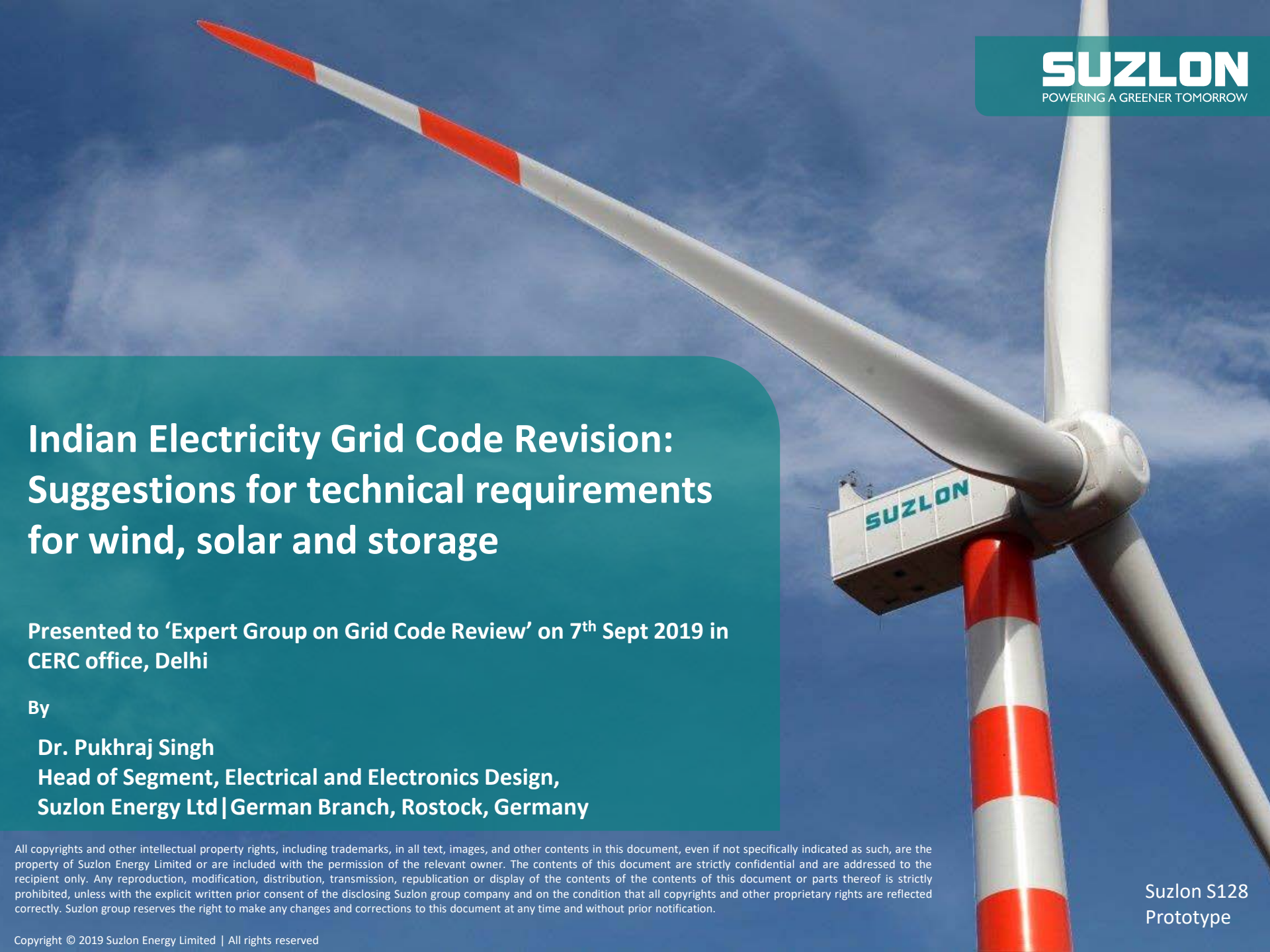

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Indian Electricity Grid Code Revision: Suggestions for technical requirements for wind, solar and storage

Presented to 'Expert Group on Grid Code Review' on 7th Sept 2019 in CERC office, Delhi

