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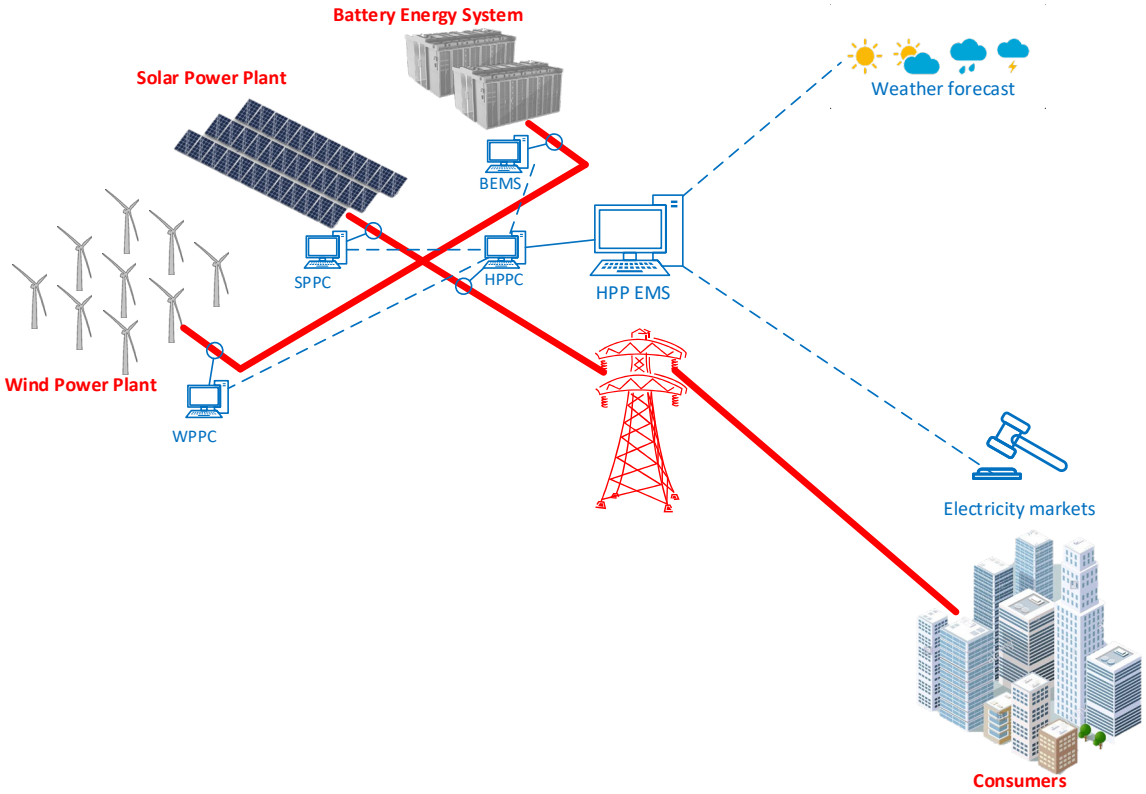
Comparison of European and Indian Grid Codes for Utility scale Wind Hybrid Power Plants

Work done as a part of Indo-Danish project “HYBRIDize” funded by Innovationsfonden Denmark

Motivation and Scope

- Reducing prices of technologies, increased availability, shared infrastructure, anti-correlation between resources, increased value in energy arbitrage, balancing and ancillary services – leading to hybridization of power plants
- Hybrid power plants are being developed all around the world.
- Grid codes applicable for hybrid power plants vary substantially all over the world
- Compare the European and Indian grid codes in terms of fault-ride-through capability, frequency and voltage operation ranges, active power control/frequency support as well as reactive power control/ voltage support.

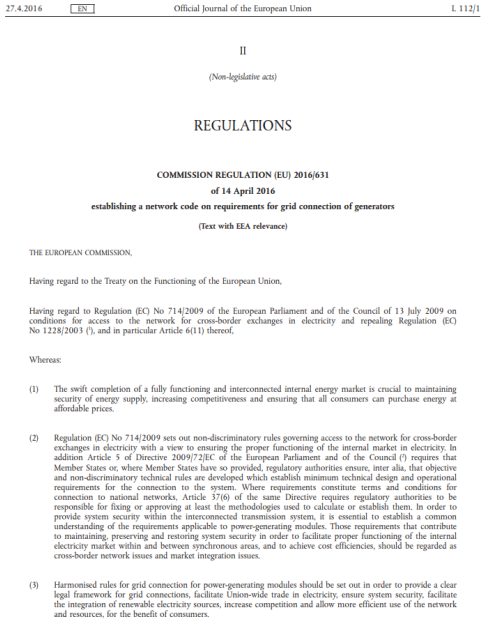
Hybrid Power Plant – Utility scale & co-located



General Features:

- More than one generation sources involved
- All the assets are owned by same company so higher controllability
- Generally one common connection point to grid
- Motivation is to reduce cost / maximize revenue from different energy markets.
  - One common energy management system
- Control of electrical load is not of concern of the power plant owner as compared to traditional Hybrid Power Systems
  - Sometime even provide near baseload generation
- Many stakeholders involved

European Commission Regulation Danish Grid Code



27.4.2016 EN Official Journal of the European Union L 112/1

II

(Non-legislative acts)

REGULATIONS

COMMISSION REGULATION (EU) 2016/631
of 14 April 2016
establishing a network code on requirements for grid connection of generators
(Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003 (1), and in particular Article 6(11) thereof,

