Grid codes
The Manufacturer´s Nightmare

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EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

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Agenda

- Why all the trouble – what is the nightmare ?
- The EWEA grid code template
- Short historical grid code overview
- Technical confusion over time – FRT as example
- Conclusion

Why all the trouble ?

Why all the trouble (1)

- Power systems vary a lot in structure and size
- The predominant problems vary among systems
- Written differently – structure and technical content
- Often vaque formulations (leaving room for interpretation)
- TSO/utilities struggle to estimate what requirements WPP´s can fairly fulfill
- Requirements can lead to substantial technical WTG design constraints
- The electrical integration is increasing in complexity

Why all the trouble (2)

- Strictness of requirements are asymmetrical from code to code
- No de-facto standard exists for e.g. voltage and frequency control
- No de-facto standard exists for simulations models and their use in studies
- Focus is gradually shifting from WTG to plant level (PPC-point)
- Experience with design and integration of <u>large plants</u> are limited (young industry)

Result:
Debate for many years
EWEA started up the grid code WG on harmonization
The EU Pilot Grid Code on Wind Power has been initiated (EU/ENTSO-E)

Important observation

The main challenge for manufacturers are not (necessary) to fulfil the physical requirements (hardware) – but to

- understand the intended functionality and the detailed technical requirements.

Another main challenge is the

- frequent and fast changing updates, drafts and new codes

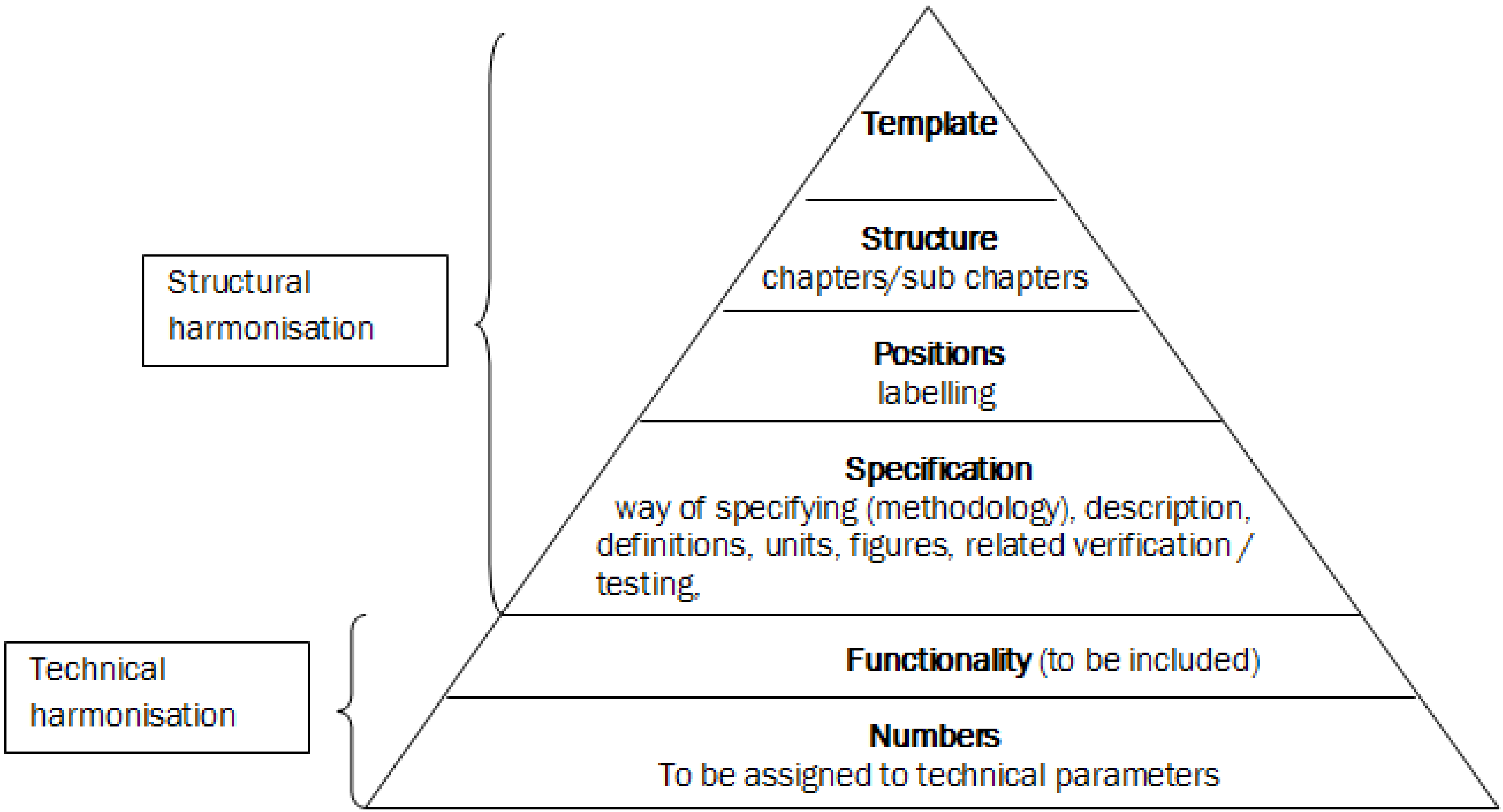
The EWEA Grid Code Template

Harmonisation is needed – how to do it

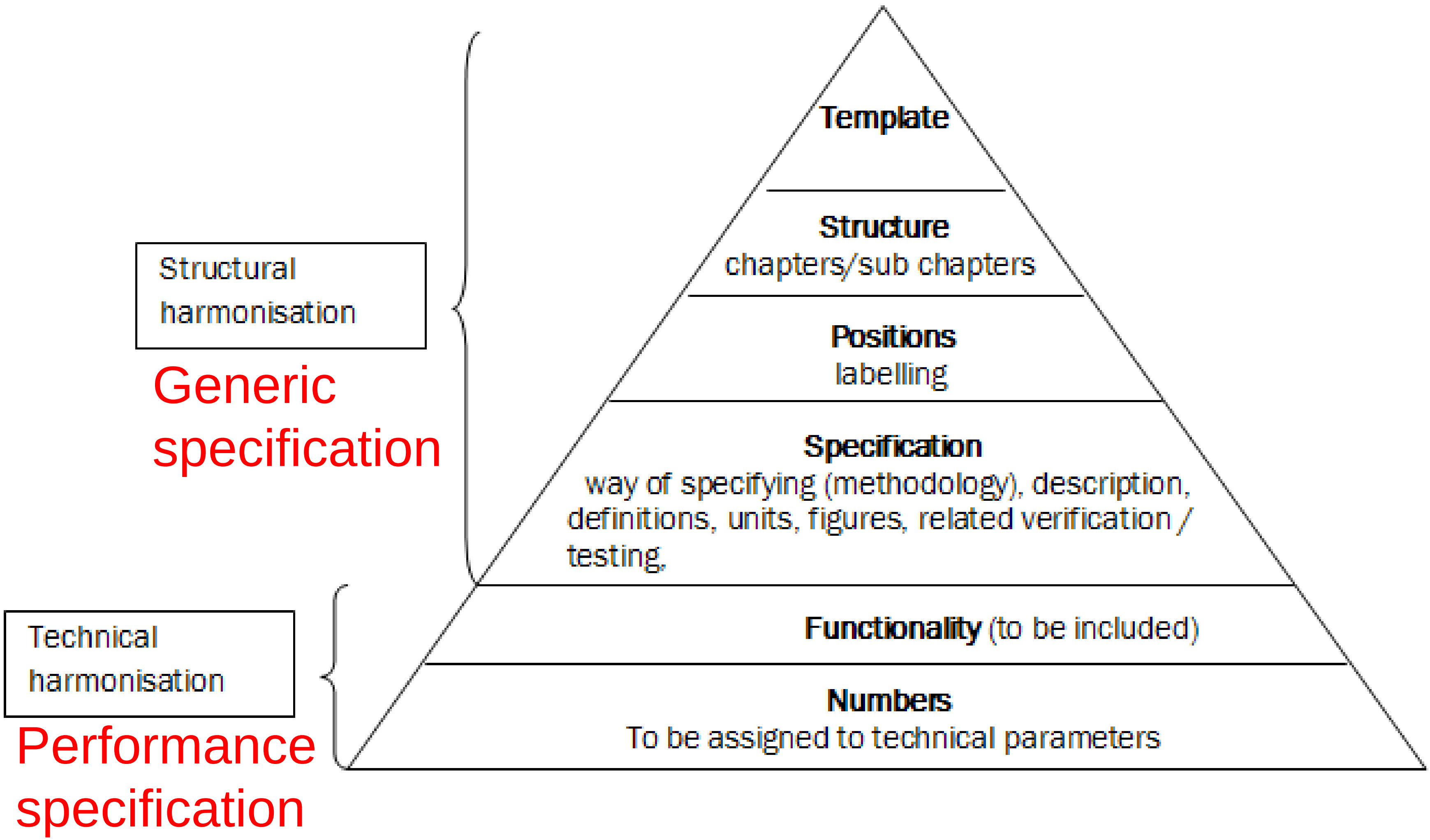
- **Structural harmonisation**
  - Structure
  - Positions / labelling
  - Method of specification
  - Definitions
  - Figures
  - Units
  - Verification
- **Technical harmonisation**
  - Functionality – preferable harmonised where technically possible
  - Numbers – may stay individually (performance requirement)
  - Numbers – preferable harmonised where technically possible

GC specifications shall be ***functional*** rather than solution specific (long term safe).