By

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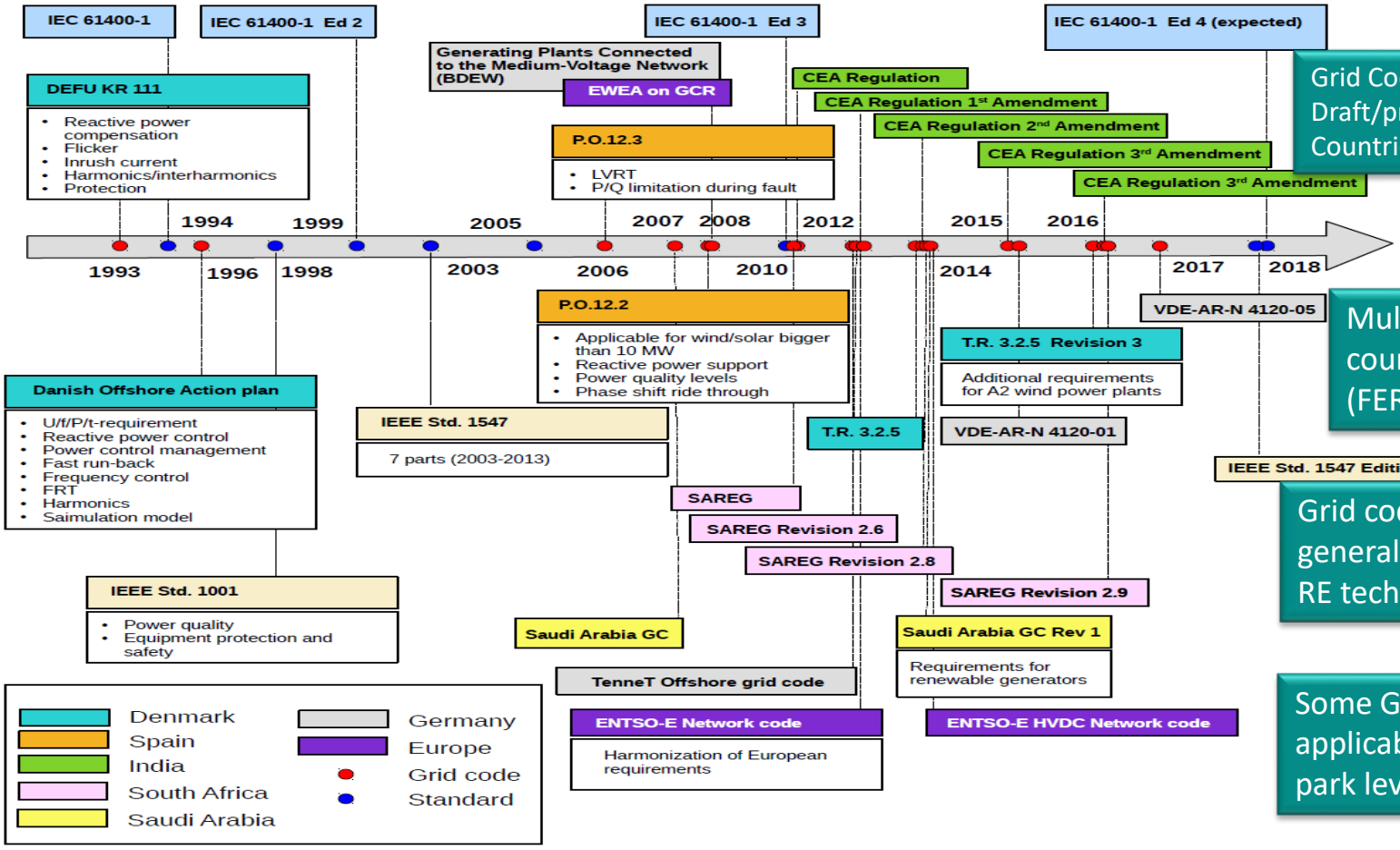
Suzlon S128
Prototype

Contents

- Evolution of Grid Code
- Wind and Solar Energy Integration in grid
- High Voltage & Low Voltage Ride Through (Wind, Solar, Storage)
- Reactive Power Capability
- Grid Frequency Regulation as Ancillary Service
- Synthetic Inertia as Ancillary Service
- Power Ramp Up/Down rate control
- Harmonic current from RE generating stations
- Power Generation forecast
- Energy Storage Integration
- Black Start, Technical Capabilities for Offshore Windfarm
- Suggestions for consideration

Evolution of Grid Code & Standards to address RE Energy Integration challenges

Capability requested to provide ancillary services, in long term replace traditional generators



Grid Codes >232
Draft/proposal stage > 50
Countries published GC > 63

Multiple GC in some country, eg USA (FERC, ERCOT..)