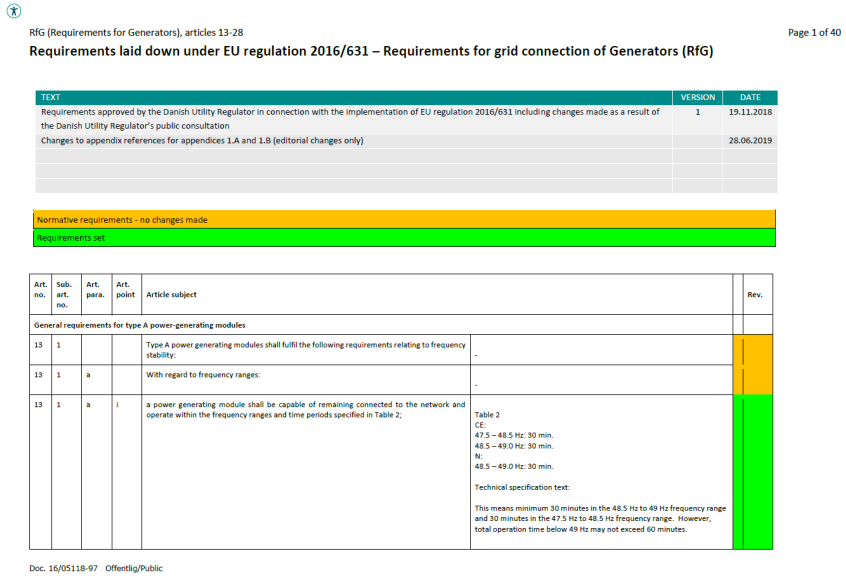
Whereas:

(1) The swift completion of a fully functioning and interconnected internal energy market is crucial to maintaining security of energy supply, increasing competitiveness and ensuring that all consumers can purchase energy at affordable prices.

(2) Regulation (EC) No 714/2009 sets out non-discriminatory rules governing access to the network for cross-border exchanges in electricity with a view to ensuring the proper functioning of the internal market in electricity. In addition Article 5 of Directive 2009/72/EC of the European Parliament and of the Council (2) requires that Member States or, where Member States have so provided, regulatory authorities ensure, inter alia, that objective and non-discriminatory technical rules are developed which establish minimum technical design and operational requirements for the connection to the system. Where requirements constitute terms and conditions for connection to national networks, Article 37(6) of the same Directive requires regulatory authorities to be responsible for fixing or approving at least the methodologies used to calculate or establish them. In order to provide system security within the interconnected transmission system, it is essential to establish a common understanding of the requirements applicable to power-generating modules. Those requirements that contribute to maintaining, preserving and restoring system security in order to facilitate proper functioning of the internal electricity market within and between synchronous areas, and to achieve cost efficiencies, should be regarded as cross-border network issues and market integration issues.

(3) Harmonised rules for grid connection for power-generating modules should be set out in order to provide a clear legal framework for grid connections, facilitate Union-wide trade in electricity, ensure system security, facilitate the integration of renewable electricity sources, increase competition and allow more efficient use of the network and resources, for the benefit of consumers.

European Commission Regulation (CR) with requirements for Generators (RfG)



RfG (Requirements for Generators), articles 13-28 Page 1 of 40

Requirements laid down under EU regulation 2016/631 – Requirements for grid connection of Generators (RfG)

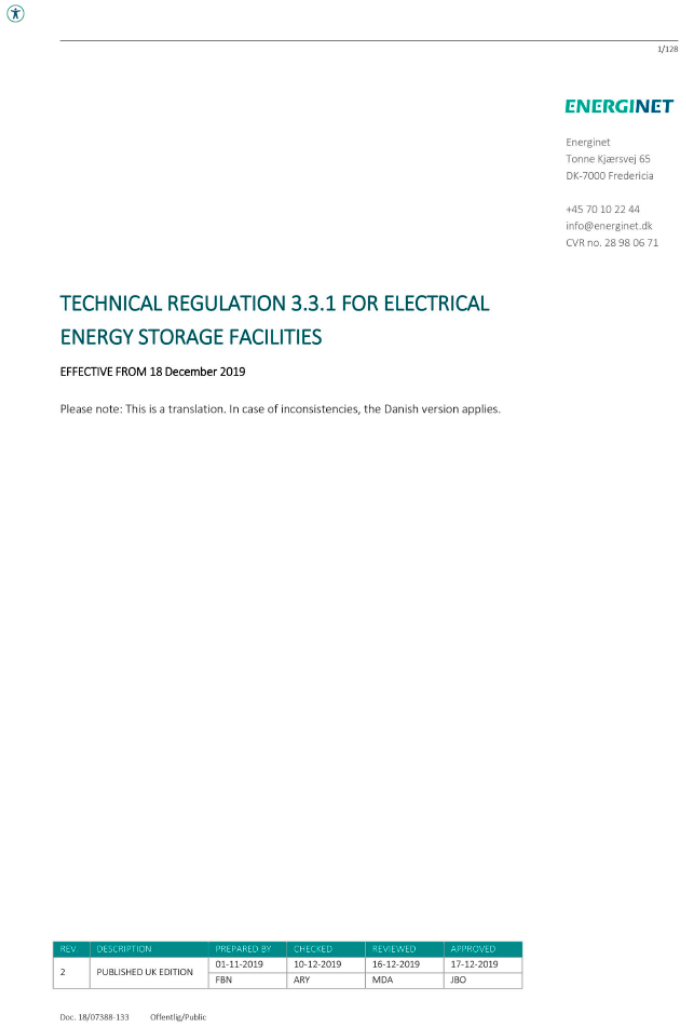
TEXT	VERSION	DATE
Requirements approved by the Danish Utility Regulator in connection with the implementation of EU regulation 2016/631 including changes made as a result of the Danish Utility Regulator's public consultation	1	19.11.2018
Changes to appendix references for appendices 1.A and 1.B (editorial changes only)		28.06.2019

