

Simon Vince
ENERCON UK
simon.vince@enercon.co.uk

Stephan Wachtel
ENERCON - International Sales
& D Systems
stephan.wachtel@enercon.de

Dr. Frank Fischer
ENERCON - R&D
Control & Simulation
frank.fischer@enercon.de

Stefan Hartge
ENERCON – R&D
Lead Electrical Engineering
stefan.hartge@enercon.de

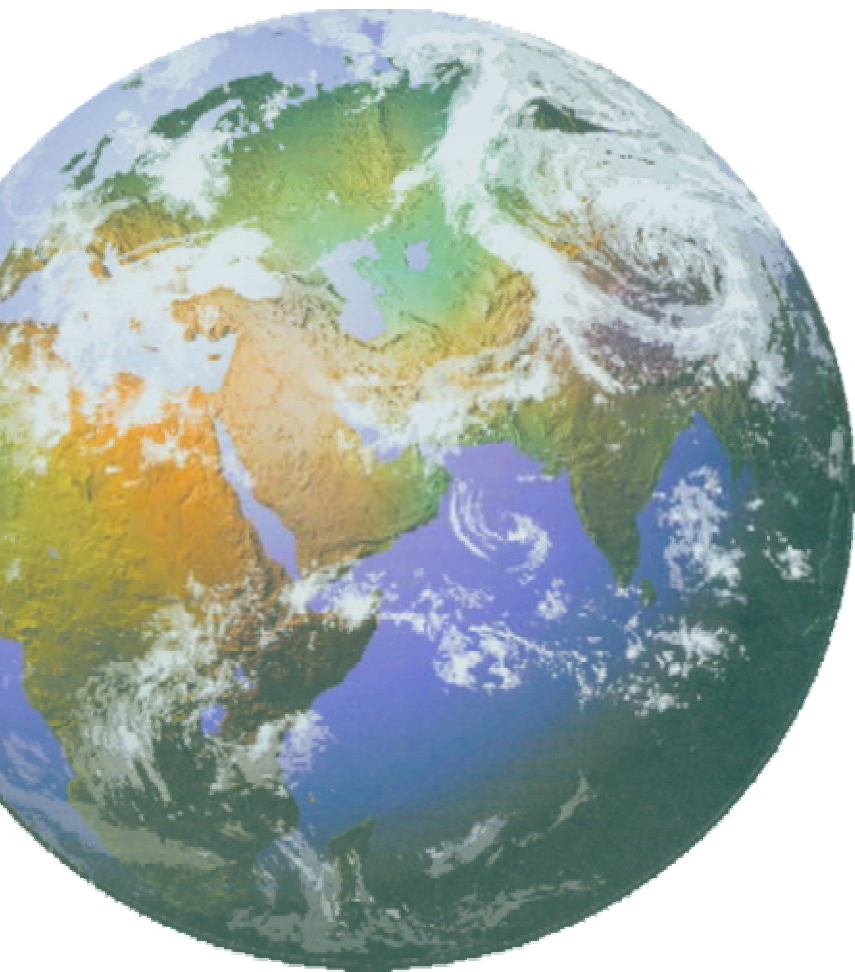
Great Britain Grid Code

OFGEM Forum

24th and 25th March 2004

London

www.enercon.de



Installed Capacity: 5.6 GW
producing more than 6.5 bill. kWh

Operating revenue
in 2000: 598 mill.
in 2001: 915 mill.
in 2002: 1231 mill.
in 2003: 1100 mill.

Production area: 284170 km²

Employees incl. sub-sup.: app.1200

Export countries:

Installed E-30: 532 WE

Installed E-40: 3802 WE

Installed E-58: 178 WE

Installed E-66: 1965 WE

Installed E-112: 2 WE



Product

Undervoltage Ride Through

Negative Phase Sequence Loading

Power Recovers immediately

Frequency Range/Control

Active Power Control

Reactive Power

Voltage Control



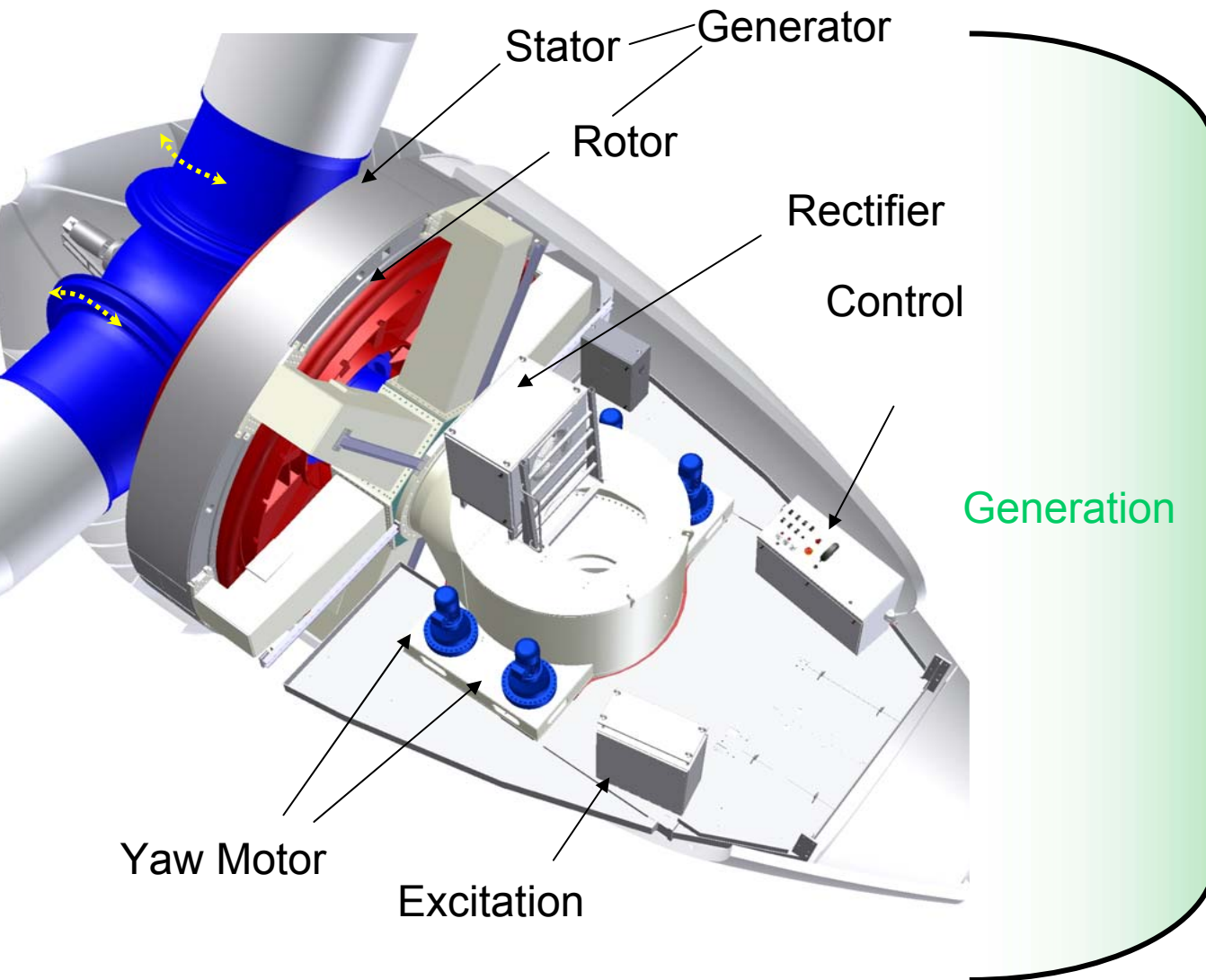
Product

ENERCON Products

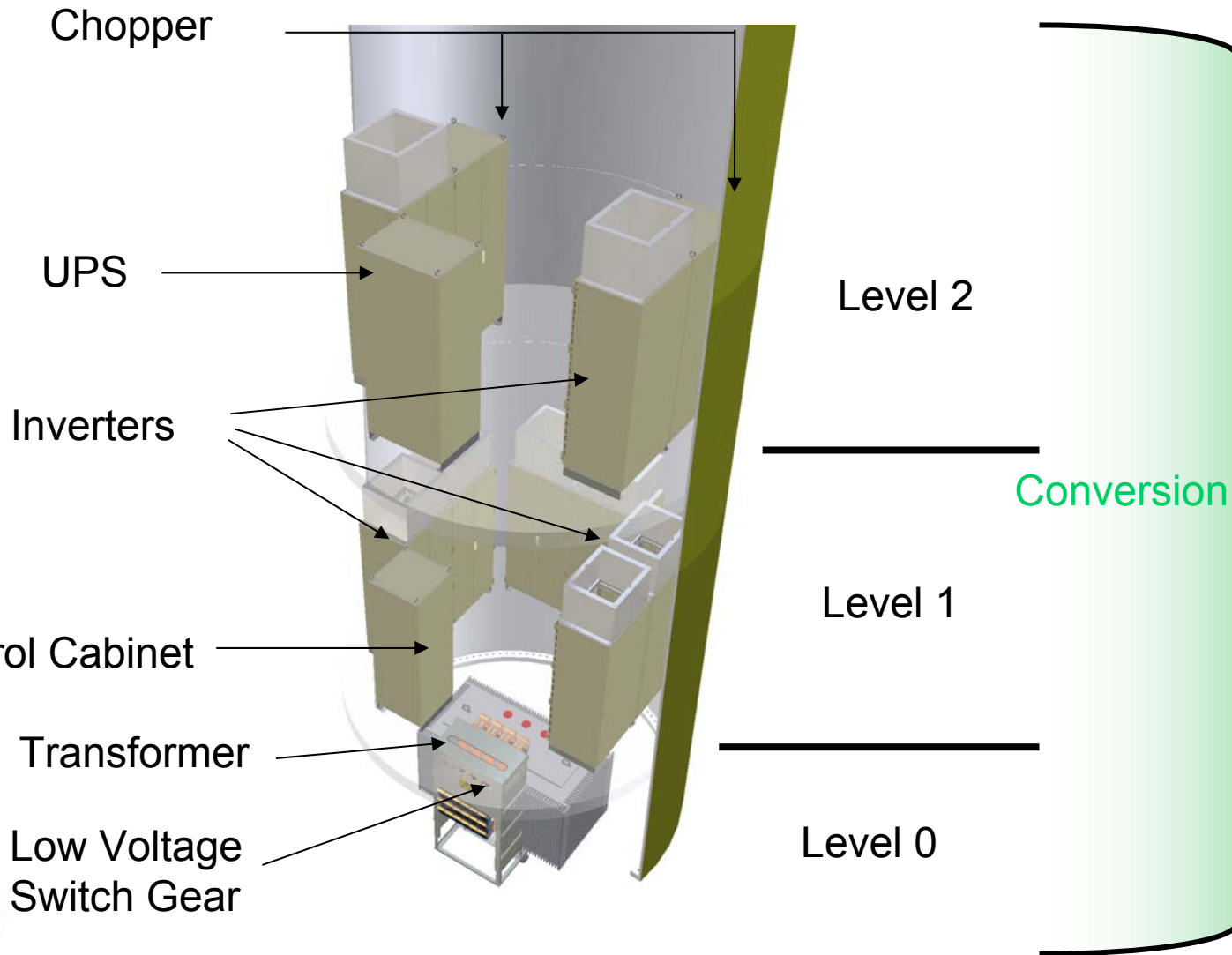
E-30
0.3 MW



PERCON Technology and the proposed GBGC



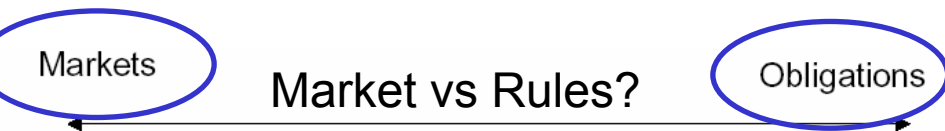
ERCON Technology and the proposed GBGC



GB Market Conditions

... 10 % renewable in 2010 (Energy White Paper) ...

... Security of the electricity system (OFGEM) ...



... Great Britain Grid Code ...
(Transmission Licensees)

- | | | |
|--------|-----------------------|------------------------------|
| Energy | Balancing bids/offers | Stability |
| | Reserve | Excitation capability |
| | Black start | Frequency control capability |
| | Reactive utilisation | |
| | ← Response activation | |

- Performance (Manufacturers)
- Undervoltage Ride Through*
- Frequency Control*
- Reactive Power*
- Voltage Control*

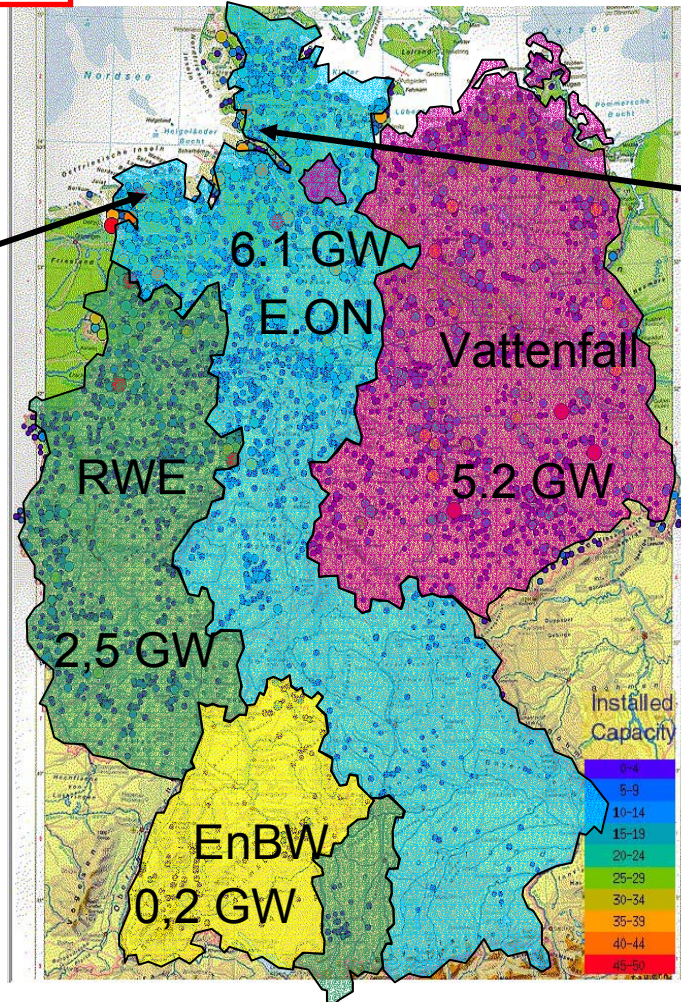
ional Grid Transco



Product

Undervoltage Ride Through

Overvoltage Ride Through



ENERCON
Head Quarter
Aurich



Test environment

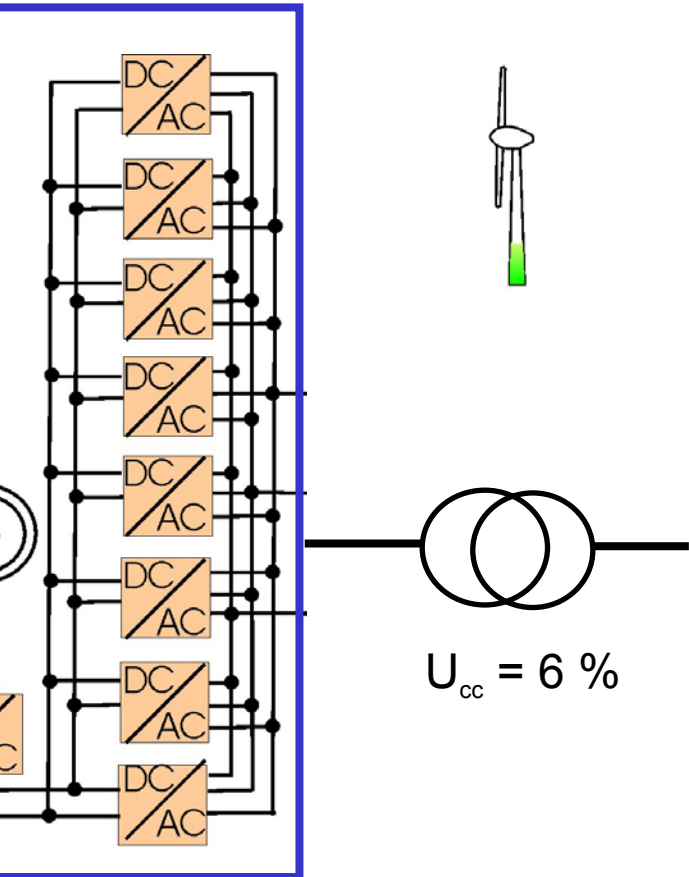
E-66 / 2 MW Transmiss



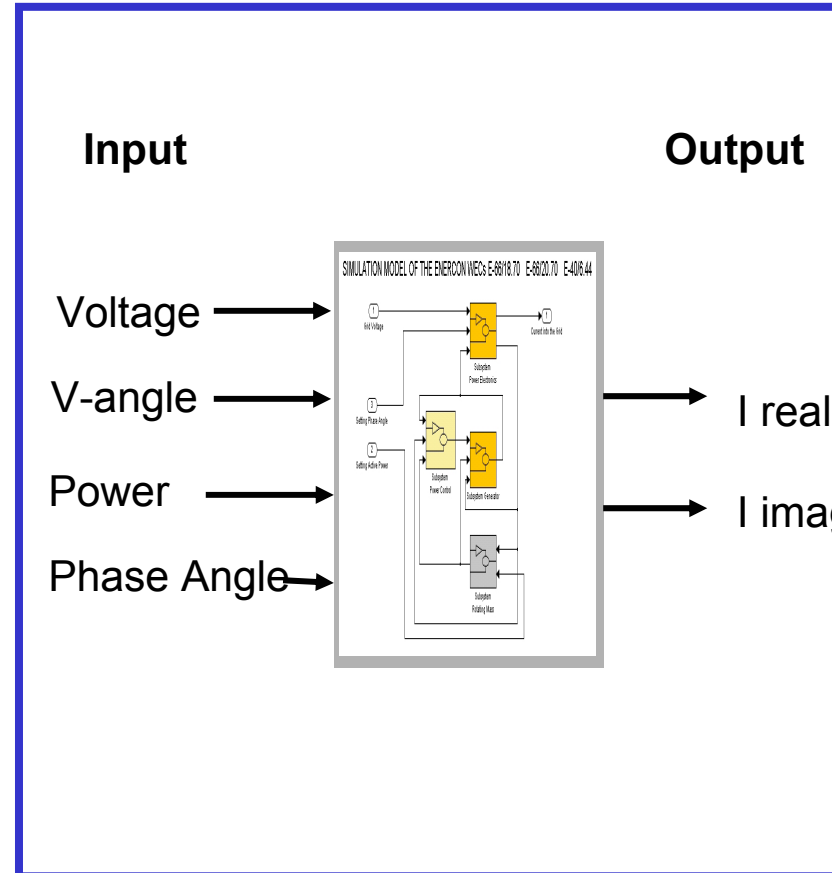
Power Plant Capabilities Certification by