Grid code are in general
RE technology neutral

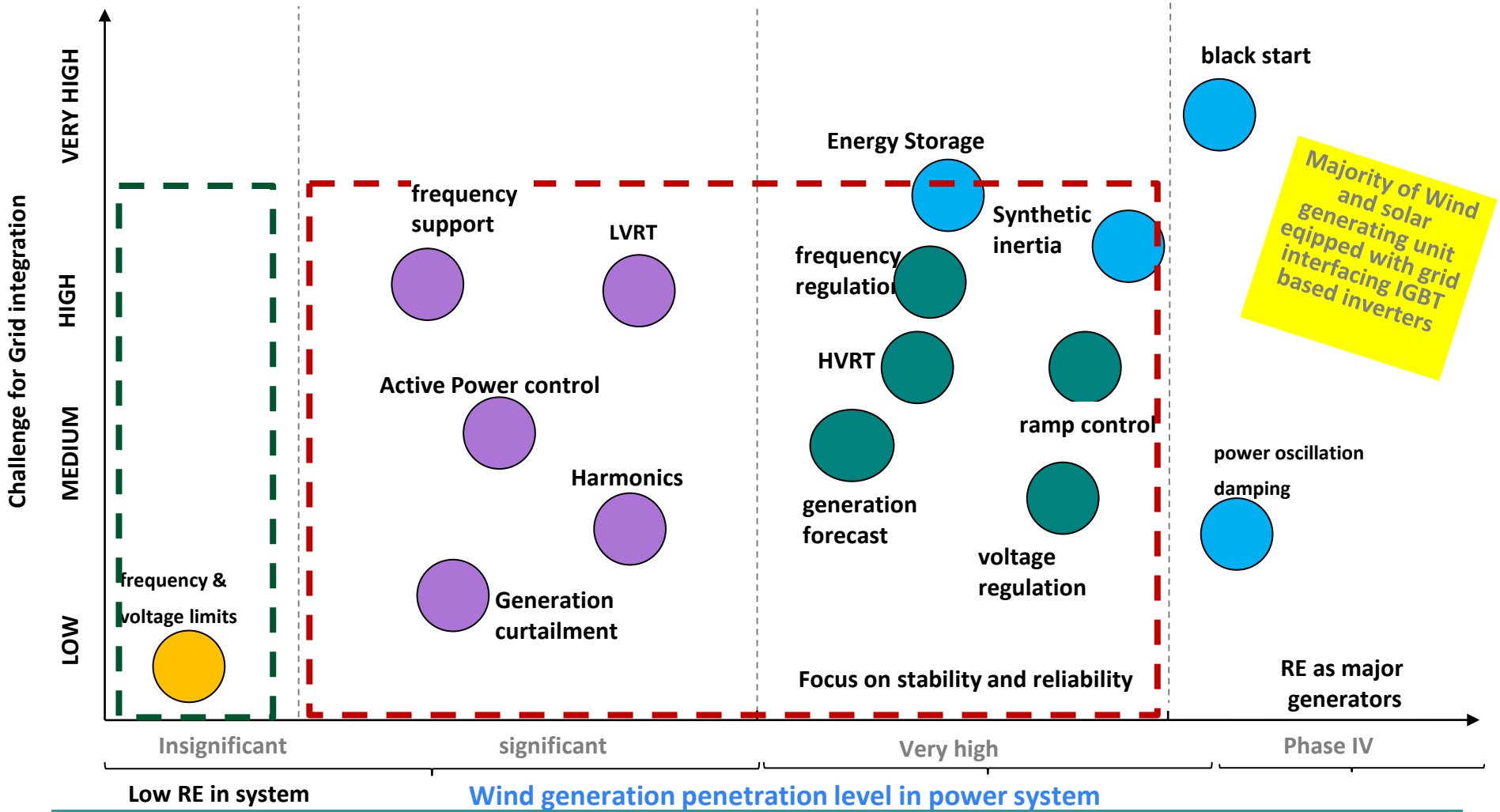
Some GC requirements applicable at WTG and or park level (India)

There should be mechanism to quickly amend grid code and technical connectivity standard based on field experiences and technology advancement ...