Normative requirements - no changes made
Requirements set

Art. no.	Sub. art. no.	Art. para.	Art. point	Article subject		Rev.
General requirements for type A power-generating modules						
13	1			Type A power generating modules shall fulfil the following requirements relating to frequency stability:	-	
13	1	a		With regard to frequency ranges:	-	
13	1	a	i	a power generating module shall be capable of remaining connected to the network and operate within the frequency ranges and time periods specified in Table 2;	Table 2 CE: 47.5 – 48.5 Hz: 30 min. 48.5 – 49.0 Hz: 30 min. N: 48.5 – 49.0 Hz: 30 min. Technical specification text: This means minimum 30 minutes in the 48.5 Hz to 49 Hz frequency range and 30 minutes in the 47.5 Hz to 48.5 Hz frequency range. However, total operation time below 49 Hz may not exceed 60 minutes.	

Doc. 16/05118-97 Offentlig/Public

Danish specifications set by Danish TSO - Energinet



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TECHNICAL REGULATION 3.3.1 FOR ELECTRICAL ENERGY STORAGE FACILITIES

EFFECTIVE FROM 18 December 2019

Please note: This is a translation. In case of inconsistencies, the Danish version applies.

REV.	DESCRIPTION	PREPARED BY	CHECKED	REVIEWED	APPROVED
2	PUBLISHED UK EDITION	01-11-2019	10-12-2019	16-12-2019	17-12-2019
		FBN	ARY	MDA	JBO

Doc. 18/07388-133 Offentlig/Public

Danish grid code for electrical energy storage

Applicable for power park modules, HVDC and synchronous generation
Not applicable for electrical energy storage (except pumped hydro)

Power plant categories

Power-generating modules

	Type C			Type D		
	V_{POC}	P_{max}	$P_{Threshold}$	V_{POC}	P_{max}	$P_{Threshold}$
CE	<110kV	≥ $P_{Threshold}$	Max. 50MW	≥110kV	Any	-
				<110kV	≥ $P_{Threshold}$	Max. 75MW
Nordic	<110kV	≥ $P_{Threshold}$	Max. 10MW	≥110kV	Any	-
				<110kV	≥ $P_{Threshold}$	Max. 30MW
Danish specifications			3MW			25MW

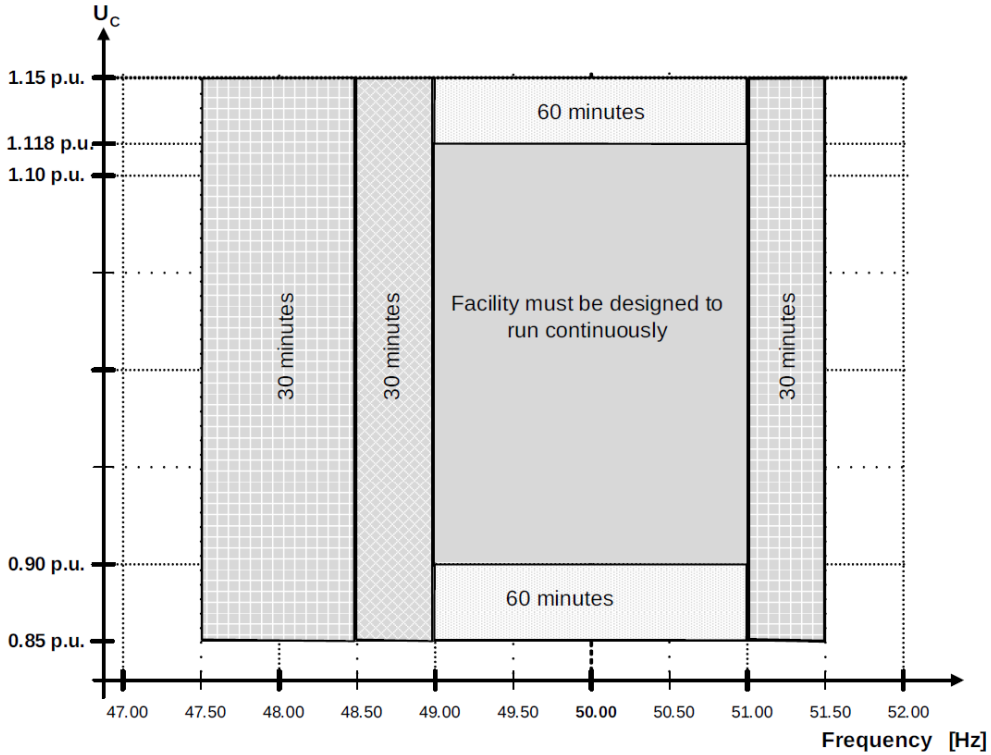
Electrical Energy Storage Facilities in Denmark

	Type A	Type B	Type C	Type D
P_{min}	-	125kW	3MW	25MW
P_{max}	125kW	3MW	25MW	-
V_{POC}	-	-	-	100kV