Structural and technical harmonisation



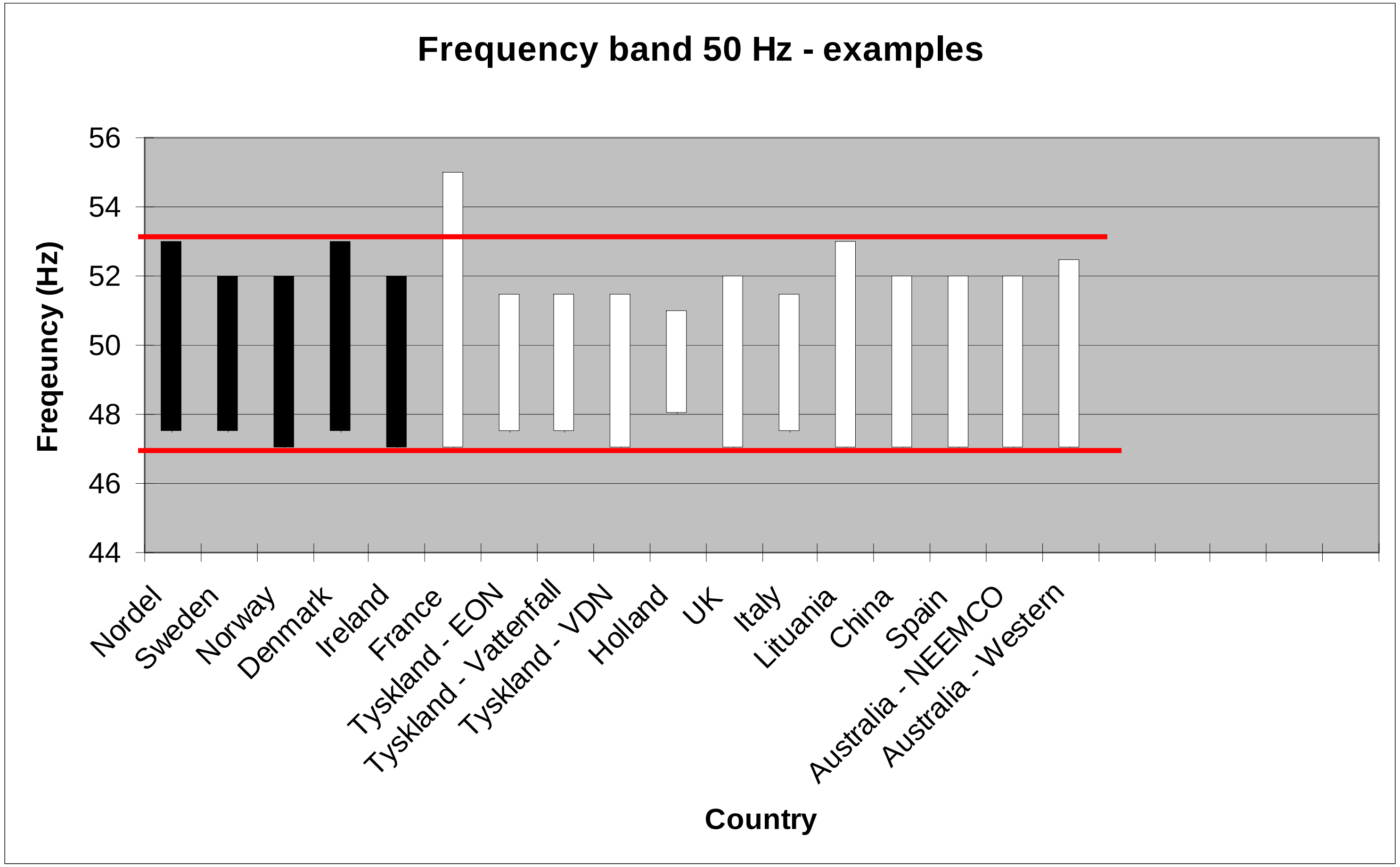
Structural and technical harmonisation



Technical harmonisation – simple example

- **To demonstrate the principle**

France:
2006 (55 Hz)
2008 (52 Hz)



EWEA recommandations (Policy paper – Feb. 2008)

- All EU-27 countries should have a **dedicated Wind Power Grid Code**
- Easy to obtain and available in **english** from the issuing body
- Shall follow the **same structure** (structural harmonisation)
- **All requirements shall refer to the Point of Connection (POC)**
- Revisions/changes should be made after consultation with the industry
- **A transition period** should be applied – **at least 18 months** from valid code ready
- Changes or upgrades shall be voluntary with additional incentives or payment

Generic grid code structure and number of paramerers

9	28	119	24	18	18
General	**Steady state performance**	**Dynamic performance**	**Communication / Control**	**Simulation models**	**Performance verification**
Identification	f, U, P rating	f gradients	Interface	***Integration/design***	(Certification)
Date in force	Q rating	Islanding / block	Plant status	***System planning***	Verification
Geograph. area	PQ parameters	Control of P	Meteorological		Commissioning
MW size limit		Limitation modes		- Type of model	Perf. testing
Voltage limit		Run-back		- Simulation platform	
Grounding		Cos fi control		- Documentation	
POC spec.		MVAr control		- Verification	
Sk - instruction		U-control			
		FRT		Ik - data	
		f-control			
		Inertia			
		Damping			
		TOV			
		Protection			

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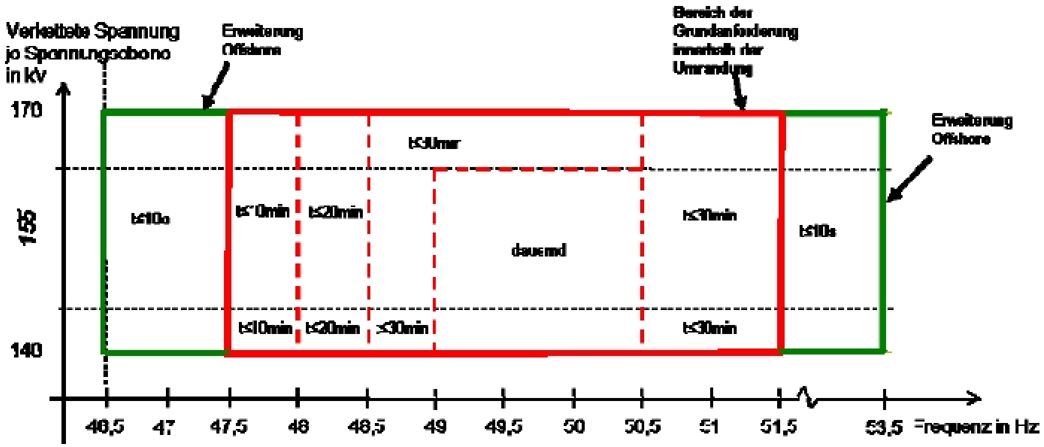
Example 1

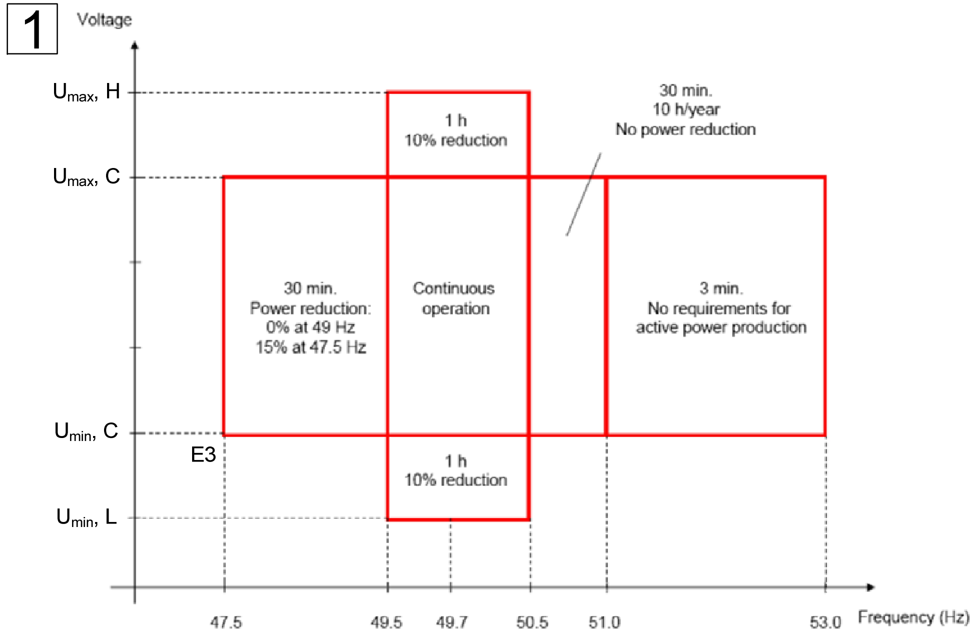
	DYNAMIC PERFORMANCE	
	Frequency gradients and power ramp rates	
39	Minimum positive frequency gradient, minimum $df/dt_{positive}$ The parameter specifies the minimum positive frequency gradient which the plant shall be able to withstand without tripping.	[Hz/s]
40	Minimum negative frequency gradient, minimum $df/dt_{negative}$ The parameter specifies the minimum negative frequency gradient which the plant shall be able to withstand without tripping	[Hz/s]
	Start–shut-down and islanding with load requirements	
41	Start/shut-down description Used for general description if needed.	[text]
42	Signal to block against restart The signal is used to prevent unintended start-up in connection with e.g. a power system restoration after blackout or other similar system emergency situations.	[text]
43	Reconnection time after trip/blackout From time to time a maximum reconnection time after a trip or blackout is specified. Such a requirement should be based upon a commercial agreement (payment for ancillary services) or otherwise based upon ready for operation signal from the plant owner. After a trip/blackout it is fair that the plant owner has time to inspect or perform fault finding before the plant is reconnected.	[text]
44	Islanding with load requirement This parameter specifies requirements in relation to potential situations where a wind power plant may island with consumer loads connected.	[text]

U/f/P/t-figure

Needed !



Numbers needed in kV !

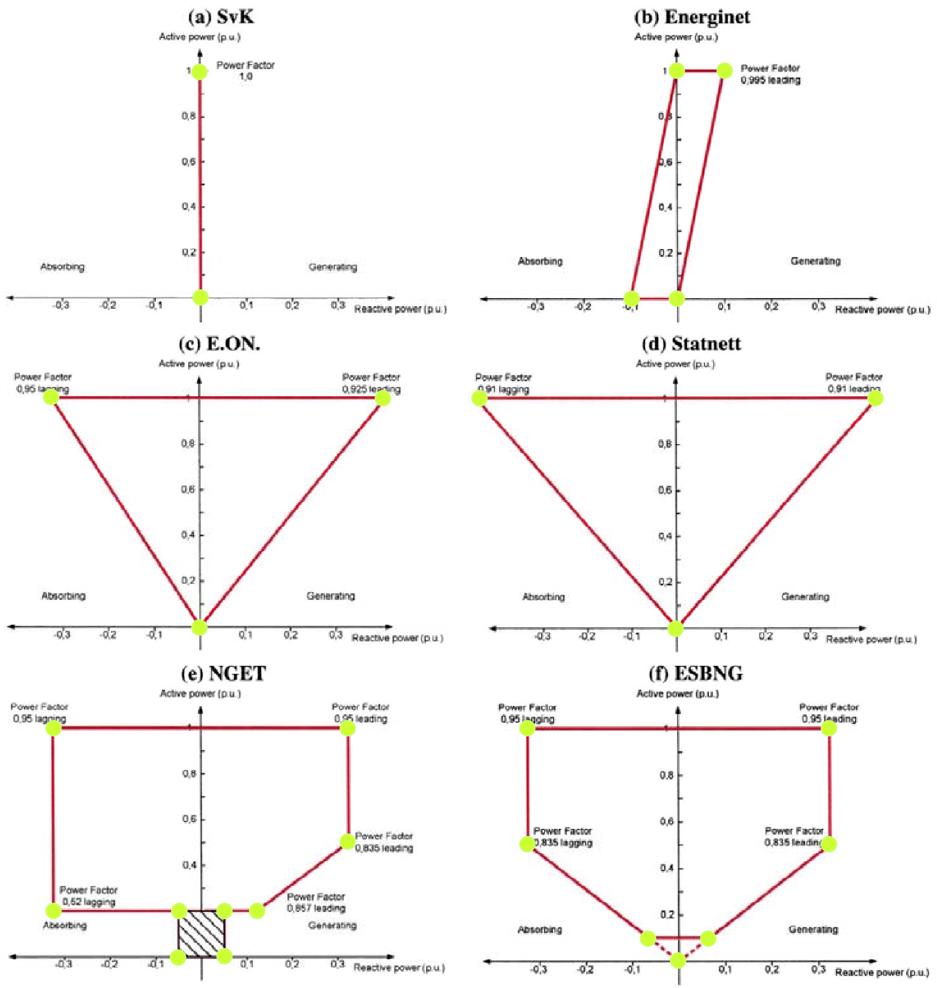


EXAMPLES ONLY

Reactive Power Capability (PQ-chart)