... To support higher RE integration challenges and meet Government target

Wind & Solar Energy Integration in Grid

Technical capabilities required according to Indian vision of RE share in grid

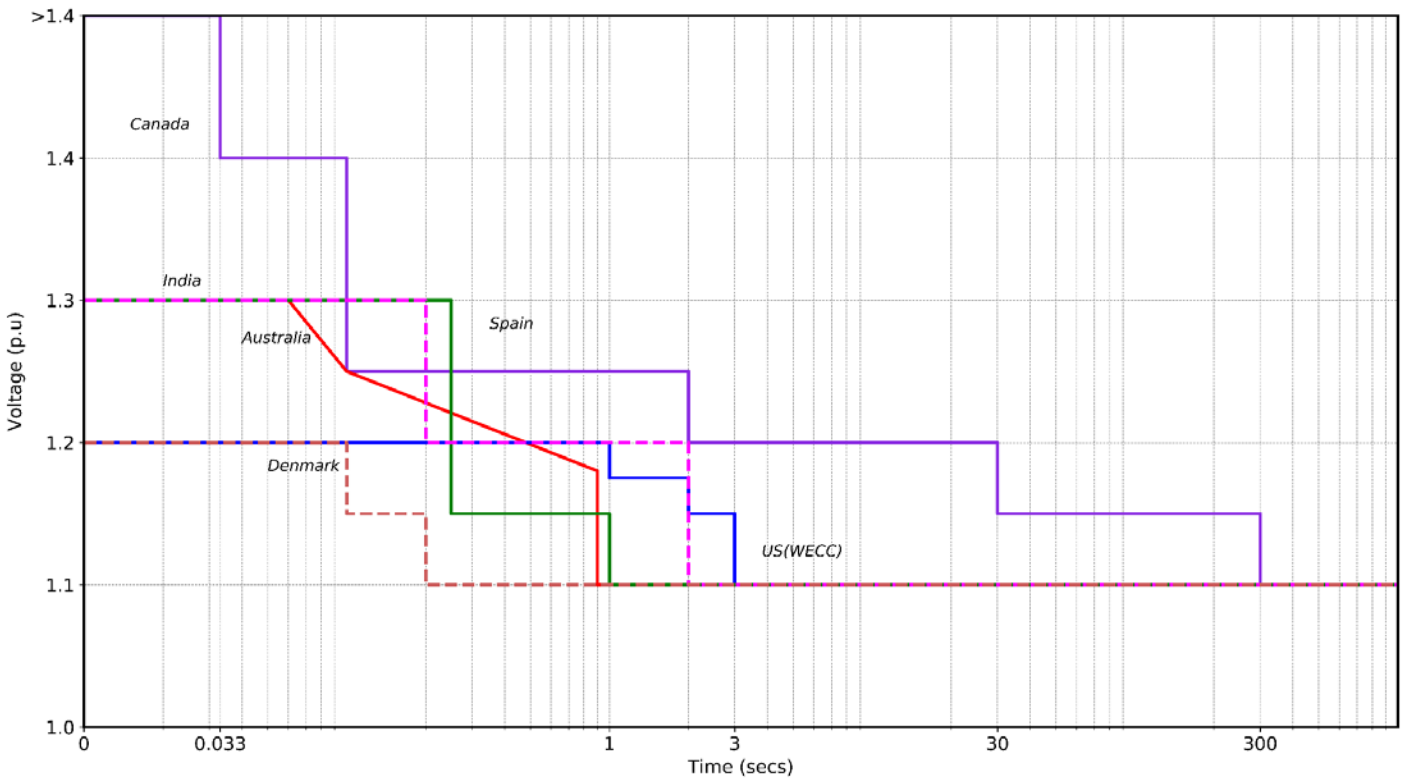


… to support grid security, stability and reliabiliy.