**FGH e.V.
Mannheim**
www.fgh-ma.de
Windtest GmbH (Measurement)

-66 2 MW Transmission

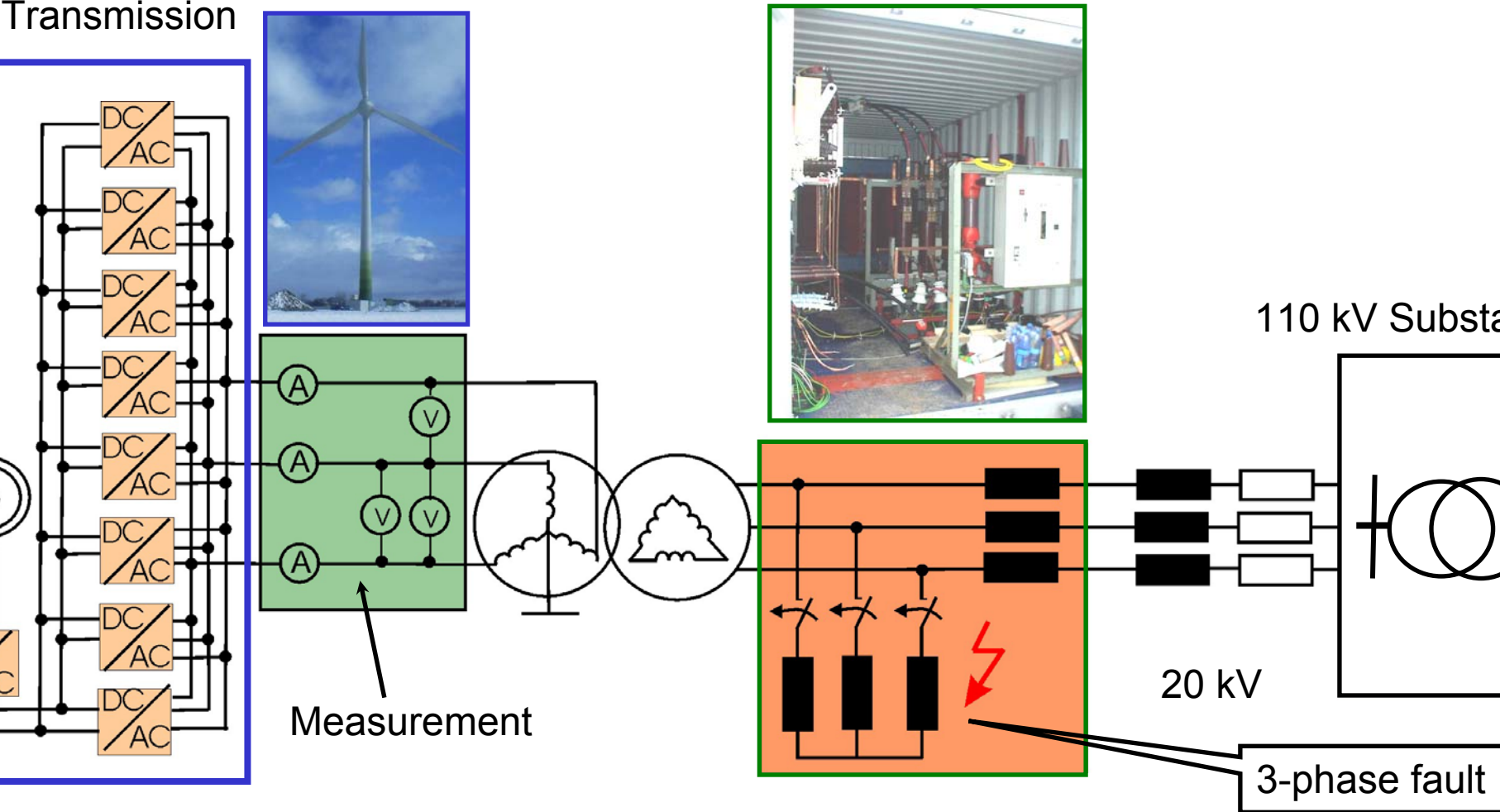


Simulation Model



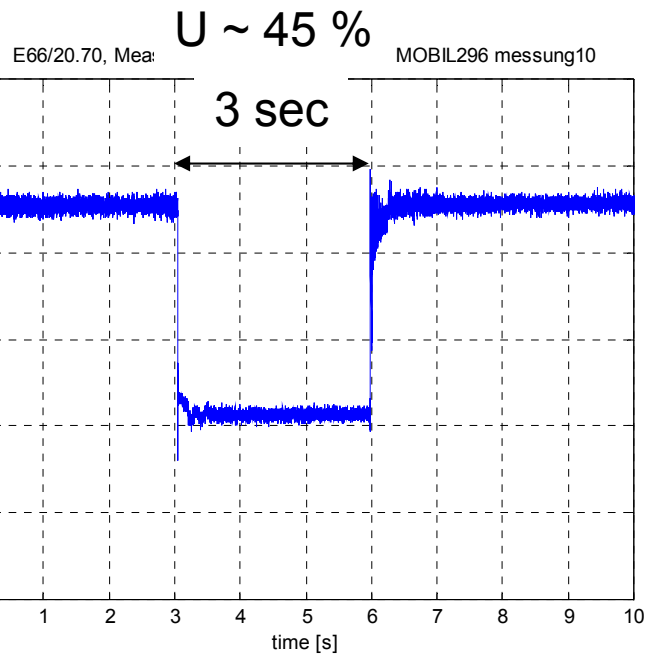
TRON Technology and the proposed GBGC

Transmission



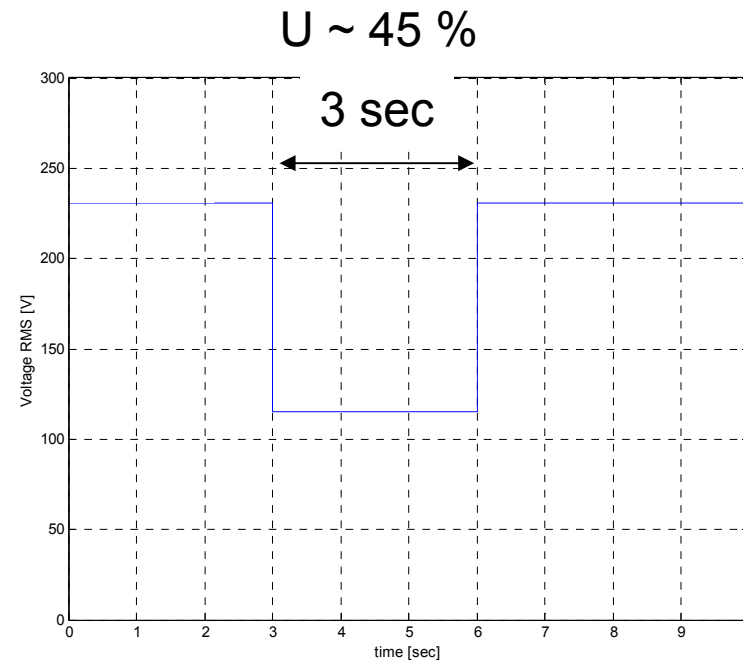
Transmission

Measurement



Voltage

Simulation

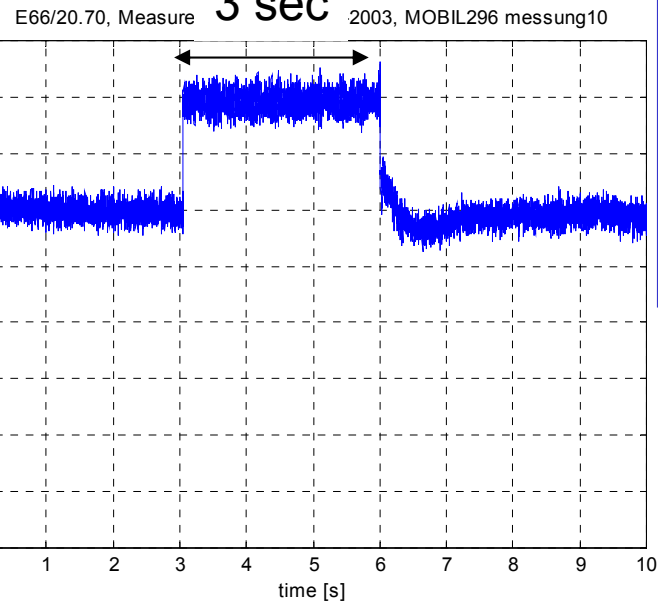


Transmission

Measurement

$U \sim 45 \%$

3 sec

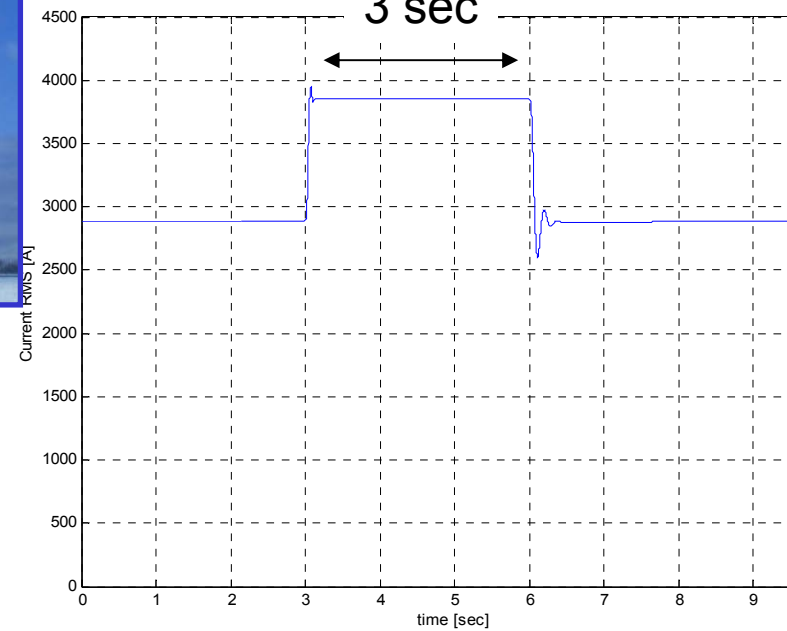


Current

Simulation

$U \sim 45 \%$

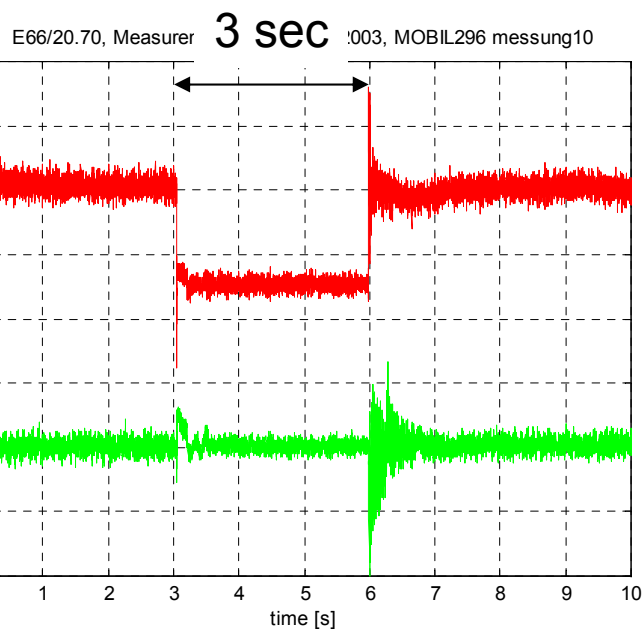
3 sec



Transmission

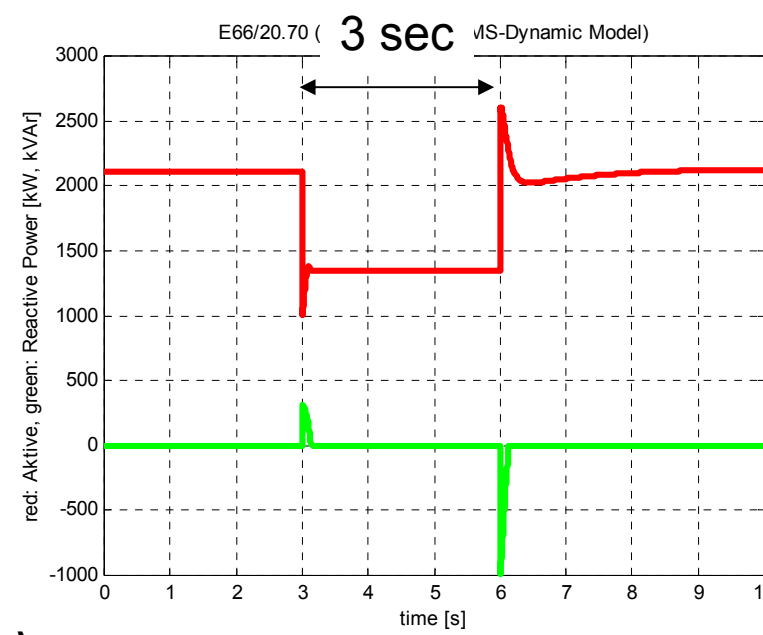
Measurement

U ~ 45 %



Simulation

U ~ 45 %



Power
(Active, Reactive)

What does it mean for the GBGC ?