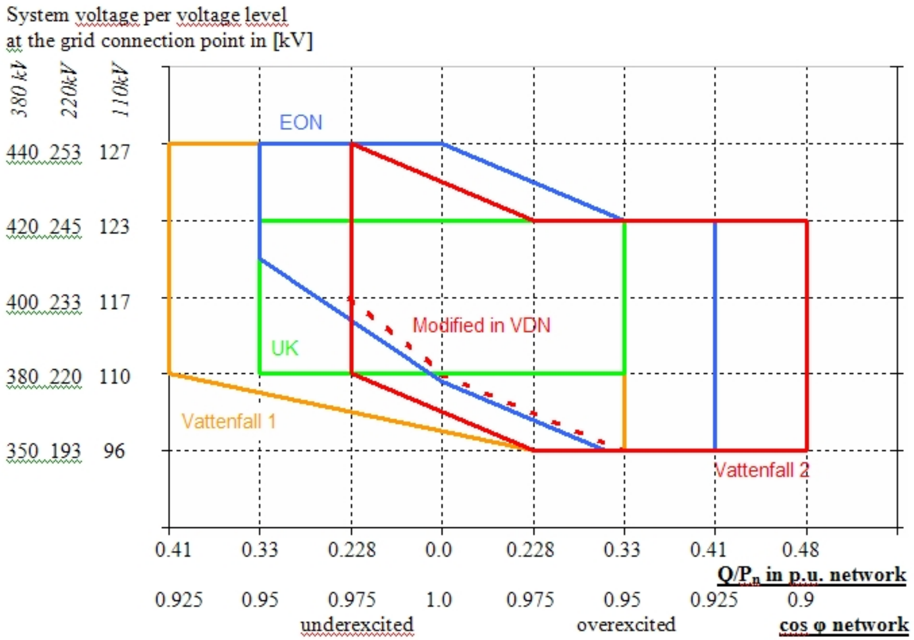
Needed !

EXAMPLES ONLY



Voltage vs. Reactive Power Capability (UQ-chart)

Needed !



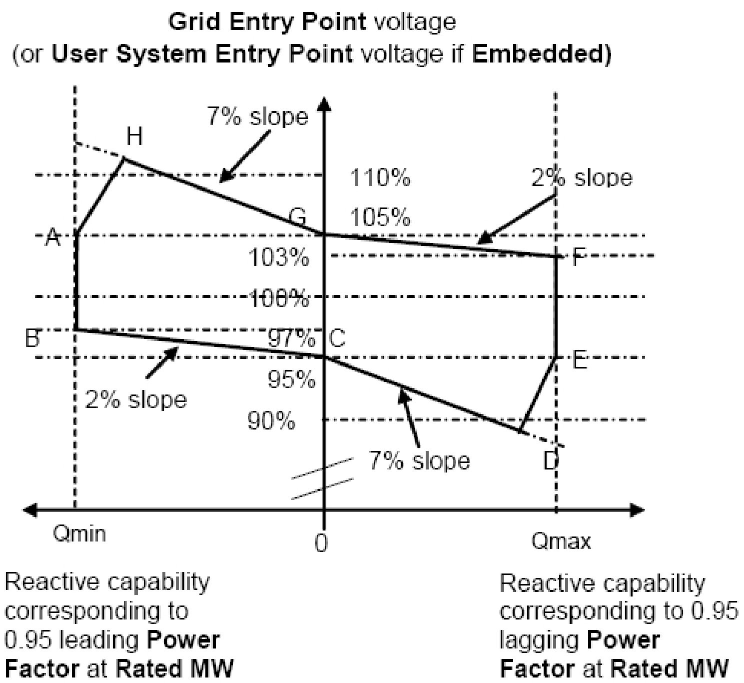
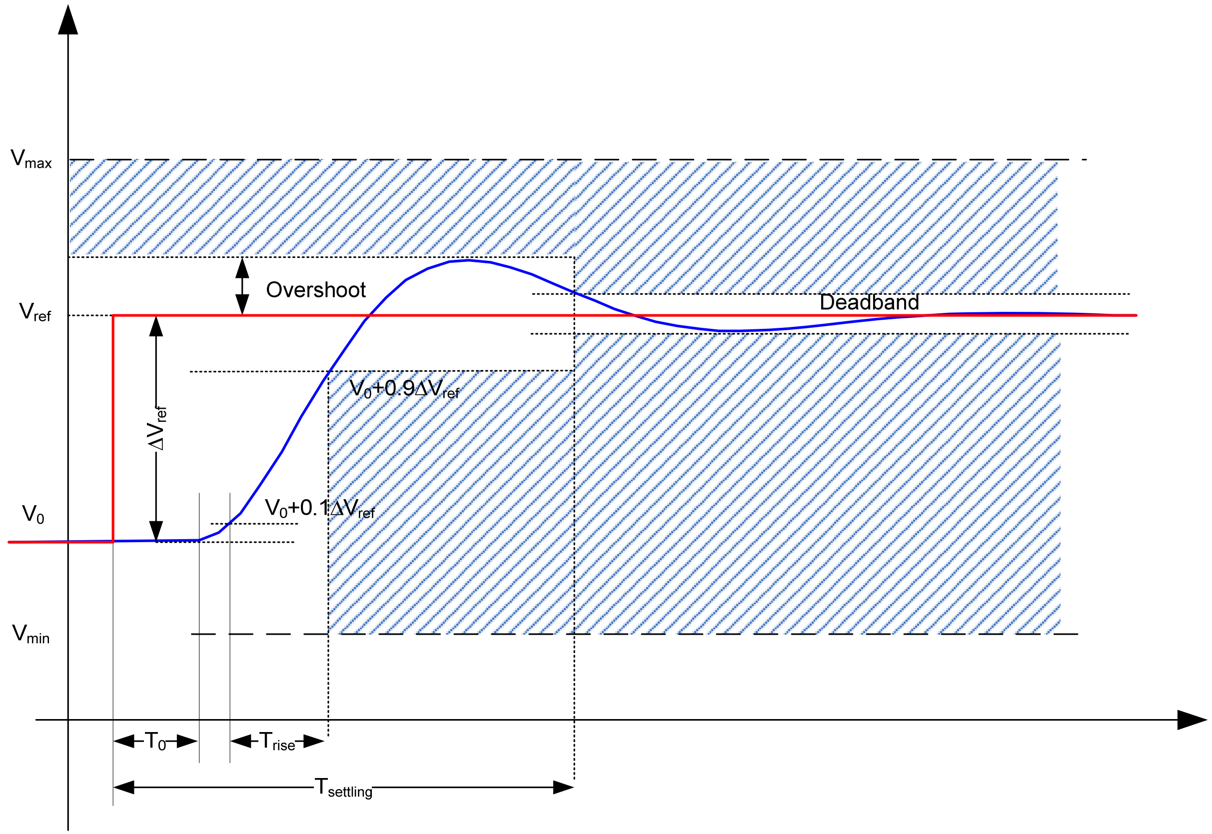


Figure CC.A.7.2.2b

EXAMPLES ONLY

Definition of voltage control performance parameters

- Detailed specification or guidance is required – also in relation to verification !



EXAMPLE ONLY

Short historical GC overview

Technical Operation Specifications for Thermal Plants – Nordel 1974 (1)

- U/f/P/t-requirement
- Plants should be able to withstand a ‘deep voltage transient’

Frekv. krav	Frekvens Hz	Gen.sp. U %	Drift-tid	Reduk-tion av last	Anmärkning
F0	49-51	90-105	Kont.	Ingen	Max. 10 h/år drift-tid inom frekvens-området 50,3-51 Hz kan förutsättas
F1	47,5-49	95-105	30 min	Liten	Enstaka störnings-tillfällen
F2A	47-47,5	95-105	1 min	Minsta möjliga	Enstaka störnings-tillfällen
F2B	46-47,5	95-105	1 min	Minsta möjliga	Enstaka störnings-tillfällen
F3	51-52	95-105	5 sek		Reglerförlopp
F4	51-53	95-105	3 min	Till max 25% last vid 53 Hz	Endast vid drift på separat nät

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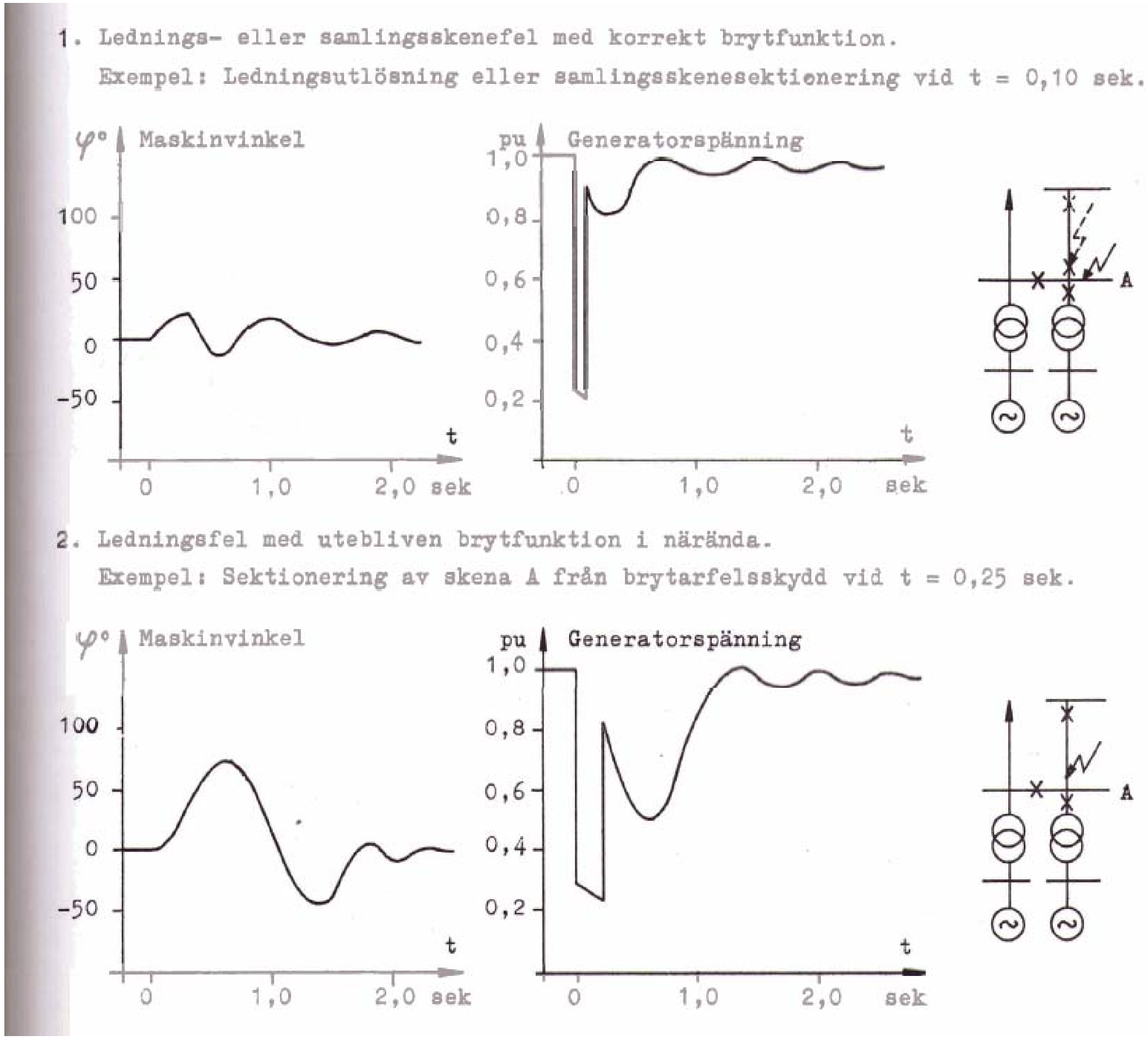
Grid codes for thermal plants – Nordel 1974 (2)