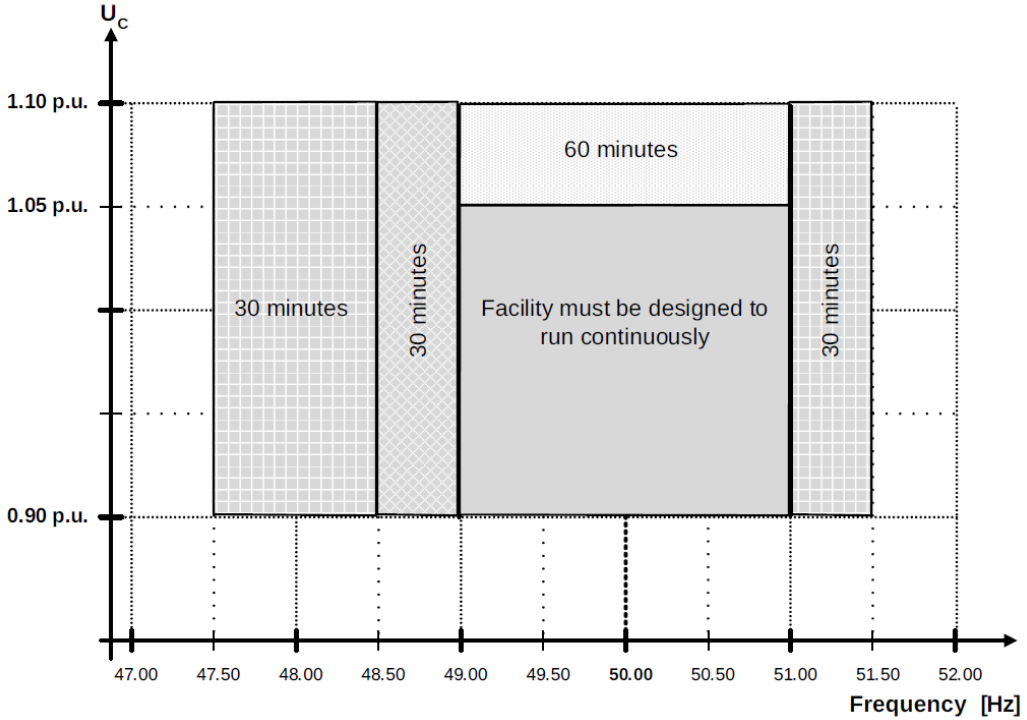
Indian Grid Code

- Does not categorize power plants
- Applicable to all generations connected at 33kV and above
- applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

Operational ranges and time



Power Park Module and Electrical Energy Storage in DK1

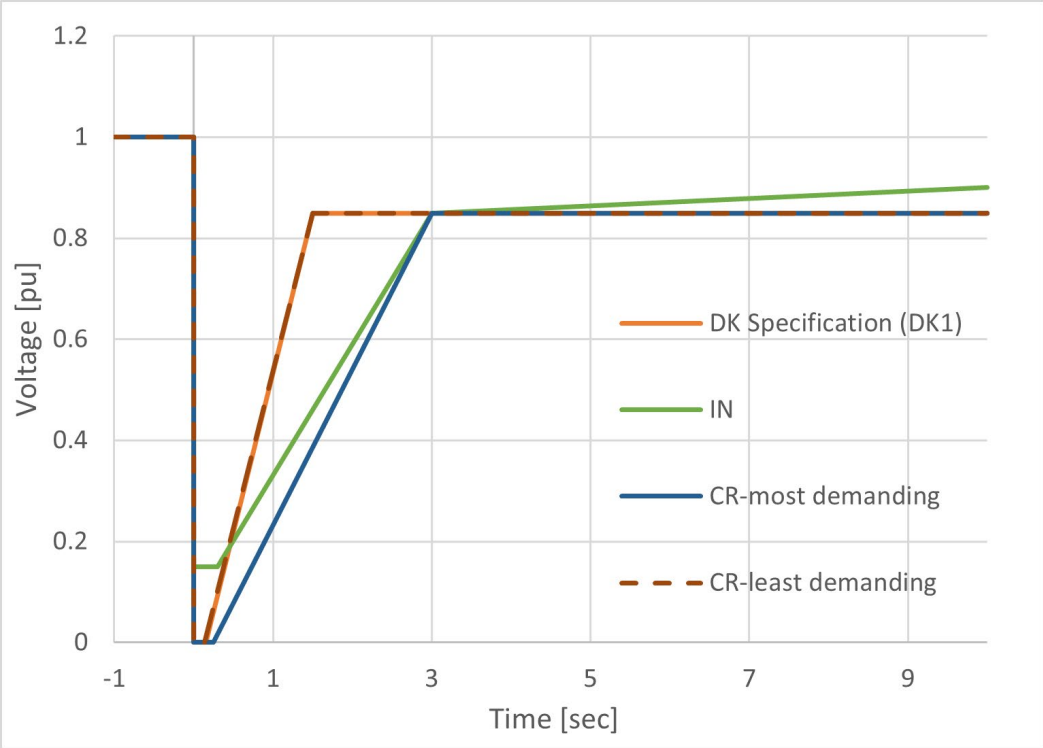


Power Park Module and Electrical Energy Storage in DK2

Indian Grid Code

- Frequency range: 47.5 – 52 Hz
  - Frequency response between 47.5-49.90 Hz and 50.05-52 Hz
- Voltage range: continuous operation in 0.85 pu - 1.1 pu