Ende Through

Disconnect

**dynamic studies,
validations required**

National Grid Transco

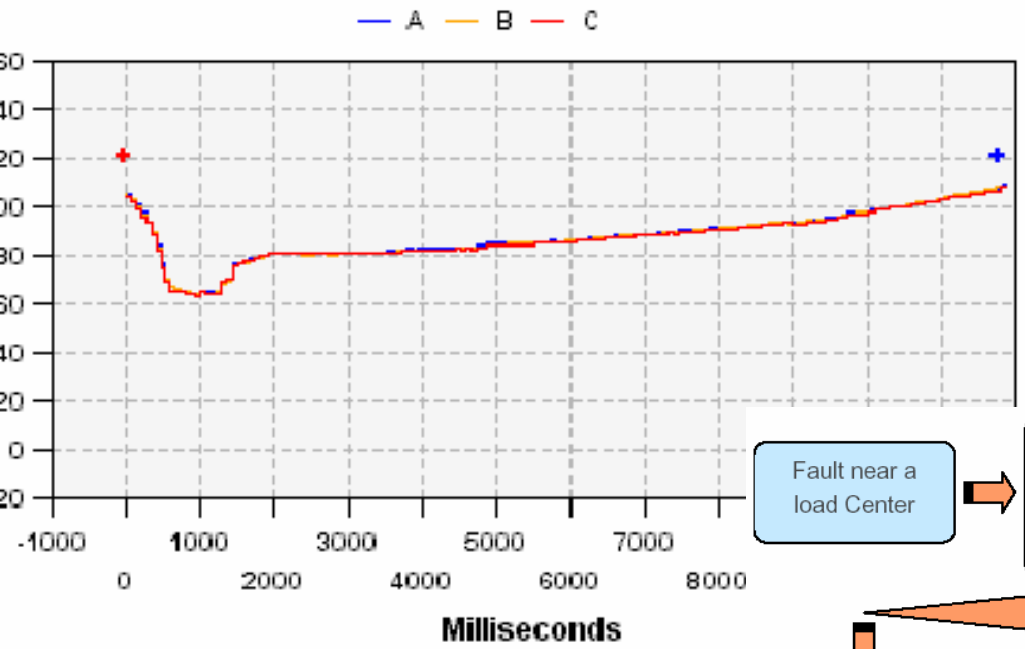
3 phase fault applied at
Walpole 400 kV substation

- Fault Location 0 % Volts
- 0 - 10 % Volts
- 10 - 30 % Volts
- 30 - 40 % Volts
- 40 - 50 % Volts
- 50 - 60 % Volts
- 60 - 70 % Volts
- 70 - 80 % Volts
- 80 - 90 % Volts

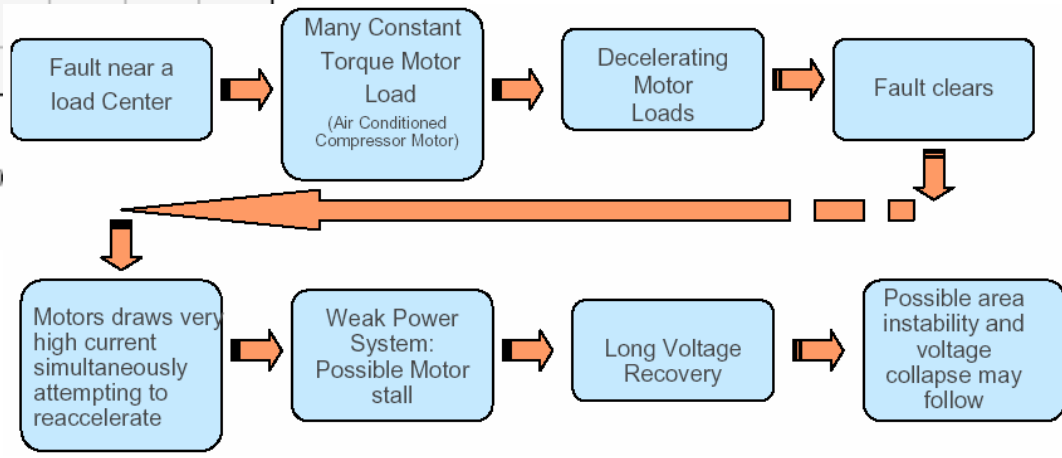


Voltage Collapse

RMS Voltage During The Event



USA Black Out August 2003

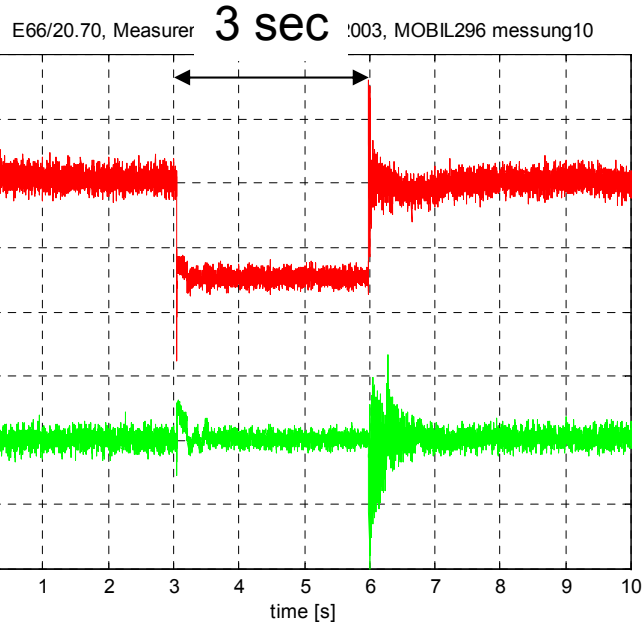


Analysis/Validations for GB has to be done

Transmission

Measurement

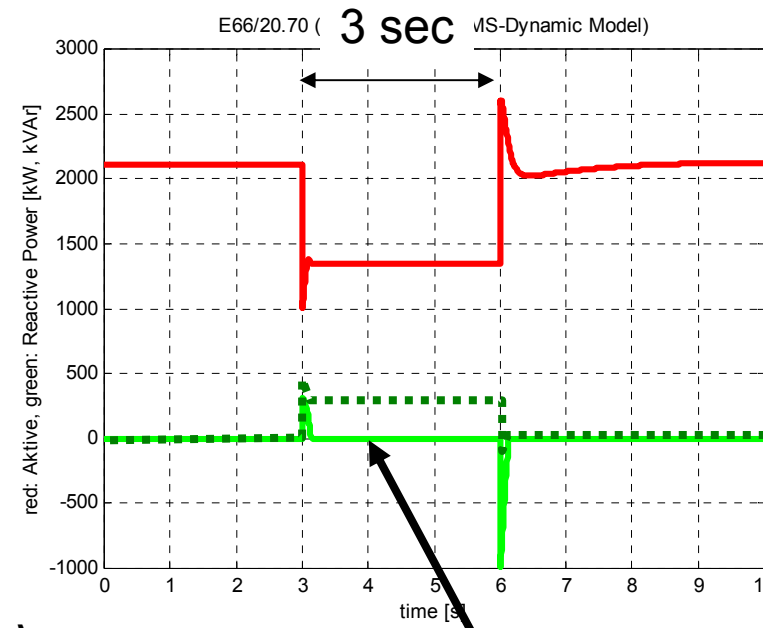
U ~ 45 %



Power
(Active, Reactive)

