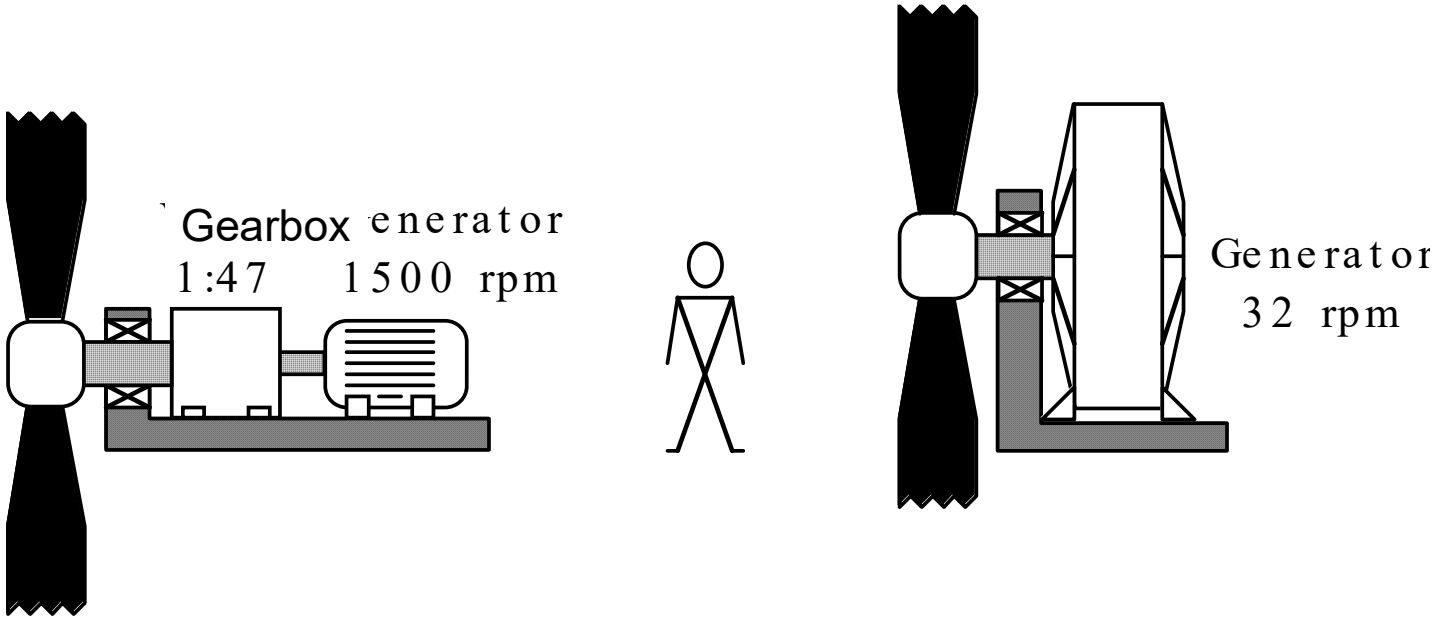


Start up with variable speed

- Full control of P & Q
- All power trough the converter
- Higher losses
- Generator AG, SG, PM
- Perfect withstand of low voltage dips