Undervoltage ride-through & Overvoltage ride-through

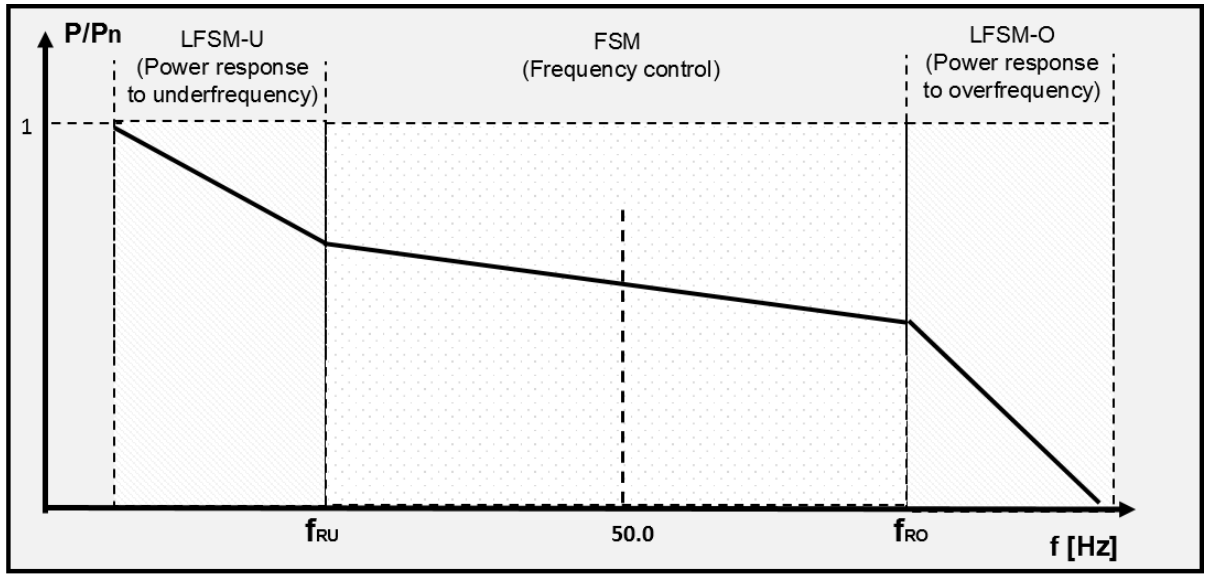


UVRT

Voltage	Minimum time to remain connected (Seconds)
1.30 < V	0 Sec (Instantaneous trip)
1.30 > V > 1.20	0.2 Sec
1.20 > V >1.10	2 Sec