Simulation

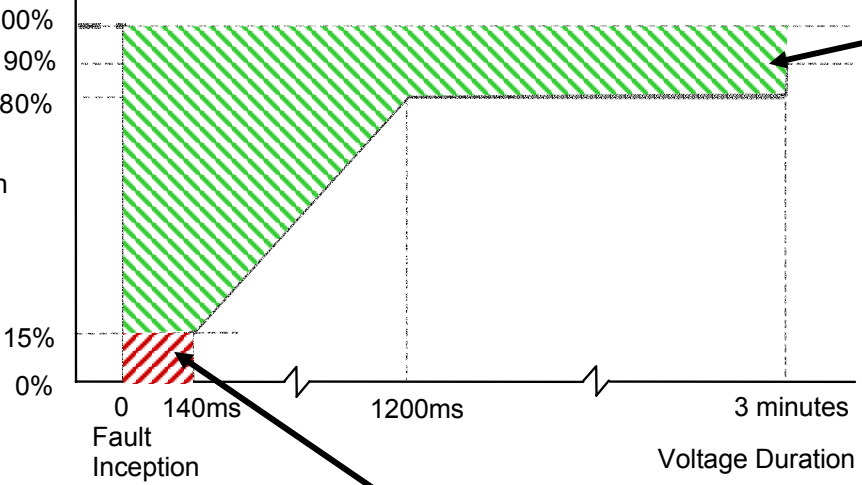
U ~ 45 %



Perspective 2004

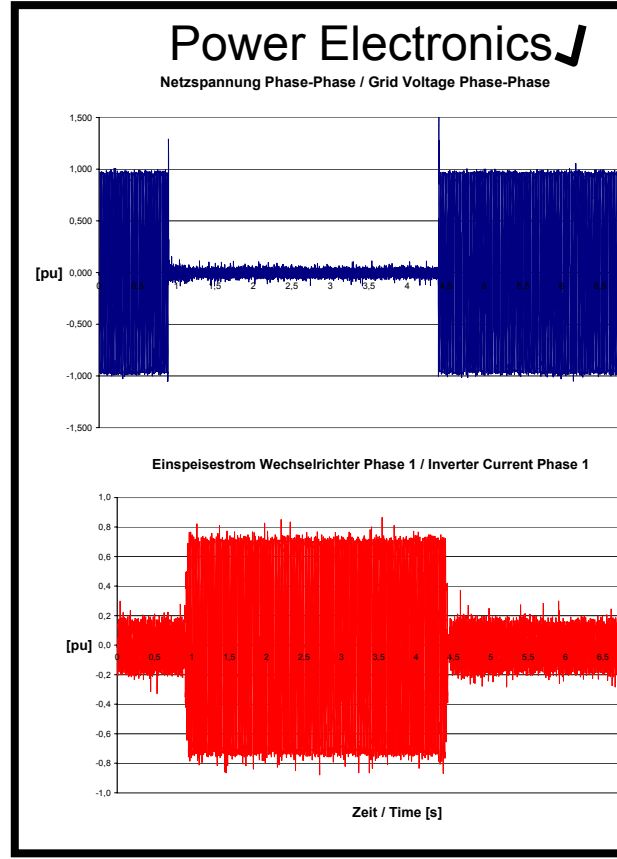
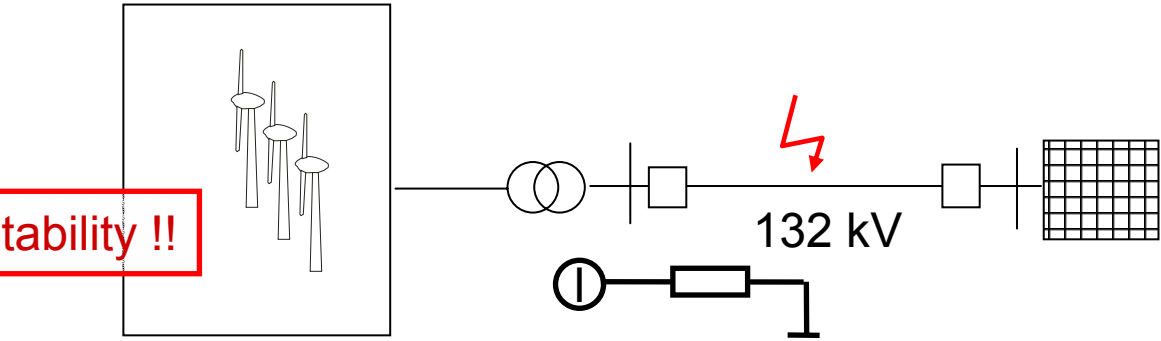
Stability Issues

Supergrid Voltage
(400 / 275 kV)