Zone 1 clearing

Zone 2 clearing

Recommandations for wind power – early 90´ties

- General

- Reactive compensation
- Flicker
- Inrush current
- Harmonics
- Interharmonics
- Protection

Distribution grid aspects !
400 V / 10 kV – customers

- Example Denmark: DEFU KR 111

Grid codes for large scale wind power – late 90´ties

- First Danish Offshore Action Plan – 1996 (1500 MW)

- First dedicated Wind Power Grid Code (WPGC)
- U/f/P/t-requirement
- Reactive power control (more advanced)
- Power control management
- Fast run-back (fast active power reduction)
- Frequency control
- Stay connected (fault ride through – FRT)
- Harmonics
- Simulation model

(HVDC under discussion)

WTG focus – variable speed:
- Power limitation
- Mechanical loads
- Maximum energy production

Grid codes for large scale wind power – 2003-2007

- Fault ride through unit testing (container testing)
- Consumption parameters
- Injection parameters (reactive current injection)

- Voltage control

- Frequency gradient
- Temporary overvoltages – TOV

- Certification / verification initiatives

Grid codes for large scale wind power – 2008-2010

- Grid code harmonization initiated (EWEA)
- System planning simulation models (reduced order standard models)
- Short circuit feed-in data
- Zero-power voltage control (rotor/blades are not turning)
- Signal to block against restart
- Islanding
- Inertia
- Damping
- HVDC connection

Technical confusion over time – FRT as example

Technical confusion over time (historical …)

- Initial only minor attention – not considered important in larger scale
- Former way of thinking, calculations not know or forgotten
- New people enters at new stakeholder groups
- New needs – new solutions – technically not identical
- Further new or other types of people enters (power electronic engineers)
- Some mistakes or adverse engineering may get introduced
- Needs may change drastically, grid codes, verification
- Things are compared – may be apples and pines
- Stakeholders fight for their standpoint
- New mechanisms introduced may mix up with forgotten aspects
- Yet new people arrive
- New green field, already obsolete mistakes may re-enter

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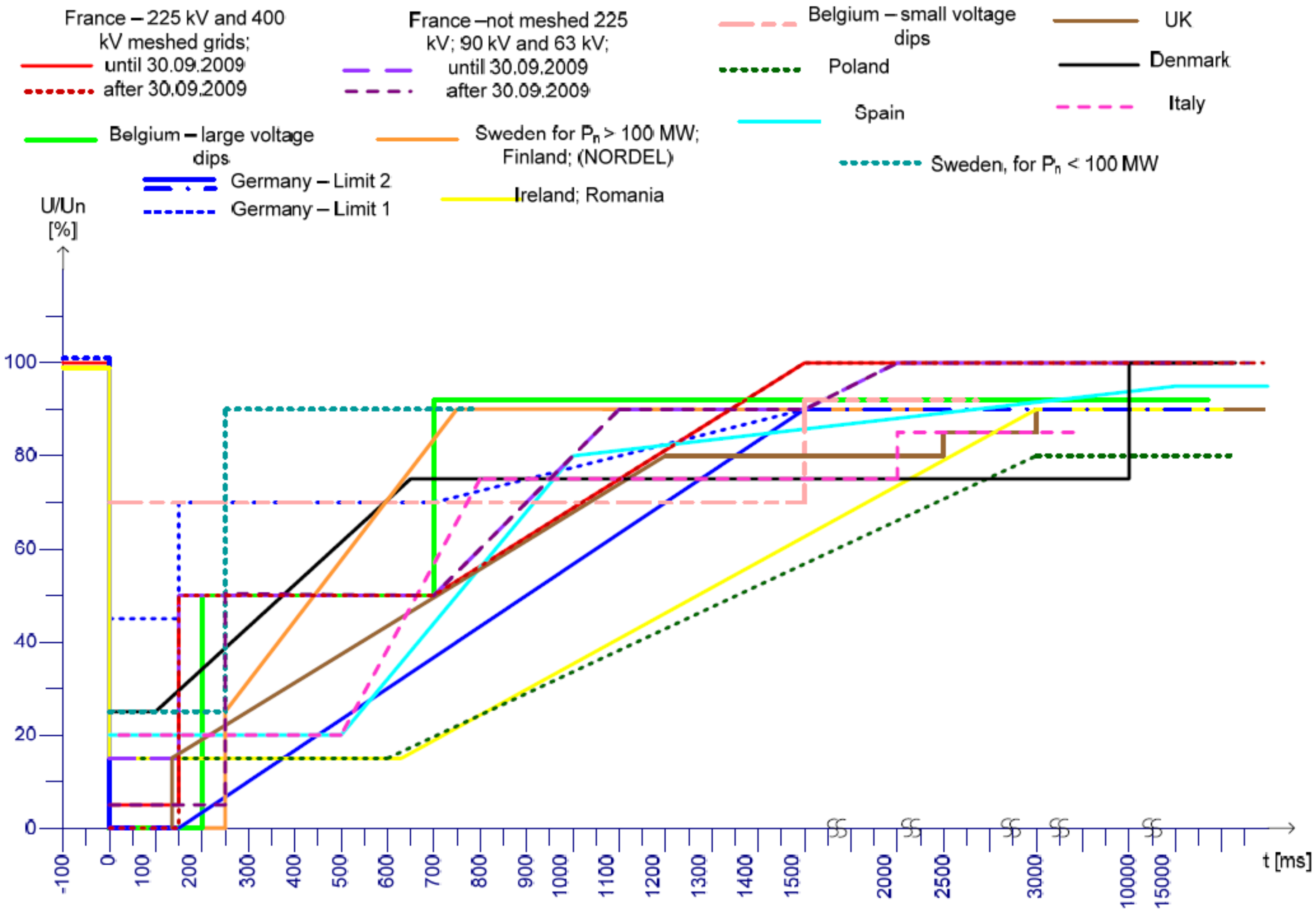
It looks nice – but is comparing possible ?



It is like comparing apples and pines

- The short circuit positions are different (transmission, PCC, gen-terminals)
- w/wo back-up protection (could be fast or slow) ?
- Valid for distribution or transmission level, or both ?
- Remote end faults included or not ?
- Telecommunication failure included ?
- Busbar faults included ?
- High level penetration at which voltage levels ?
- Requirements to active power recovery time ?
- Requirements for current injection or voltage control ?
- What is the strength of the grid ?
- How is the FRT voltage profiles to be understood ???

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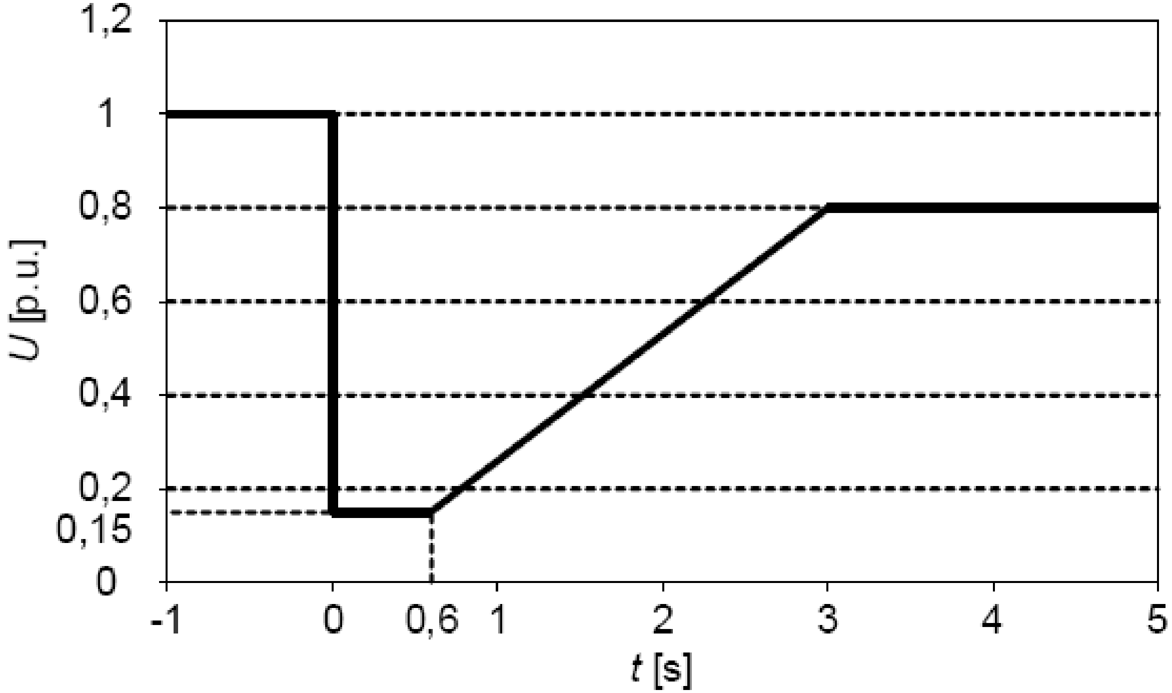
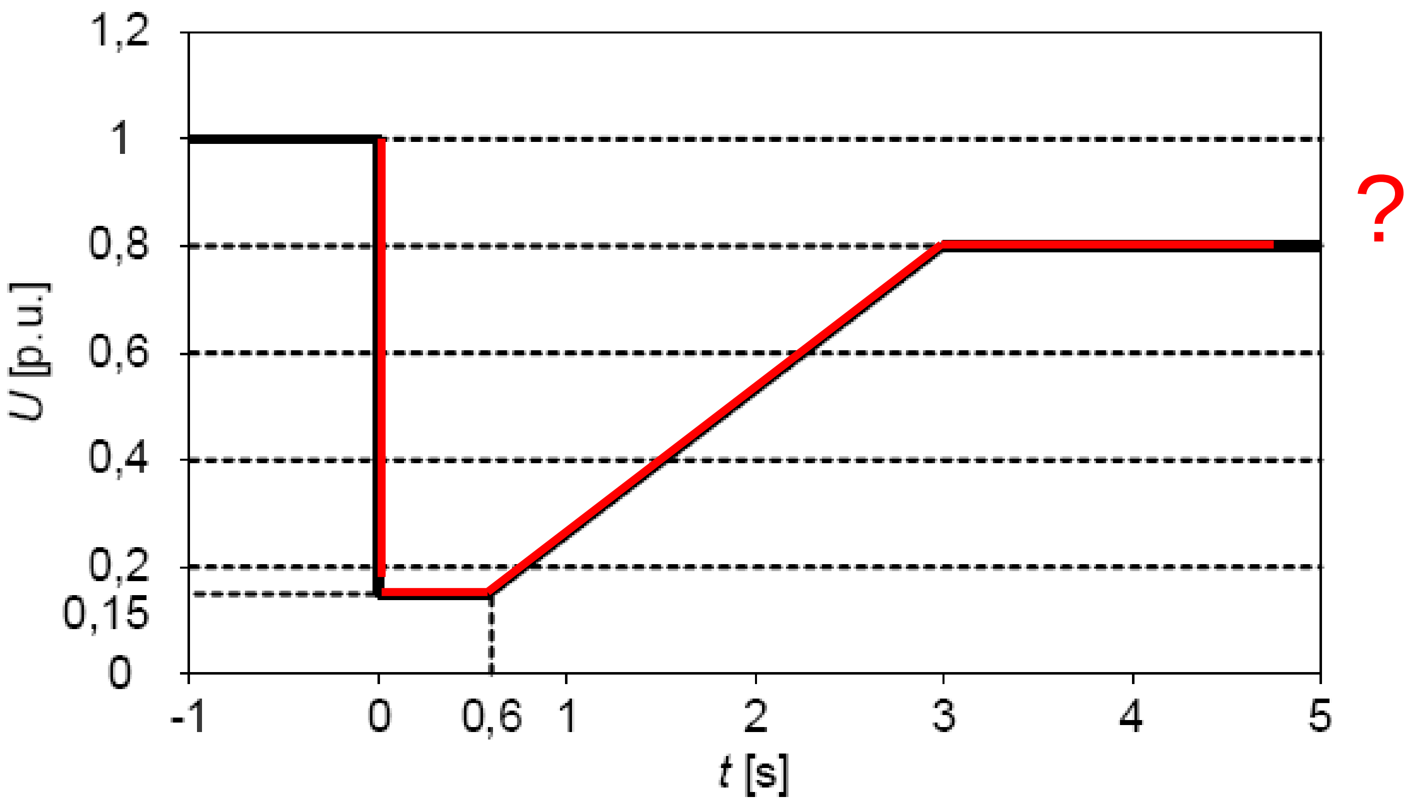
What is the assumptions behind the old 3 s profile ??