OVRT in India

Frequency Support

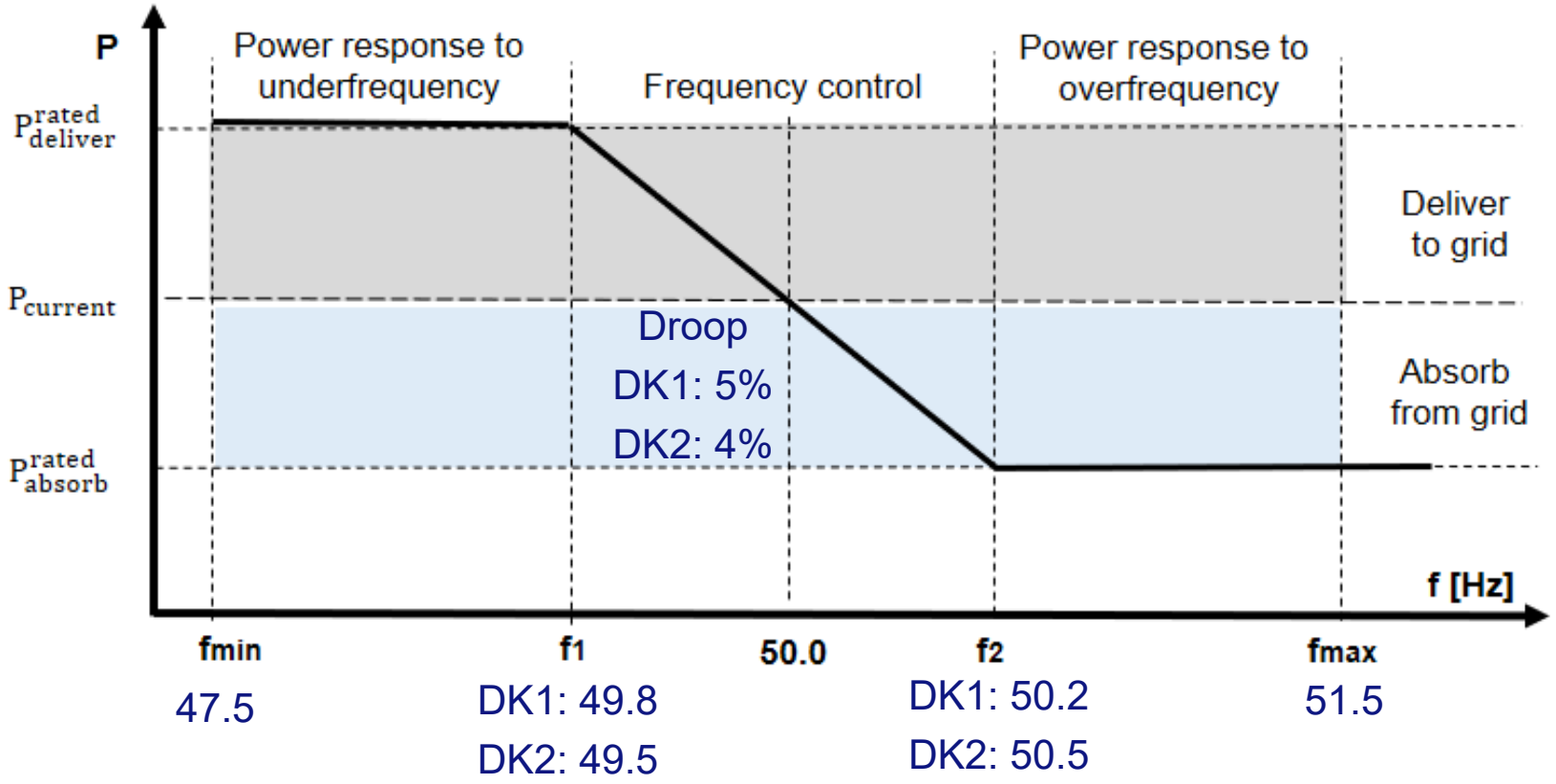


FSM Characteristics	CR ranges	Danish Specs.		Indian Grid Code
		DK1	DK2	
Freq. control ranges [Hz]	49.5-50.5	49.8-50.2	49.5-50.5	49.7 - 50.3
Droop [%]	2-12	12	12	3-6
Dead band [mHz]	0-500	0-200	0-500	±30
Power reduction [% of Pn]	1.5-10	1.5-10	1.5-10	10

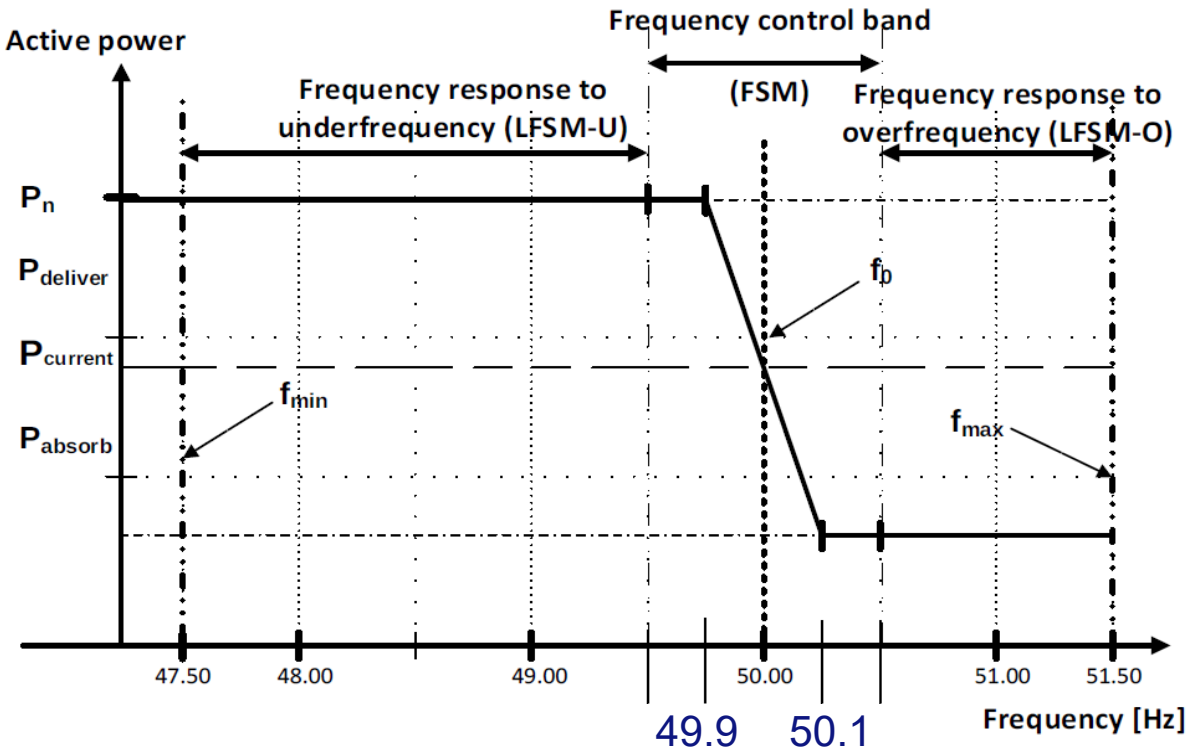
LFSM-U Characteristics	CR ranges	Danish Specs.		Indian Grid Code
		DK1	DK2	
f_{RU} [Hz]	49.8-49.5	49.8	49.5	49.7
Droop [%]	2-12	5	4	Step
Resolution [mHz]	10-30	10	10	-
Power reduction [% of Pn]	1.5-10	6	6	≥ 10