None Zero Impedance Fault

Zero Impedance Faults





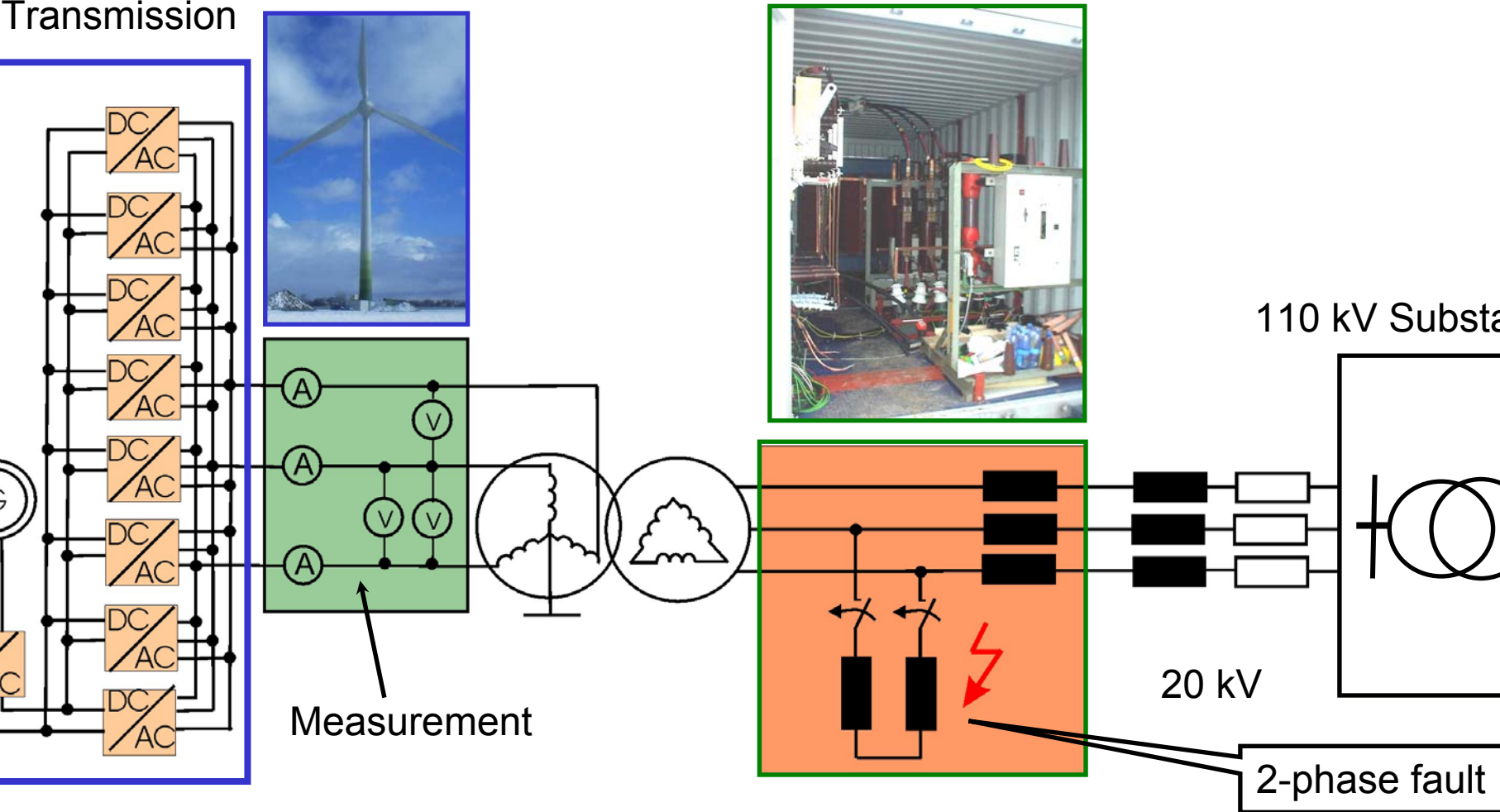
Product

Undervoltage Ride Through

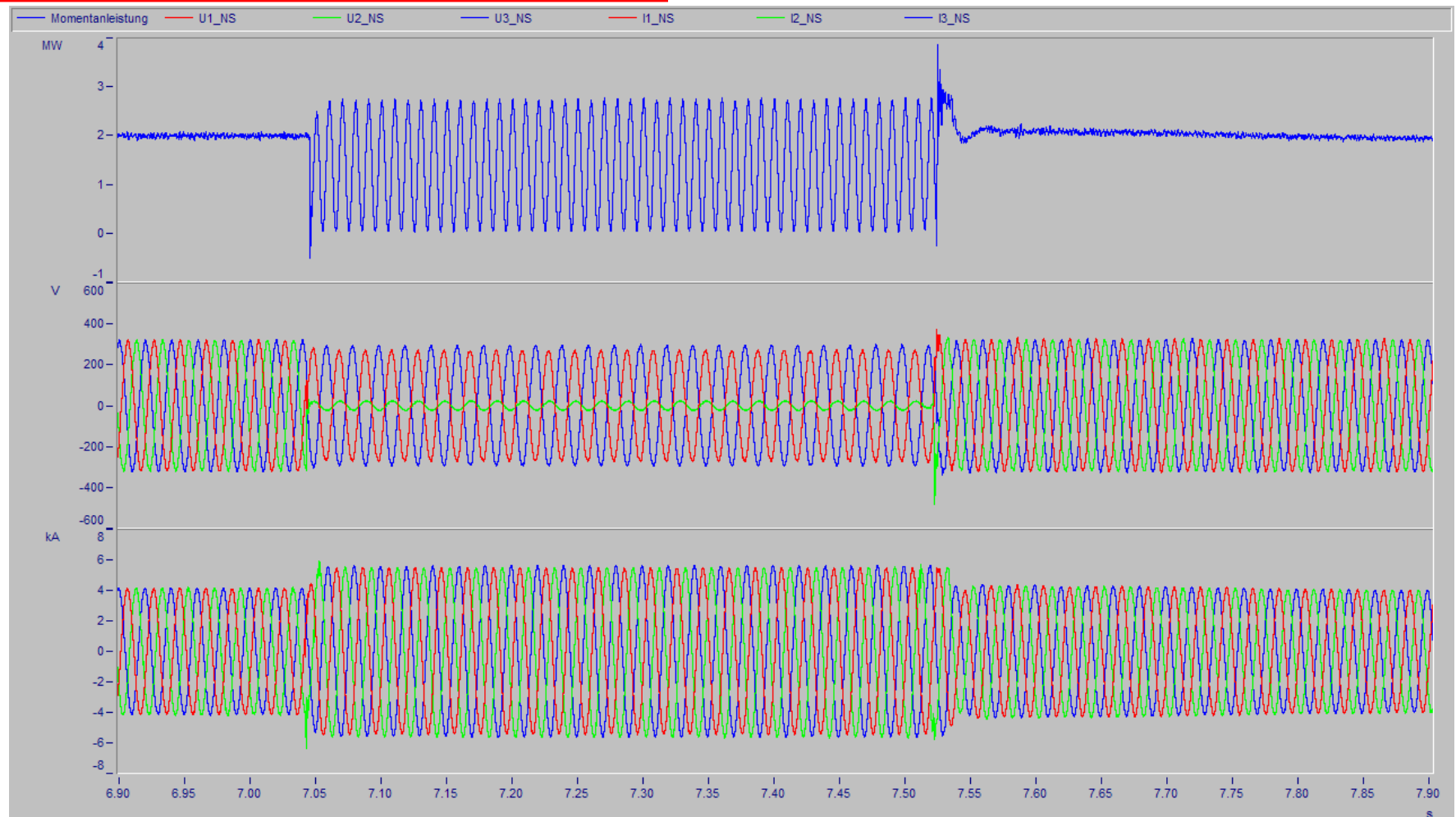
Negative Phase Sequence Loading

TRON Technology and the proposed GBGC

Transmission



Positive Phase Sequence Loading





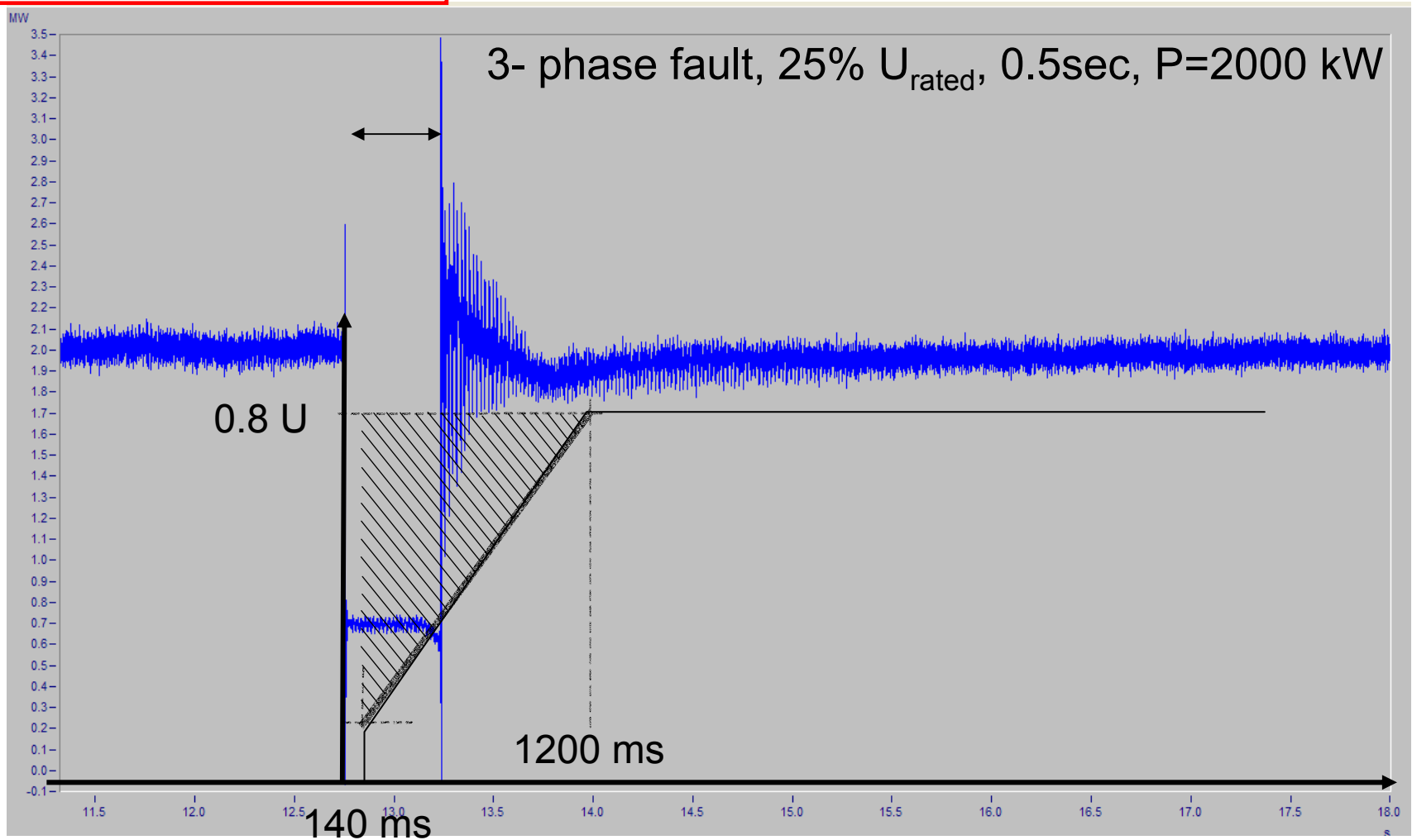
Product

Undervoltage Ride Through

Negative Phase Sequence Loading

Power Recovers immediately

Power recovers immediately





Product

Undervoltage Ride Through

Negative Phase Sequence Loading

Power Recovers immediately

Frequency Range/Control

Frequency Range/Control

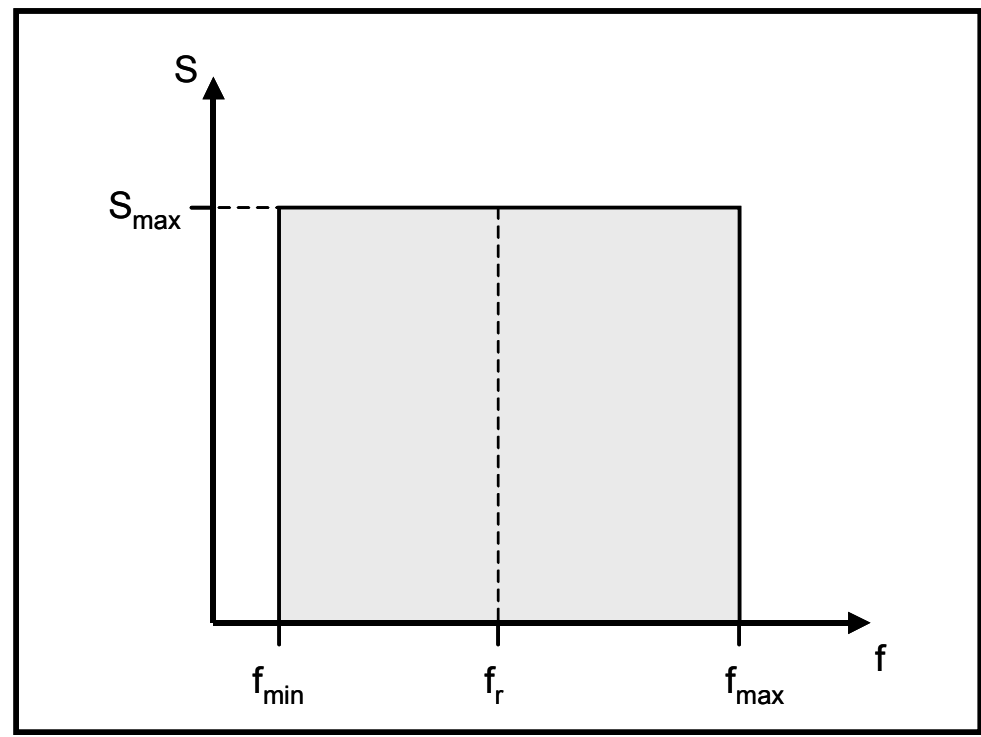
Maximum Frequency:
Nominal Frequency:
Minimum Frequency:

Grid with 50 Hz

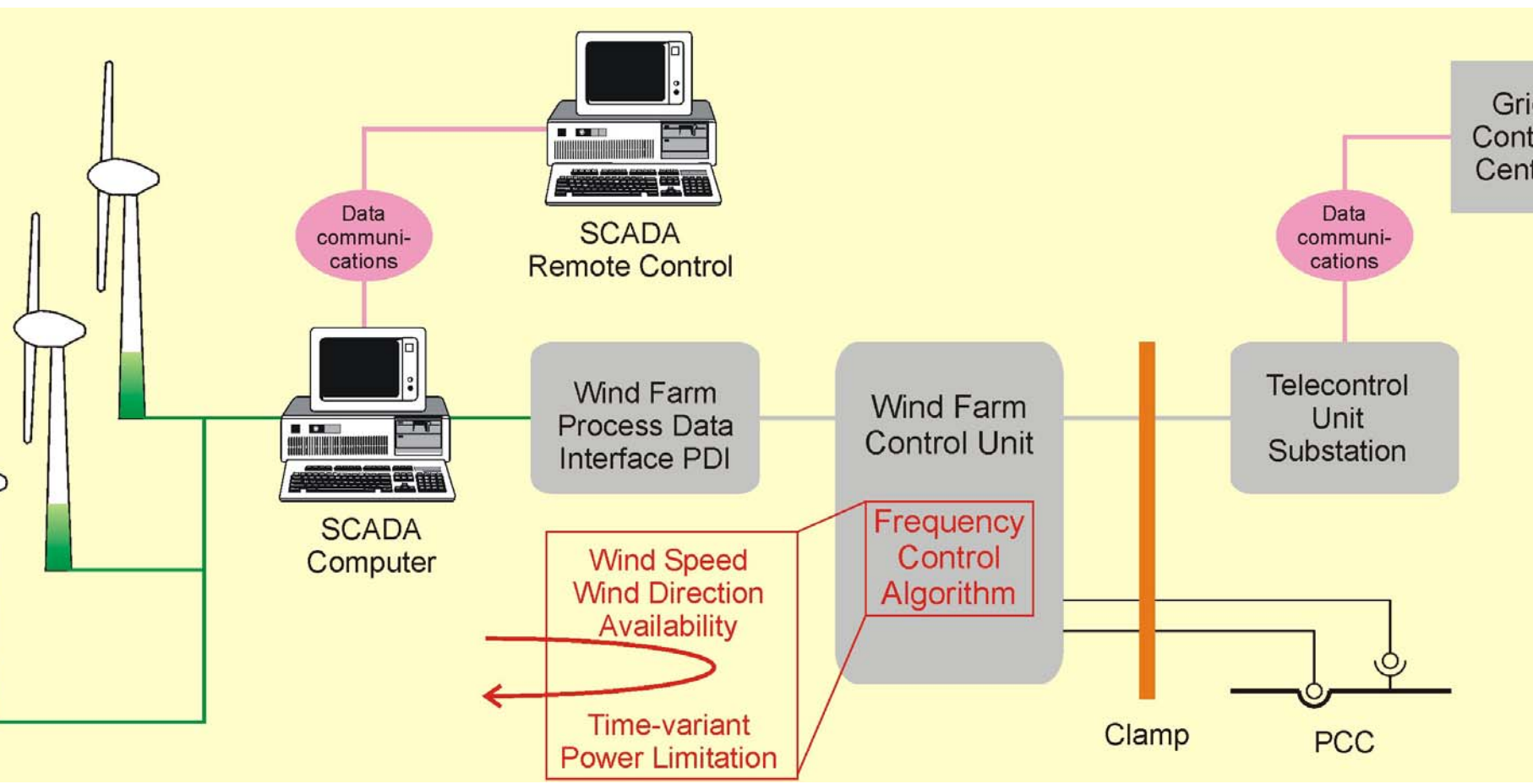
$f_{\max} = 57 \text{ Hz}$
 $f_r = 50 \text{ Hz}$
 $f_{\min} = 43 \text{ Hz}$