Chalmers 1984, industry 1990

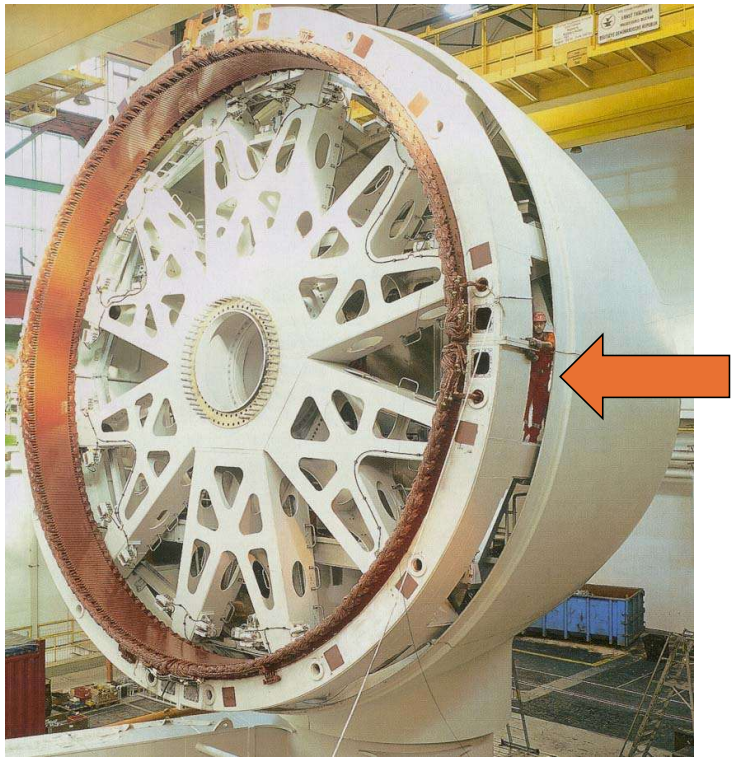
Generator with and without gearbox, 500 kW



- Lower the costs for the drive line
- Lower the losses in the energy conversion from mechanical rotation to electric power
- Increase the availability for the wind turbine, there by higher energy production

Direct driven generator – from Enercon

- Extremely heavy due to stiffness requirements
- Generator weight 220 tons(4.5 MW power)
- Compare size with the man!



Chalmers wind turbine: 30 kW

Design and operation by Chalmers Univ.

You are welcome to collaborate for research

Changing the frequency converter for the pitch motor

Wooden tower: designed and constructed by Modvion

- 30 m at Chalmers wind turbine in operation since 2020
- 100 m in operation since 2024
- 140 m under design

Frequency control by wind turbines

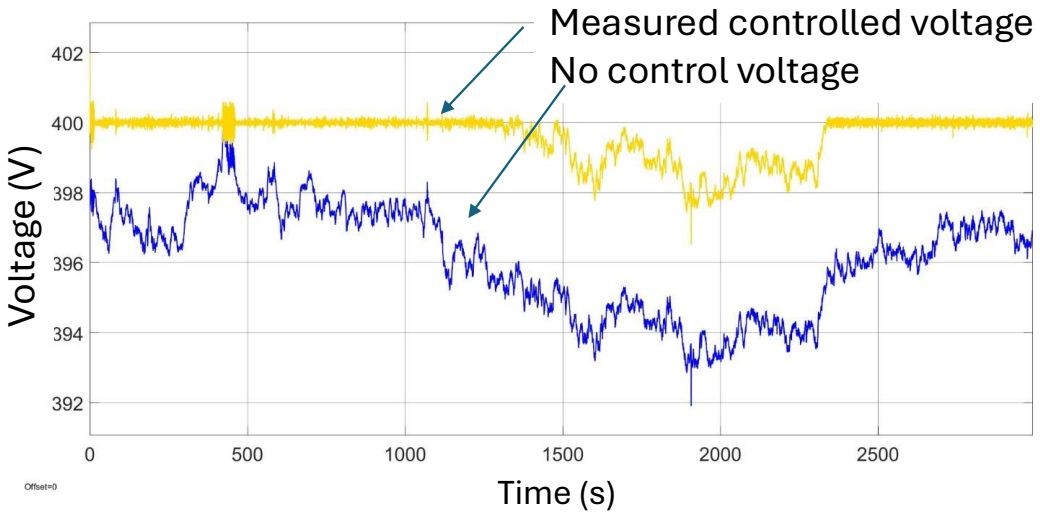
- **Frequency control** is necessary to keep the frequency in a power grid – balance between consumption and production
- **Frequency control** by wind turbines is to control the power output from the wind turbine in a not optimal energy way and get paid for the ancillary services.