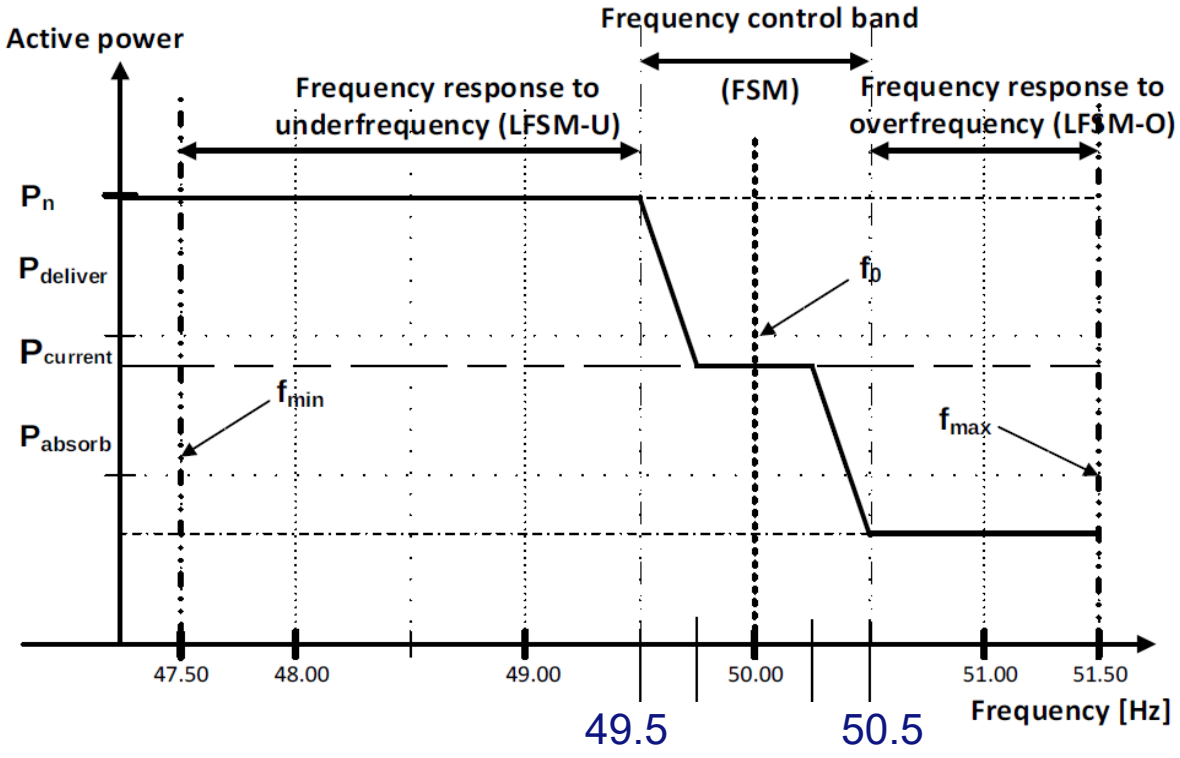
LFSM-O Characteristics	CR ranges	Danish Specs.		Indian Grid Code
		DK1	DK2	
f_{RO} [Hz]	50.2-50.5	50.2	50.5	50.3
Droop [%]	2-12	5	4	Step
Resolution [mHz]	10-30	10	10	-
Power reduction [% of Pn]	1.5-10	5	5	≥ 10