- Advice:
  Consider carefully what is really needed in each power system.
  Importing this profile may be very costly.

How are FRT curves to be understood ?



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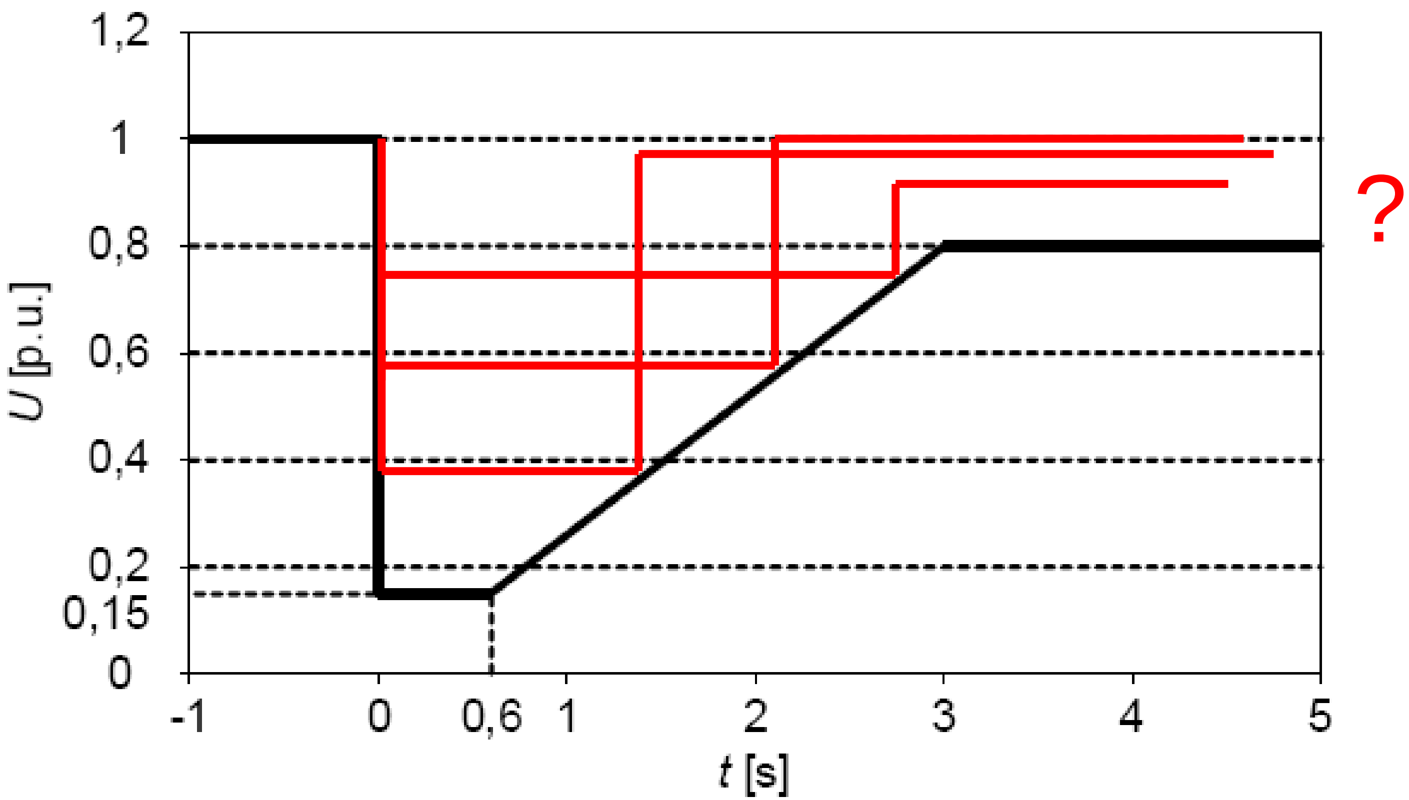

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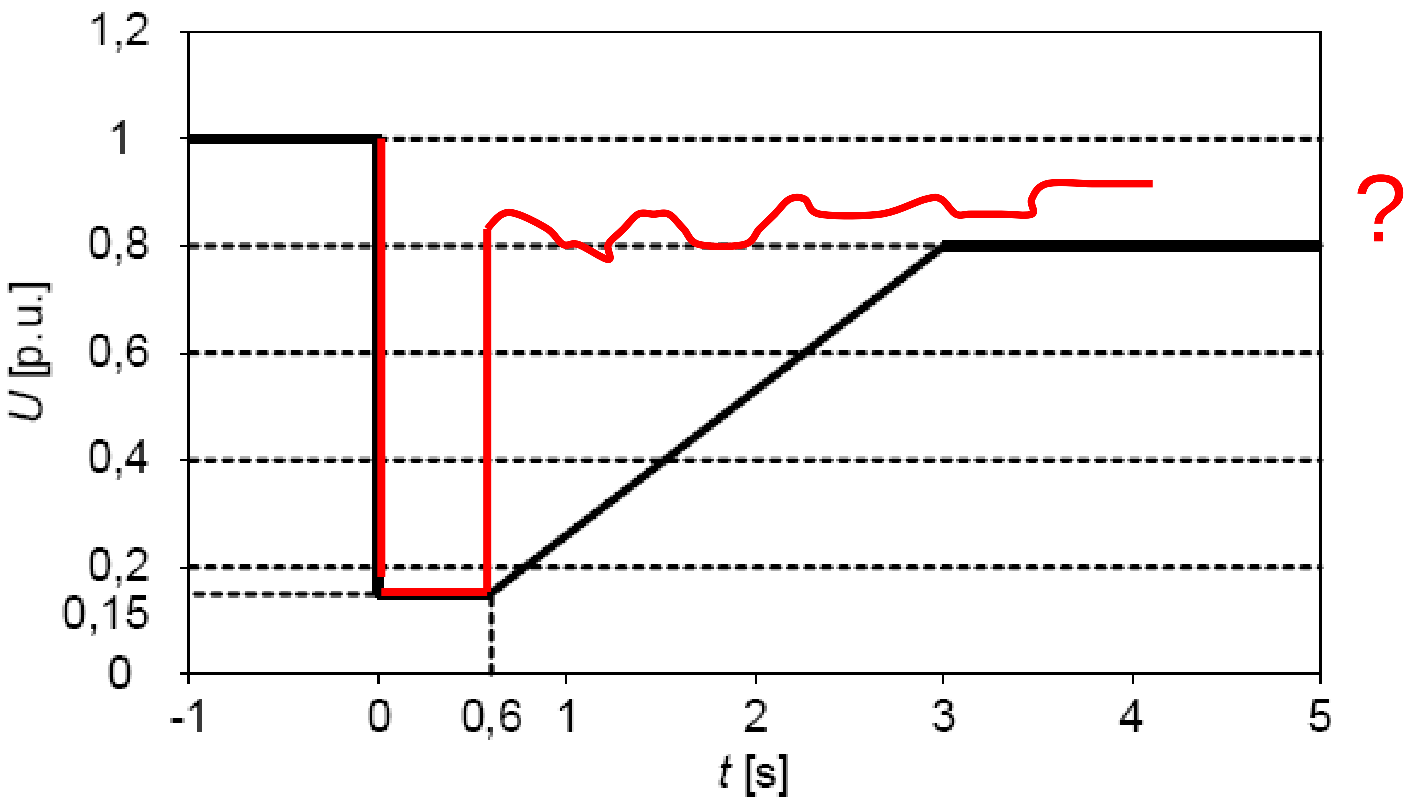

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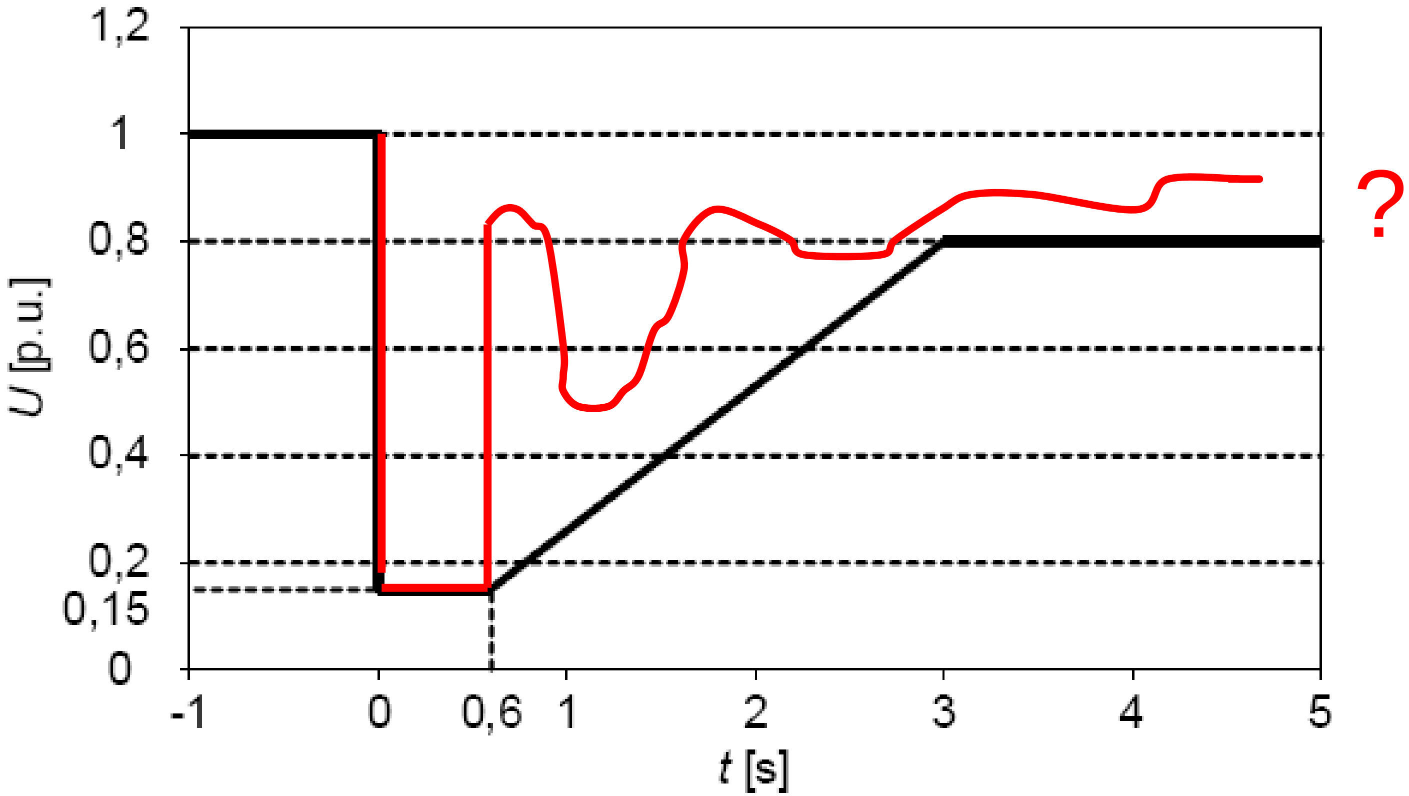