Grid with 60 Hz

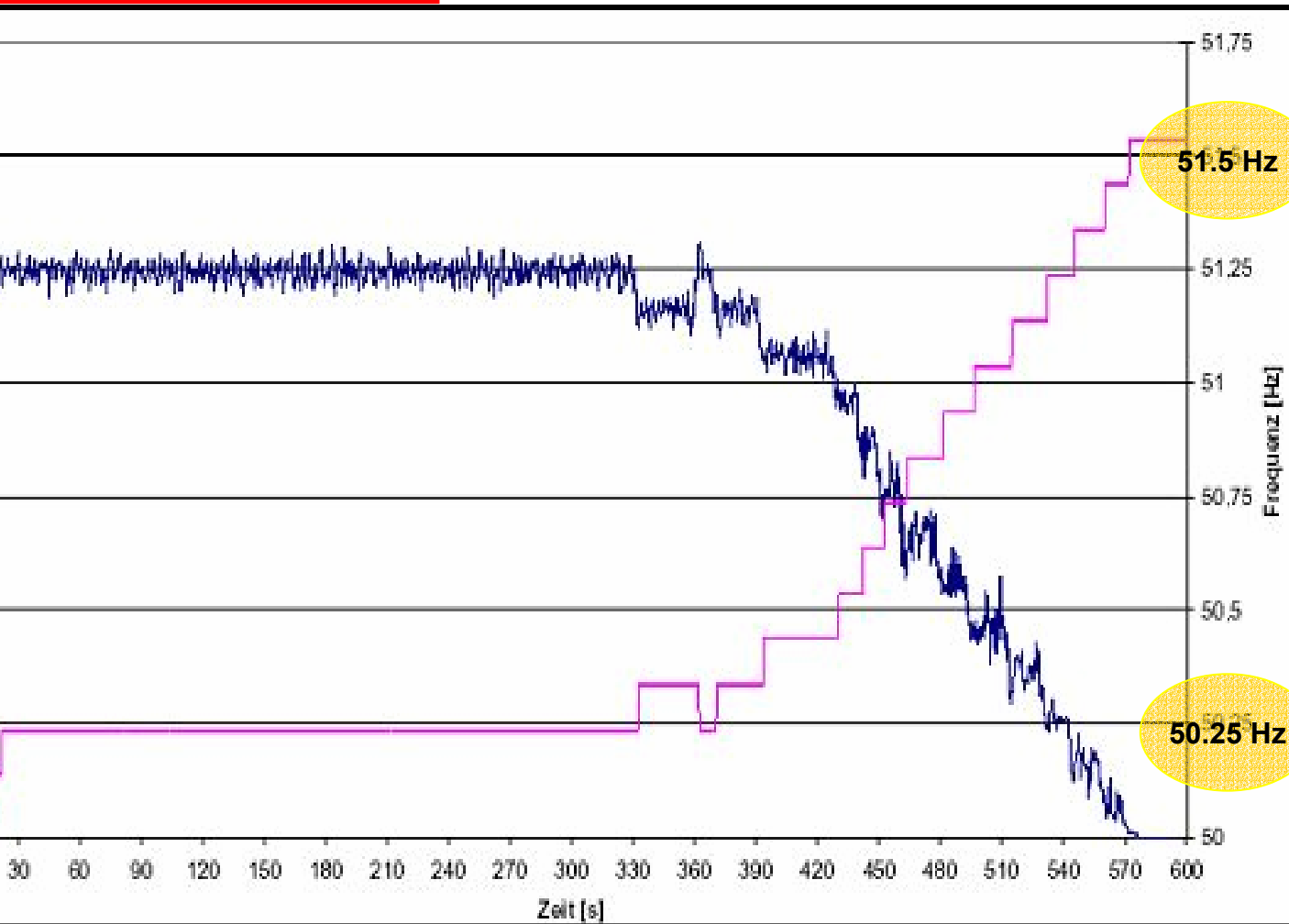
$f_{\max} = 67 \text{ Hz}$
 $f_r = 60 \text{ Hz}$
 $f_{\min} = 53 \text{ Hz}$



Frequency Range/Control



Frequency Range/Control



Limits of E.ON M requirements



Product

Undervoltage Ride Through

Negative Phase Sequence Loading

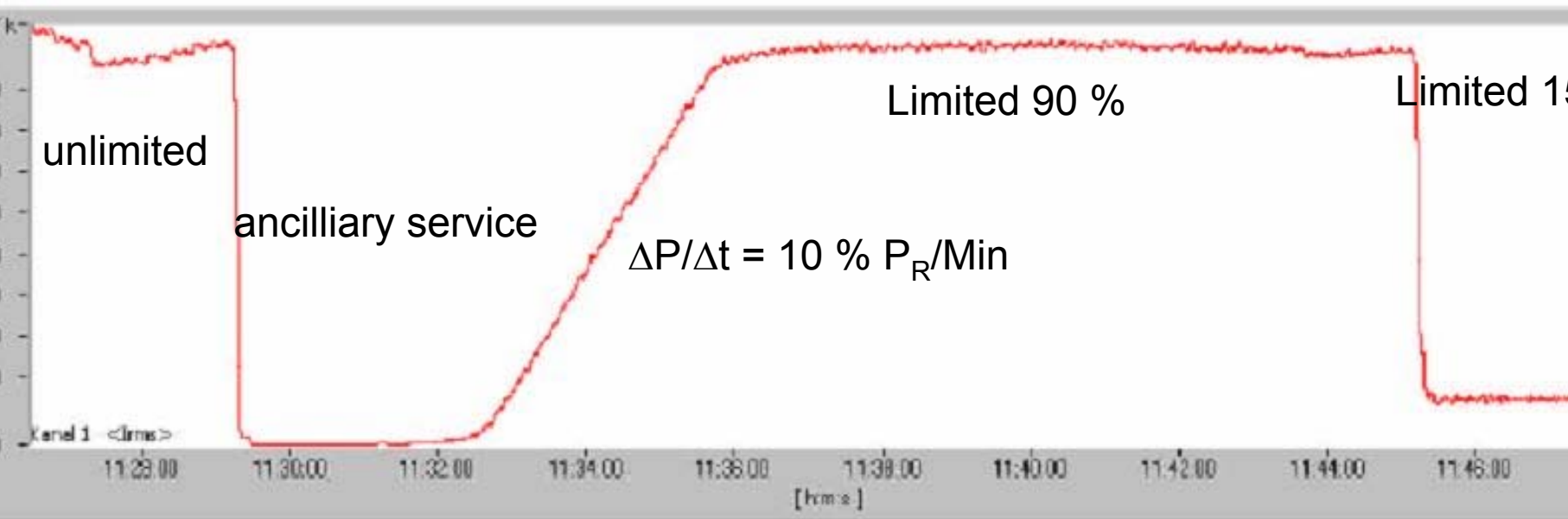
Power Recovers immediately

Frequency Range/Control

Active Power Control

Active Power Control

Example: 52.5 MW Windfarm
35 x E-66 with 1.5 MW
Connected via WF-Substation to the 110 kV grid