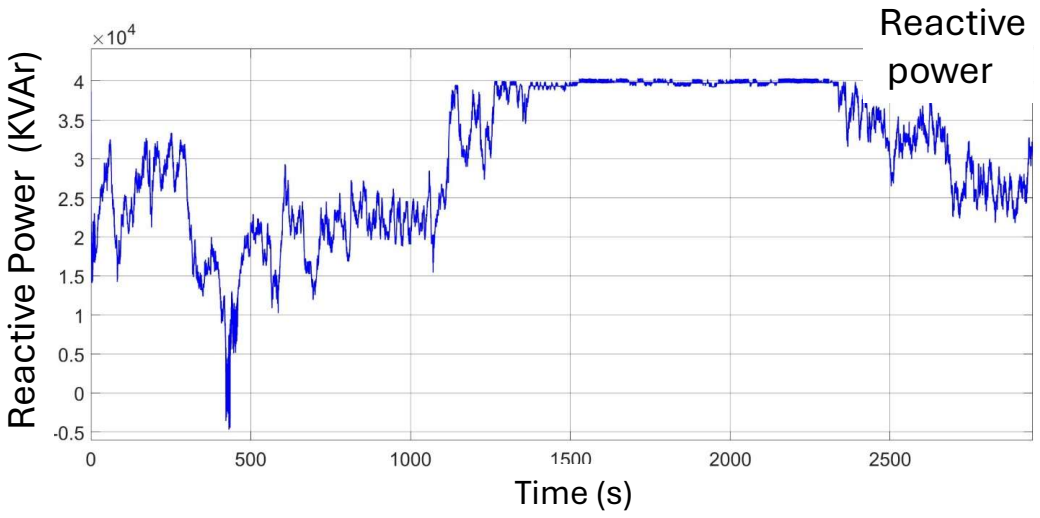
The wind turbine should be able to:

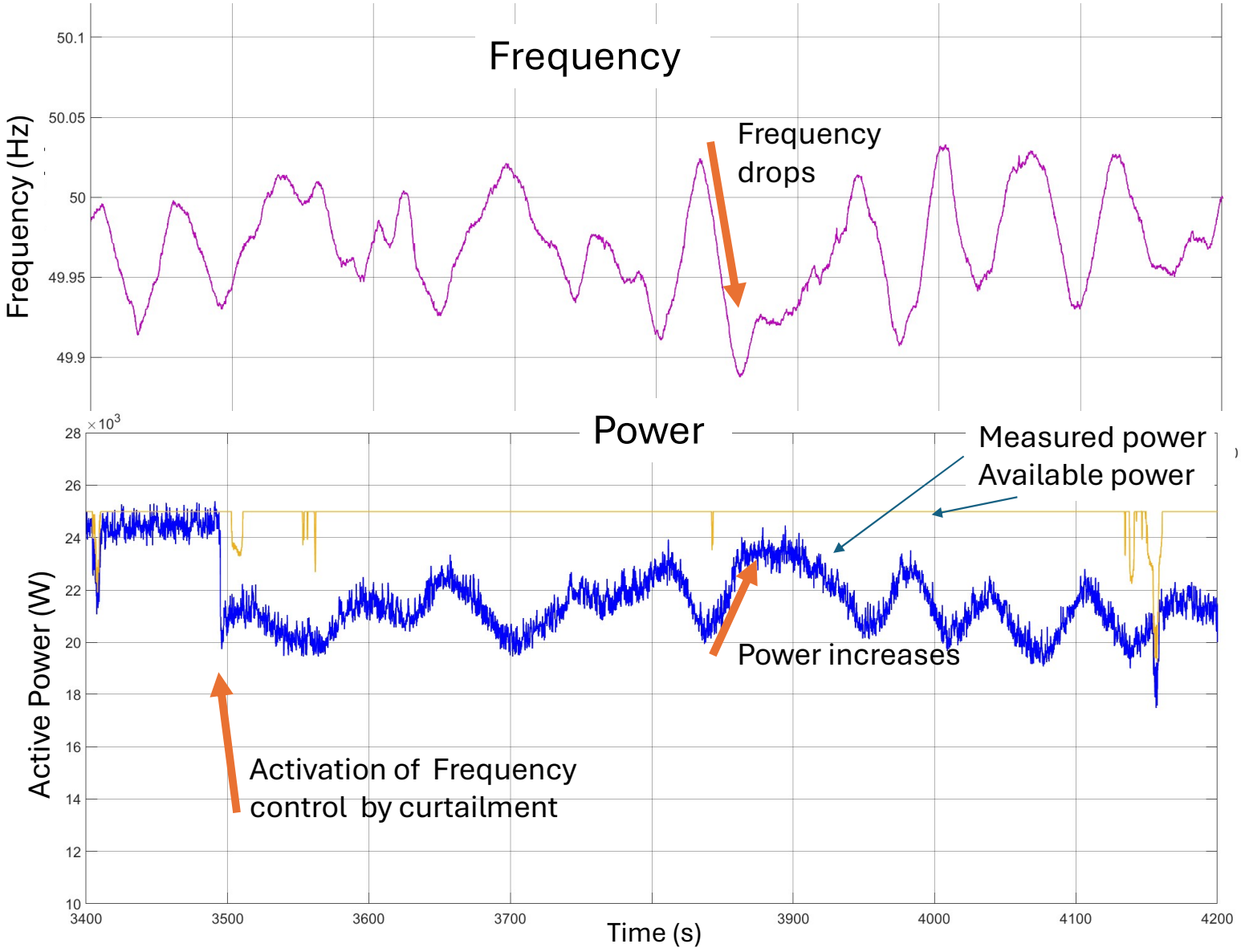
1. **Decrease the power output** with a specific amount of power and **stay** at that level for a specified period of time, minutes to hours.
2. **Increase the power output, during 5 seconds** a specific amount of power and **stay** at that level for a specified period of time, minutes to hours. Then the wind turbine need to **spill the wind** in the previous operation situation.
3. **Increase the power output**, by 10-20% of rated power, for a short period of time, 5-30 seconds and after that **recover the power production** to normal and after 15 minutes be ready to support with extra power again. This increase has to come within the time less than 1 second.

Control towards 400 V at Chalmers wind turbine

The wind turbine converter has the rated power of 40 kVA







Frequency service at Chalmers wind turbine

Curtailment
0 kW at 49,9 Hz,
5 kW at 50 Hz
10 kW at 50,1 Hz

Swedish Wind Centre

Most of the Swedish wind power researchers are joining the centre.
Make it possible to coordinate research projects and create large projects

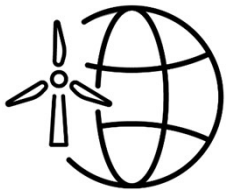
CHALMERS RI. SE LUNDS UNIVERSITET LTH LUNDS TEKNISKA HÖGSKOLA LULEÅ UNIVERSITY OF TECHNOLOGY SMHI SLU KTH VETENSKAP OCH KONST UPPSALA UNIVERSITET

+

Energiforsk

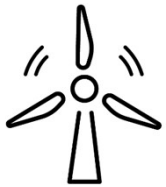
Website: https://www.swedishwindcentre.se

Research themes and research topics

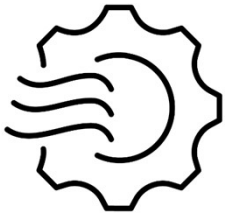


Planning of wind power

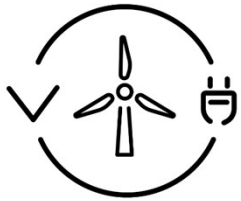
Siting



Turbine technology



Operation & maintenance



Electrical system integration

Participating companies

Key take-aways

Wind power increases worldwide rapidly

Torque control in the drive-train is essential for development of wind turbines

Wind power can control the voltage and frequency in a power system