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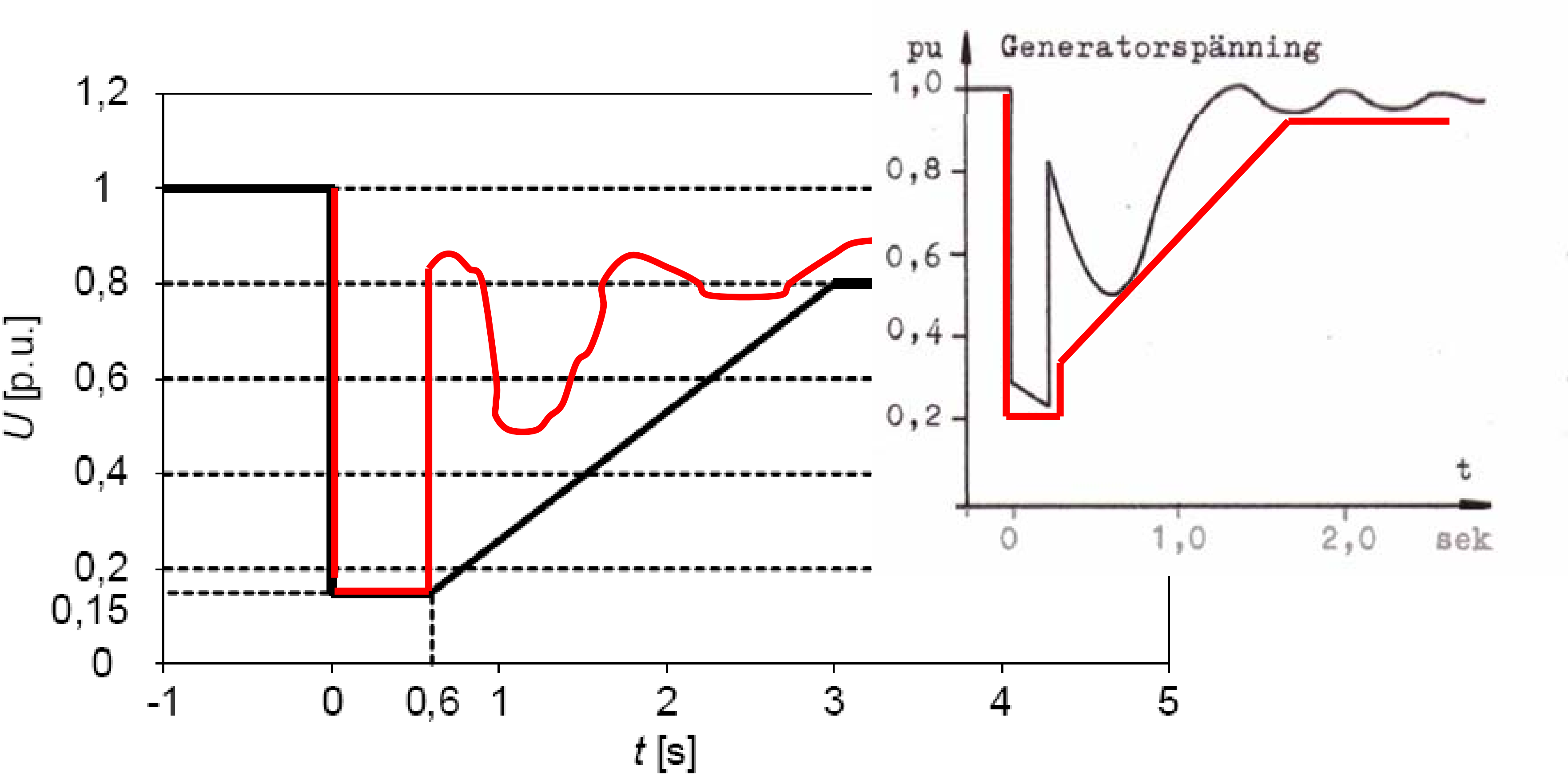


Fault Ride Through – why was it introduced

- If wind power becomes equal to **largest unit** in the system
- If **weak transmission corridor(s)** may be stressed/overstressed (voltage collapse and/or transient stability)
- To avoid potential **regional voltage collapse** in critical grid regions

Many names over time:

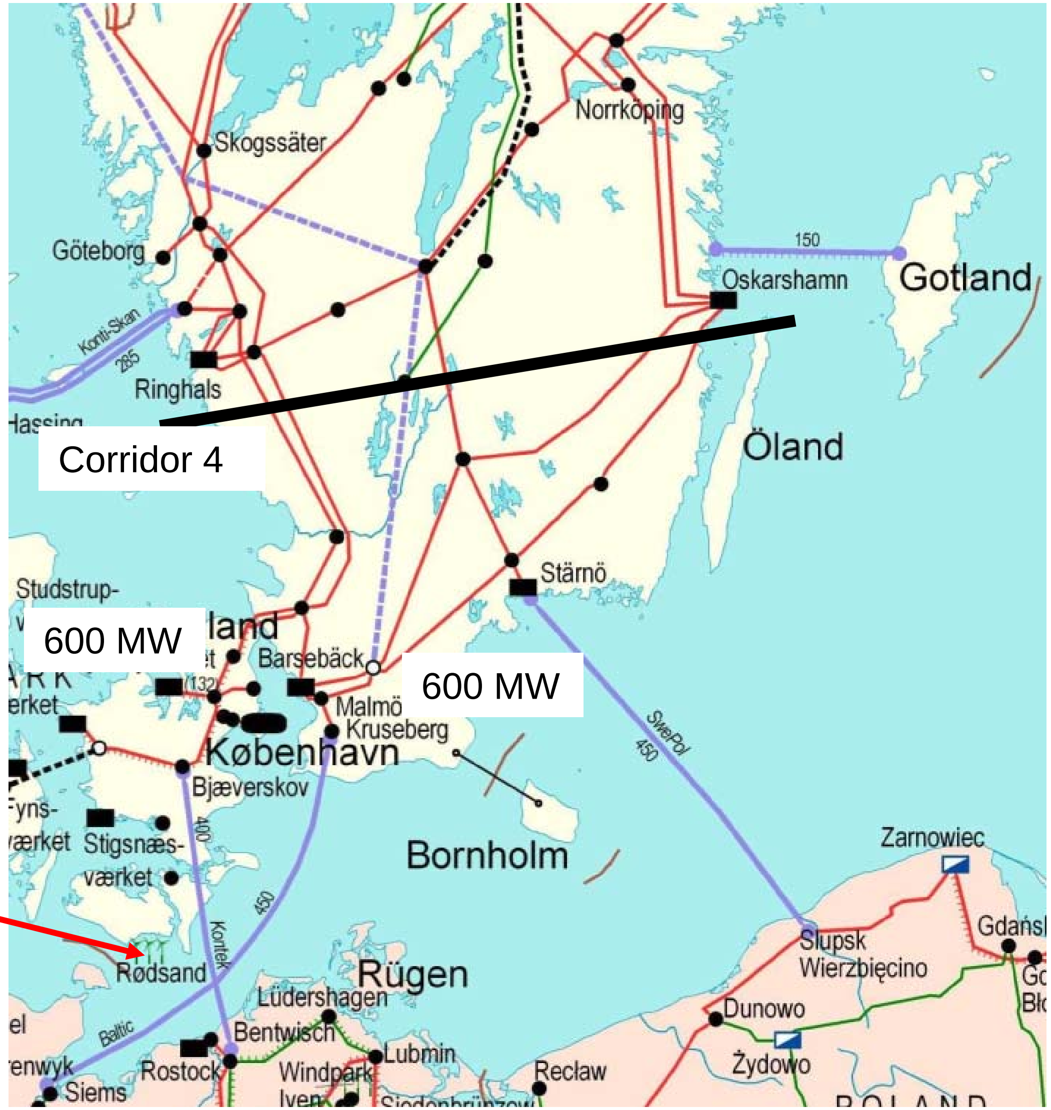
- Stay connected
- Ride through
- Fault ride through - FRT
- Deep voltage ride through
- Zero voltage ride through - ZVRT
- High voltage ride through - HVRT (……..)

FRT – largest unit and important corridor (DK)

East Denmark 1998:

Offshore wind power
was to be launched

Wind power
150 MW / 2. year



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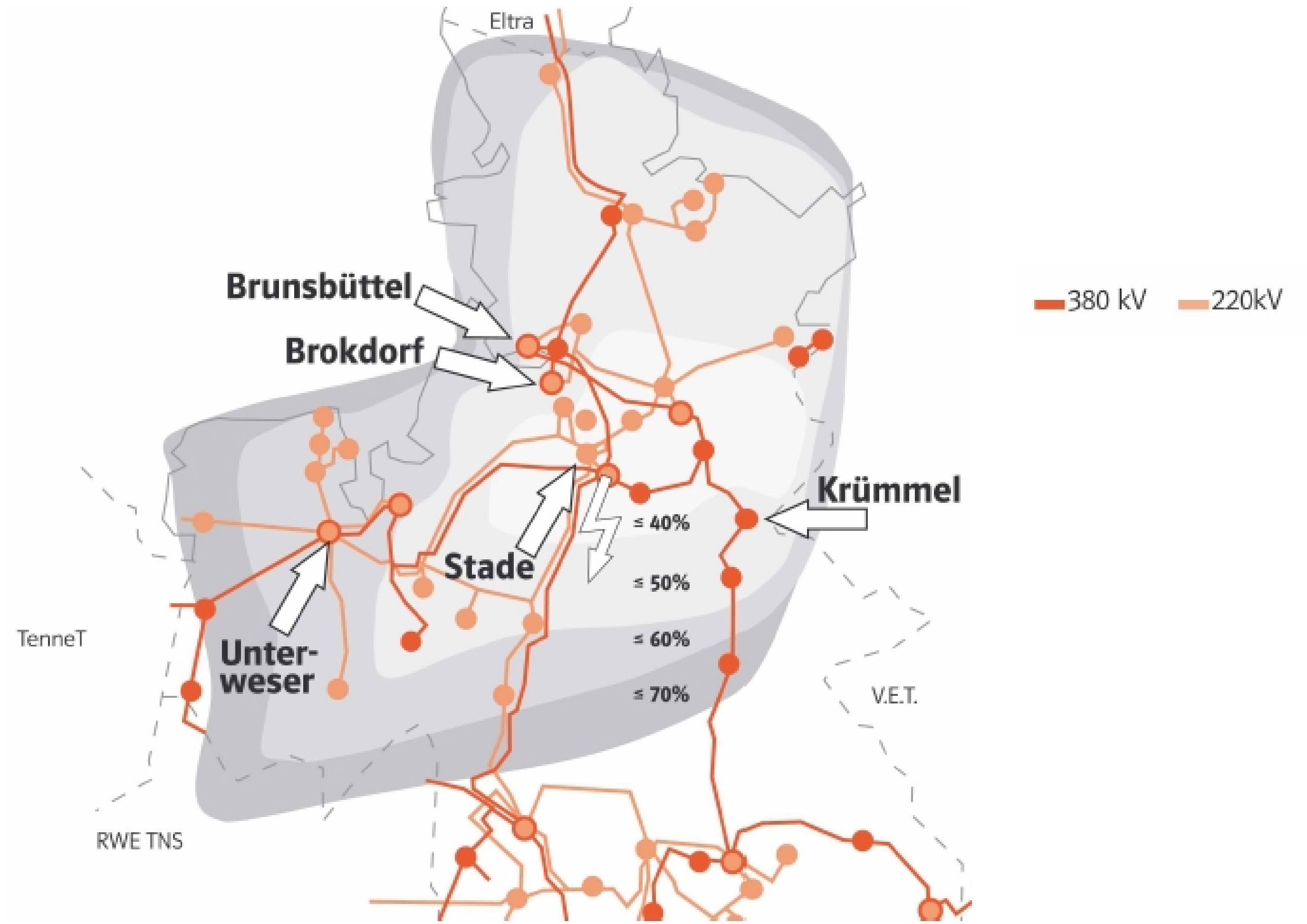
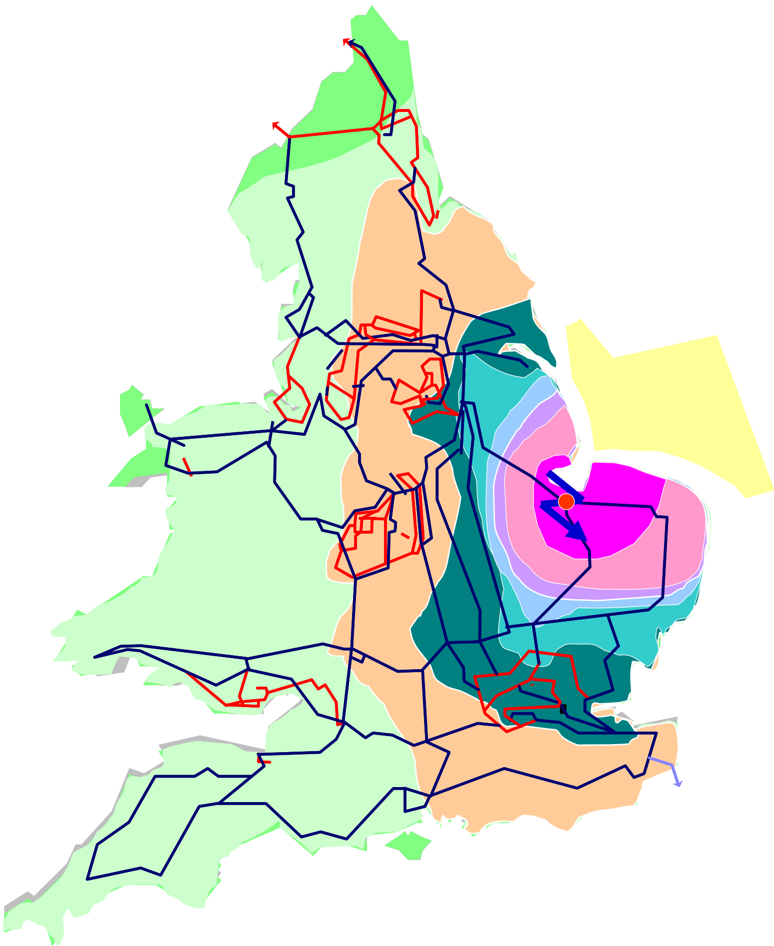
FRT – Regional voltage collapse (Germany – North)



FRT – Regional voltage collapse (England)



3 phase fault a Walpole
400 kV substation

- Fault Location 0 % Volts
- 0 - 15 % Volts
- 15 - 30 % Volts
- 30 - 40 % Volts
- 40 - 50 % Volts
- 50 - 60 % Volts
- 60 - 70 % Volts
- 70 - 80 % Volts
- 80 - 90 % Volts

Fault Ride Through – the main aspects

- What is the main system reason(s) requiring fault ride through
- What will be the correct short circuits positions to include in the system (events)
- What is the optimal shape for the FRT voltage profile
  - Size of voltage depth
  - Fault time (length of fault or fault clearing time)
  - Recovery shape
- How to administrate: a <u>general system wide</u>, <u>regional</u> or <u>site specific</u> profile
- Is absorption parameters required
- Is reactive current injection required (or can it be replaced by voltage control)
- What will be the requirement to active power recovery time

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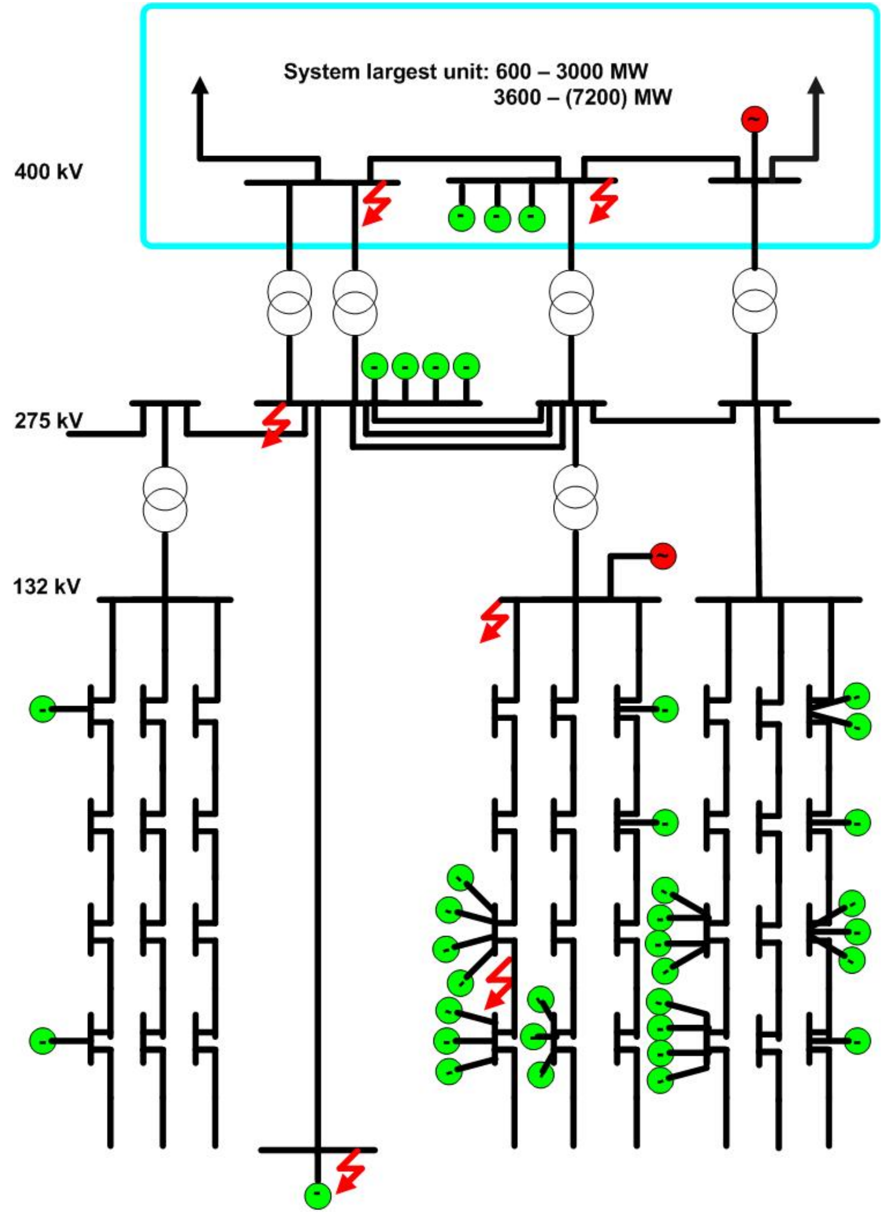
FRT – large scale penetration in different parts of a system

- What is the decisive mechanism and situation ?
- How to administrate in practice ?



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FRT – large scale penetration in different parts of a system

- What is the decisive mechanism and fault event(s) ?
- How to administrate in practice ?
- **Consider:**

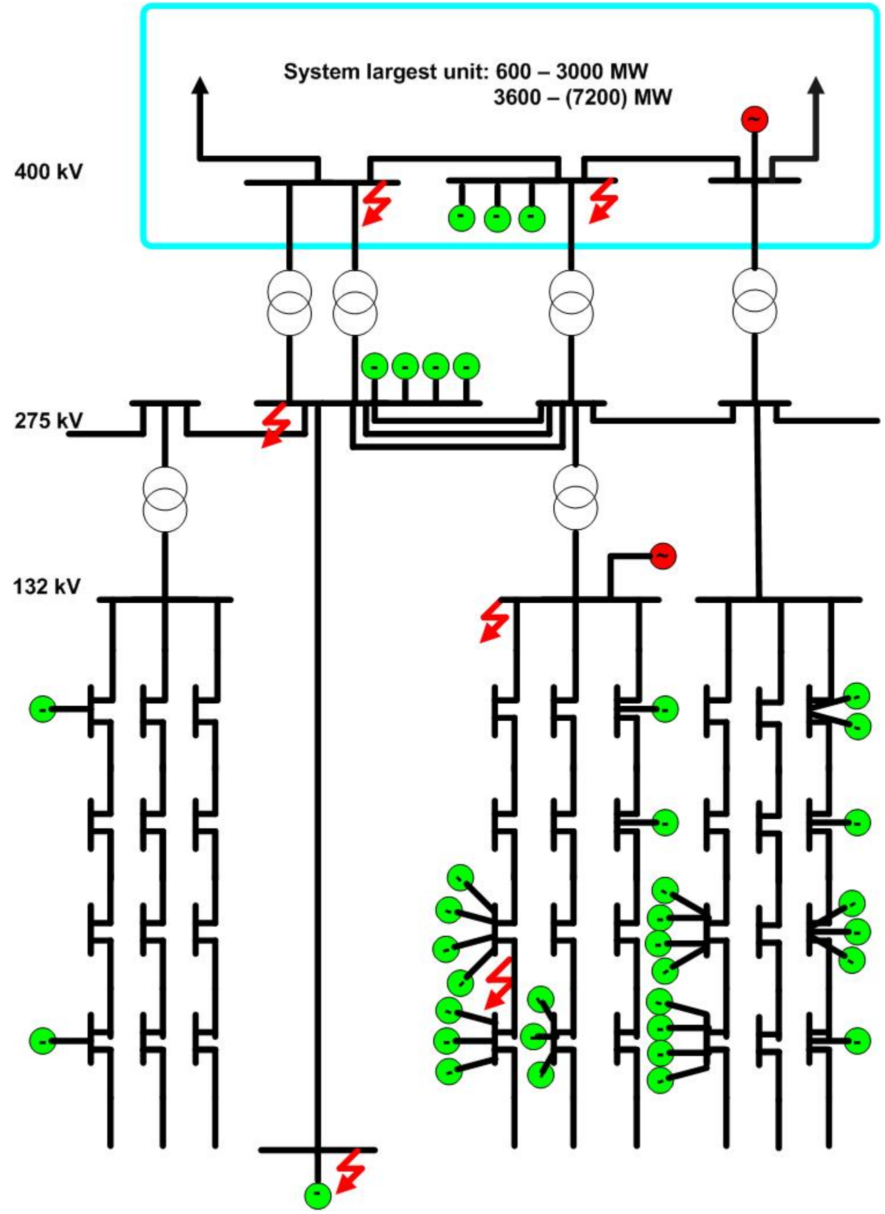
  Distribution and transmission together ?
  Be carefull ....