Product

Undervoltage Ride Through

Negative Phase Sequence Loading

Power Recovers immediately

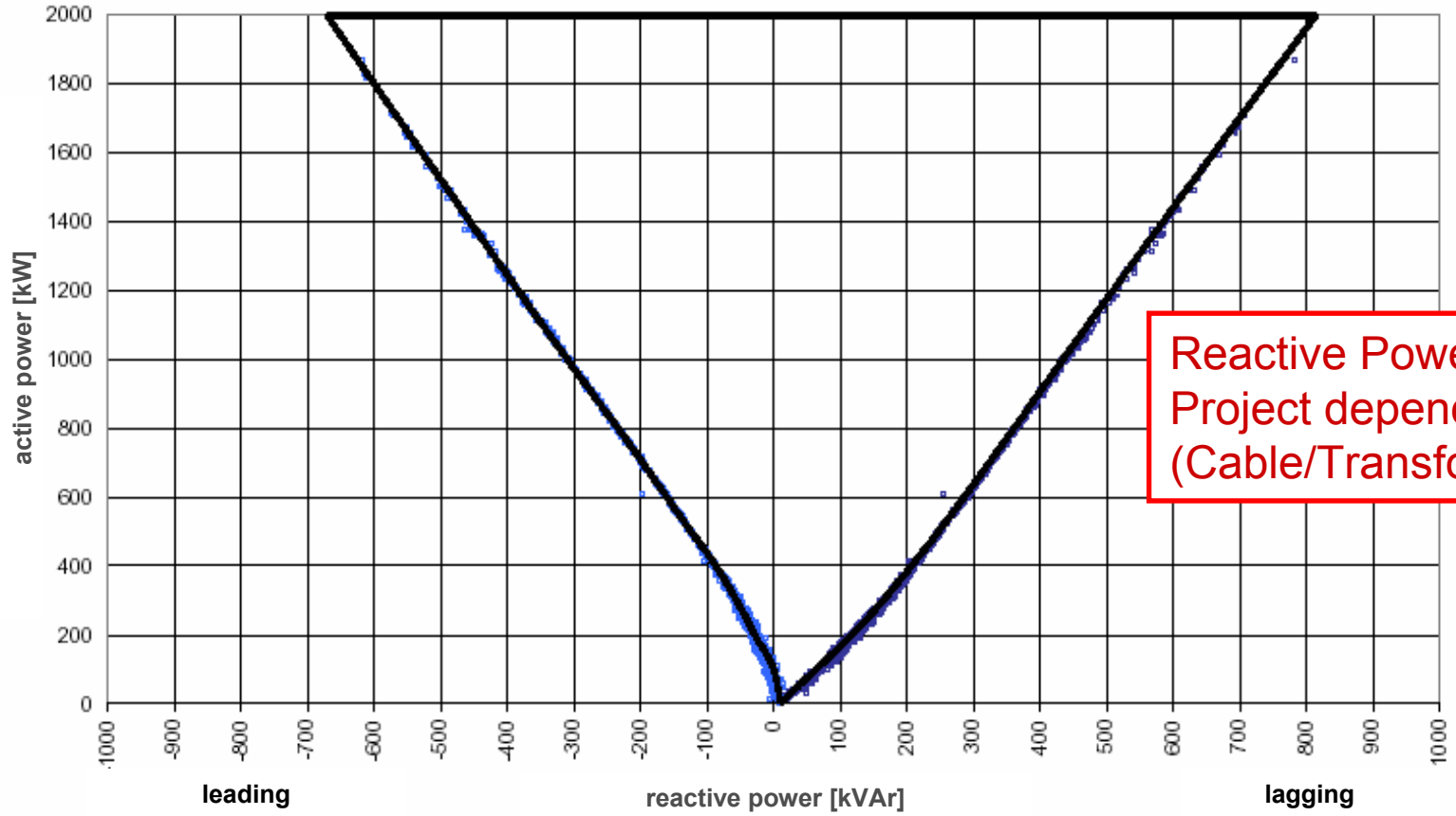
Frequency Range/Control

Active Power Control

Reactive Power

Reactive Power at WEC Terminals

E-66 2MW Transmission : limit rating diagram



Reactive Power at P
Project dependent
(Cable/Transformer e



Product

Undervoltage Ride Through

Negative Phase Sequence Loading

Power Recovers immediately

Frequency Range/Control

Active Power Control

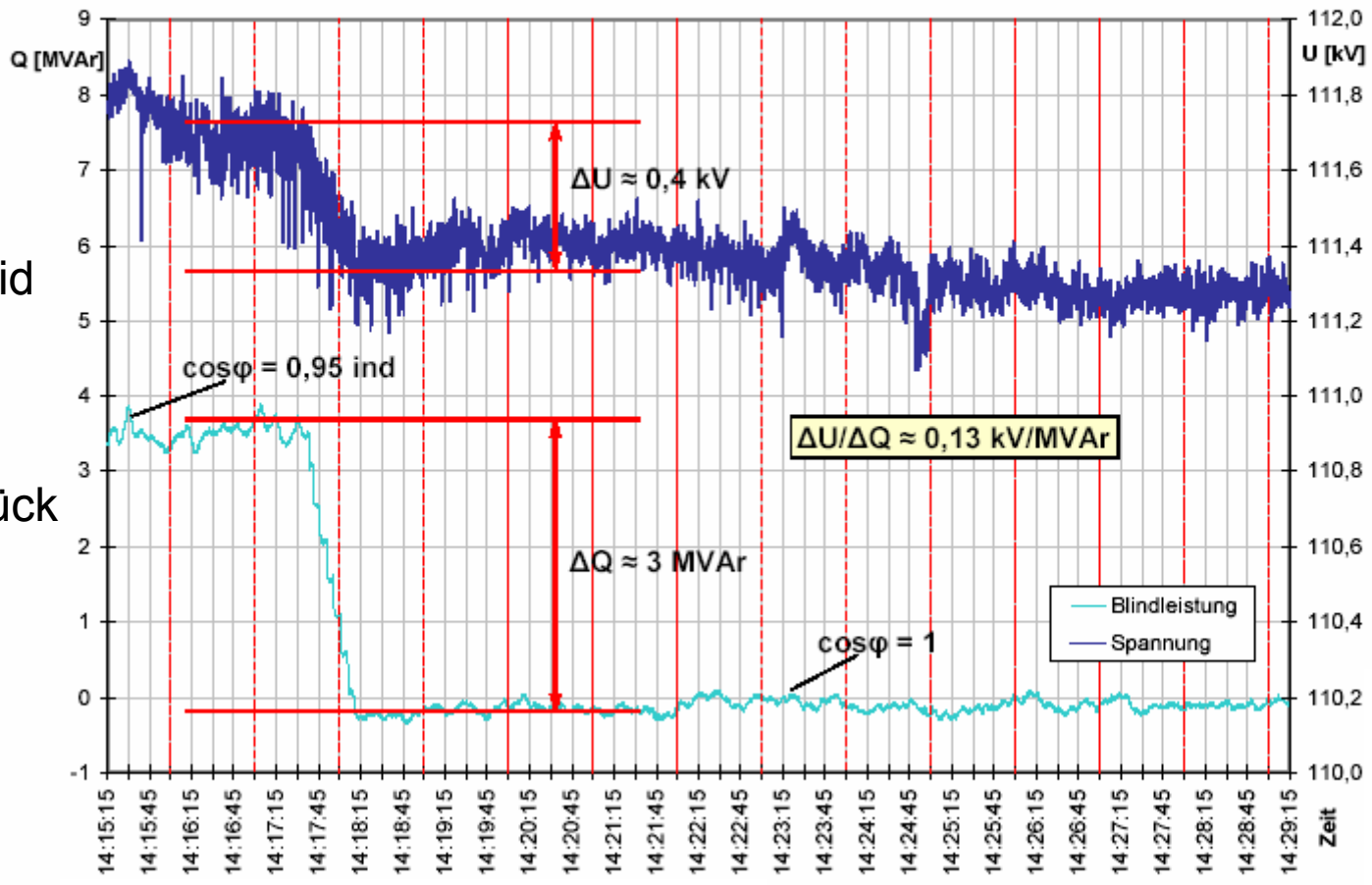
Reactive Power

Voltage Control

Voltage Control

cosφ-Steuerung Windpark Bimolten 05.02.04, 14:15 – 14:29 2/3

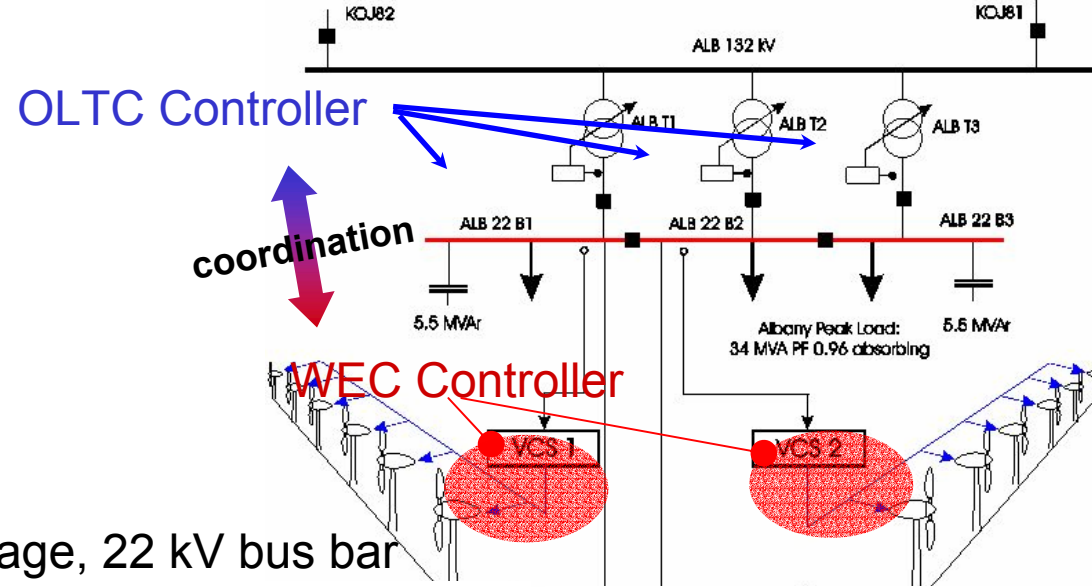
Example:
100 MW Windfarm
E-66
connected to 110 kV grid
at 110 kV substation
power factor controlled
by WE GCC, Osnabrück



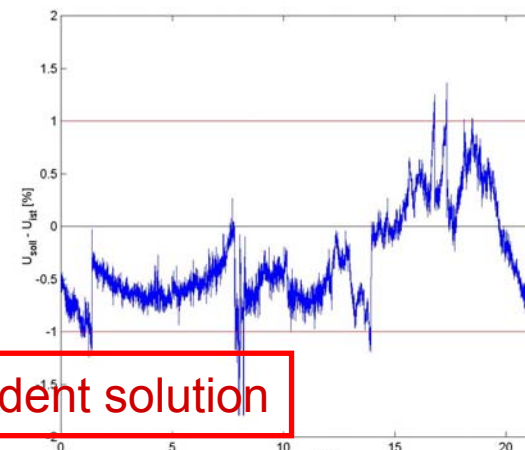
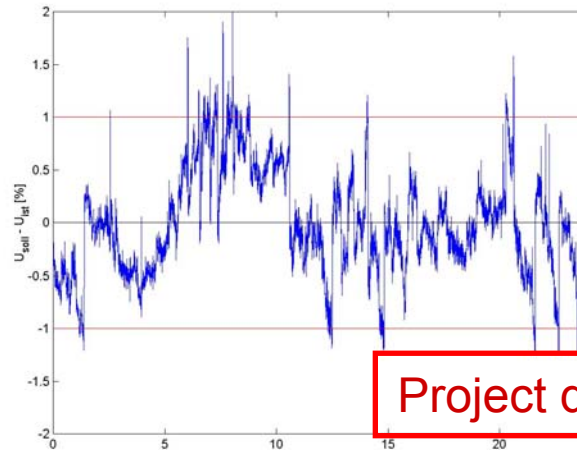
Voltage Control



2 x E-66/1.8 (21,6 MW)



Voltage, 22 kV bus bar



Project dependent solution

GB Market Conditions

... 10 % renewable in 2010 (Energy White Paper) ...



... Security of the electricity system (OFGEM) ...



... Great Britain Grid Code ...
(Transmission Licensees)



Reliable Performance
(tests, certificates)

Co-operation with Transmission Licensees
(stability and project dependent issues)

Validated Measurements and Simulations
(as given in this presentation)

Performances (Manufacturers)
Undervoltage Ride Through
Frequency Control
Reactive Power
Voltage Control



Thank You!

Any Questions?

Product

Undervoltage Ride Through

Negative Phase Sequence Loading

Power Recovers immediately

Frequency Range/Control

Active Power Control

Reactive Power

Voltage Control



Energy for the
World