Frequency Control for Electrical Energy Storage

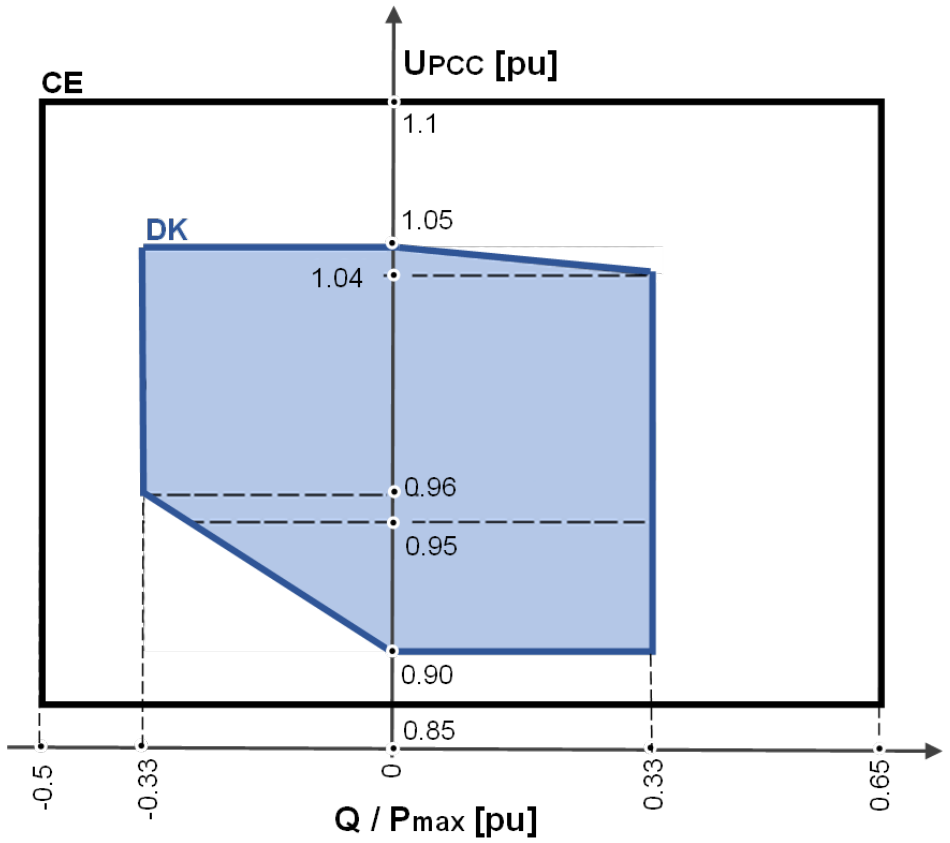


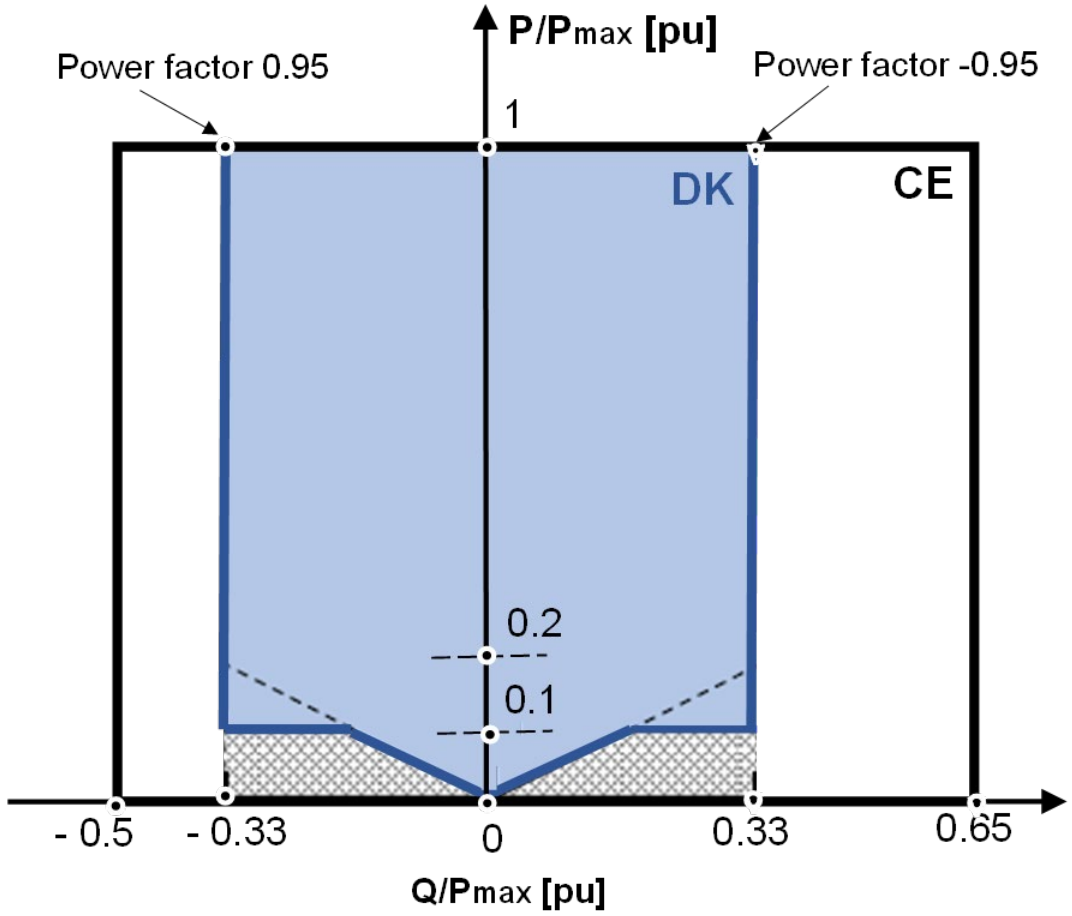
Frequency Control for Electrical Energy Storage





Reactive power provision capability





Voltage Control / Reactive Power Control / PF control

Modules	Control modes	Danish code	Indian code
Wind & Solar Power parks	Voltage control	Accomplished within 5 s Droop value 2-7% Deadband ± 5% Un	
	Q control	Step ≤ min(5 MVAr, 5%of Qn)	
	Power factor control	Resolution: 0.01 Initiated within 2 s Accomplished within 30s	Continuous operation within the power factor range from 0.95 leading to 0.95 lagging
Electrical energy storage facilities	Voltage control	Initiated within 2 s Accomplished within 10 s Droop value 2-12% Standard droop 4%	Same as above if storage is combined with wind/solar power plants
	Q control	Initiated within 2 s Accomplished within 10 s Max. deviation: 1% of Qn over 1 min	
	Power factor control	Resolution: 0.01 Initiated within 2 s Accomplished within 10 s	

Comparison Summary

Grid requirements		Danish code	Indian code
Frequency operation range	Continuous operation	X	X
	Abnormal operation	X	X
Voltage operation range	Continuous operation	X	X
	Voltage swells	X	X
	Voltage dips - UVRT	X	X
Active power control	Frequency Response	X	X
	Ramp rate limit	X	X
Reactive power control	PQ & UQ profiles	X	-
	Voltage control	X	-
	Reactive power control	X	-
	Power factor control	X	X

Discussions

- Both countries provide specifications for continuous and abnormal frequency and voltage operation ranges

- Frequency regulation is narrower in Denmark compared to Indian grid.
  - might make the cost of the power plants higher.

- Indian grid code requires the power plants to ride through overvoltage events and stay connected for voltages up to 1.3 pu.

- Danish grid code has shorter UVRT time, while the Indian grid has a more severe UVRT requirement, asking to keep recovery ability for longer time

- The freq. response requirements in Indian grid code are very brief and abstract.
  - Details should be provided in terms of frequency resolution, frequency measurement accuracy, etc.
  - Since Indian grid frequency is generally fluctuating due to generation-load imbalance; it is not clear that whether frequency response from the power plants would be utilized for contingencies or for minimizing other imbalances.
  - This issue becomes more challenging for Indian power system since the procurement of the frequency reserves are done for long-term making it difficult for weather-based generations to participate in the market.

- PQ-profiles and UQ-profiles are not considered in Indian grid code explicitly, as compared to Europe.
  - European specifications require power generating units to have voltage, reactive power and power factor control functionalities.
  - Indian grid code requires power generating units to have power factors that are dynamically adjustable within the range from $\pm$0.95 at PCC.

Thank You

- More details: A.D. Hansen et. al., “European and Indian Grid Codes for Utility Scale Hybrid Power Plants”, submitted to MDPI Energies
- Contact - kdas@dtu.dk

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