  Busbar arrangements

  Upgrading of relays/communication ?

  Under voltage load shedding ?

  Large central SVC (overload capability) ?



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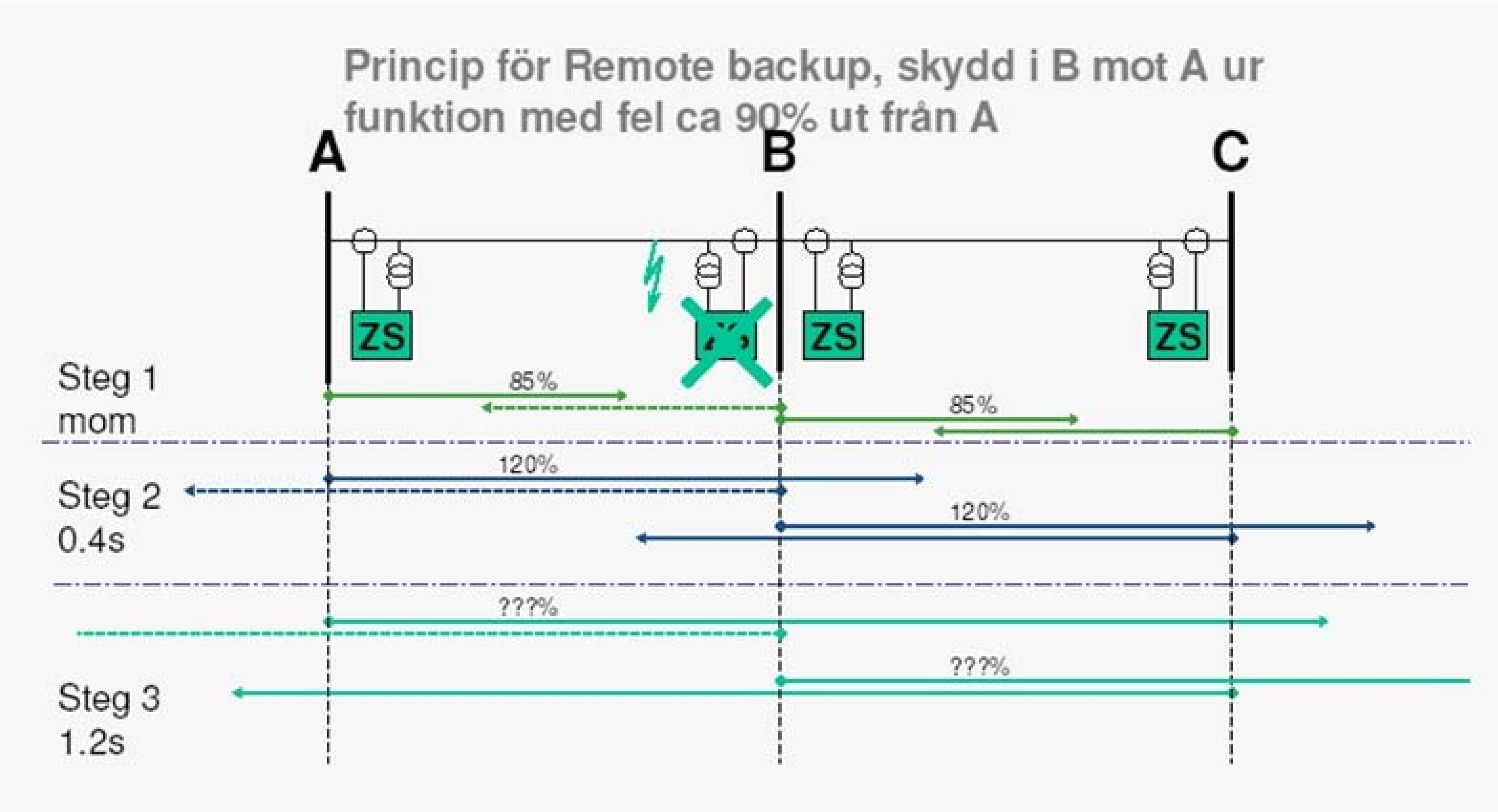
FRT – Size of voltage depth

- The voltage at the fault position should be assumed zero (PCC) (high penetration)
- Otherwise it is a question about the electrical distance to the fault position
- Three phase bus bar faults are often the most critical
  (can not be handled by conventional, maybe wind)
- If different from zero – how can that be argued ?
- Can faults other than three phase be disregarded as non-decisive ?

FRT – Maximum fault time

- Mainly decided by the relay, breaker and telecommunication performance



FRT – Recovery shape

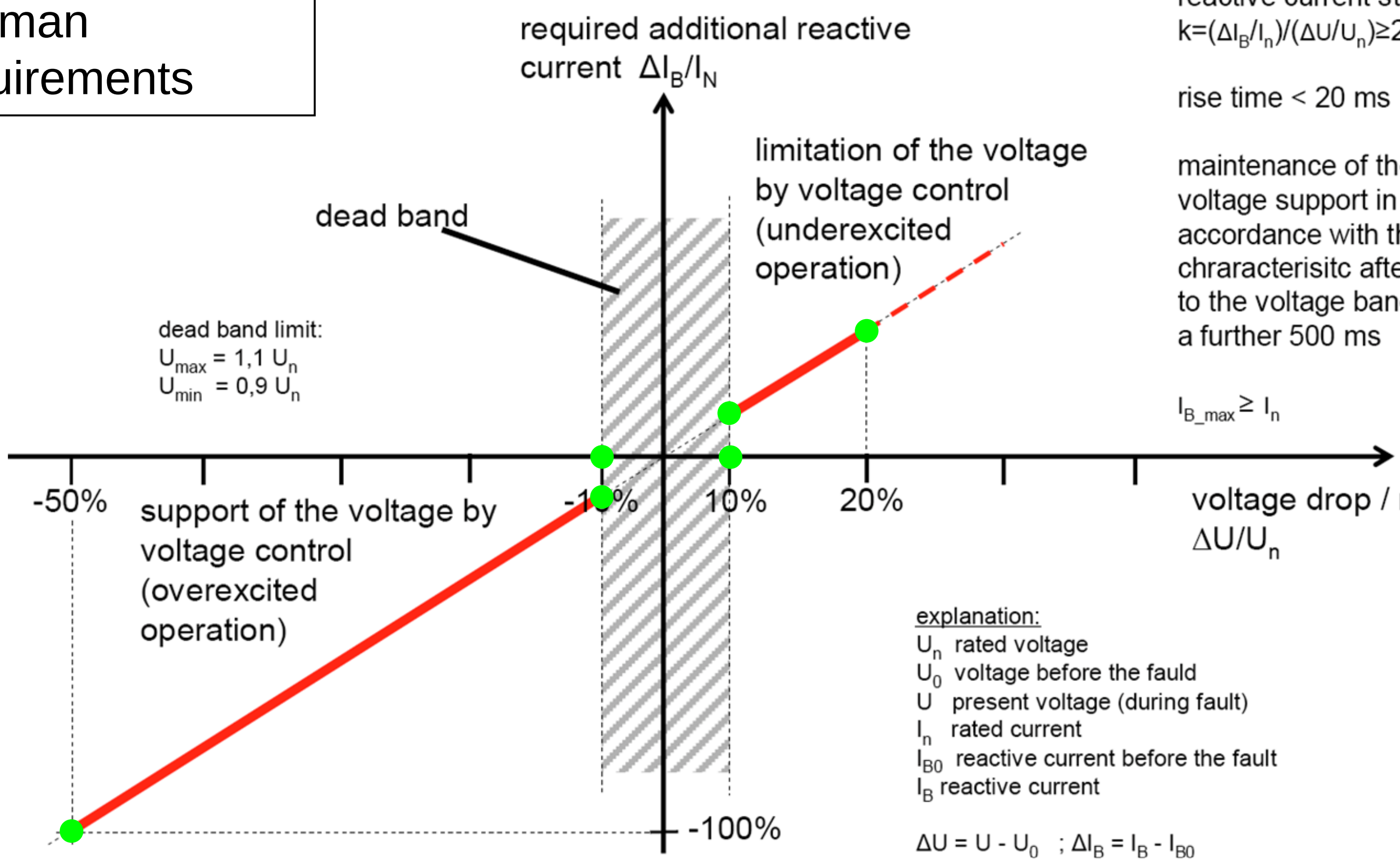
Depends upon:

- Power flow pattern
- System configuration
- Available generation and voltage support (dynamic voltage control)
- Voltage dependence of the load

- Remember: under voltage load shedding (as a possibility ….?)

FRT – Reactive current injection (Germany

German requirements



reactive current static:
$k=(\Delta I_B/I_n)/(\Delta U/U_n) \geq 2{,}0$ p.u.

rise time < 20 ms

maintenance of the voltage support in accordance with the chraracterisitc after return to the voltage band over a further 500 ms

$I_{B\_max} \geq I_n$

explanation:
- U_n rated voltage
- U_0 voltage before the fauld
- U present voltage (during fault)
- I_n rated current
- I_{B0} reactive current before the fault
- I_B reactive current

$\Delta U = U - U_0$; $\Delta I_B = I_B - I_{B0}$

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FRT – Recovery of active power (90 % of pre-fault)

- World-wide: 0,1 – 10 seconds
- Europe: 0,5 – 10 seconds

A few comments:

- A high number of grid codes have no requirement to active power recovery time
- Why specify FRT or even inertia –
  if no requirement or a very long recovery time of active power is accepted ??
- This requirement has to be seen in close relation to the FRT voltage profile

Conclusion

Conclusion

- The structural harmonization is extremely important due to the increasing complexity – and very beneficial for all stakeholders in the industry
- It is estimated to be one of the most important elements in ensuring the future power system security (less layering of in-homogeneous or even wrong technology)
- The European TSO´s will benefit a lot and should engage into a even more tight and close collaboration to establish the needed framework. In a such process – the EWEA GC template could be part of a fast track solution influenced also by TSO´s
- As the example with FRT has underlined there is a strong need to continue the process creating technical consensus, de-facto tradition and harmonization

Thanks for listening – any questions ?

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