Not to forget to define the technical capabilities according to Indian grid conditions

High Voltage Ride Through (wind, solar, storage)

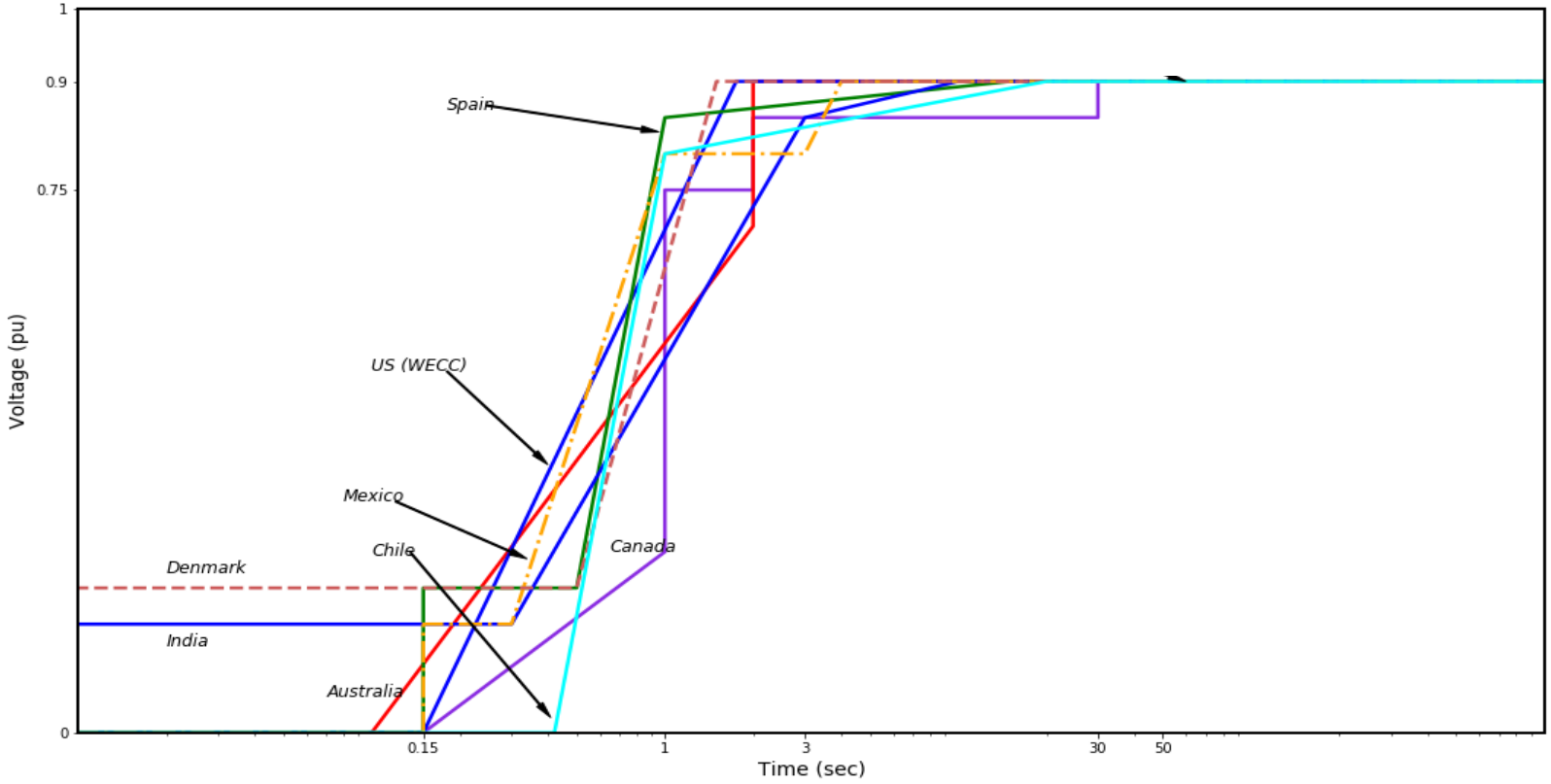
Suggest to limit HVRT upto 120%



- Over voltage should be limited up to 120% at the point of connection as the grid will be further strengthened and regulated
- **Testing of wind farm at point of connection not possible**
- Suggest to define performance during over voltage condition (active power, reactive power, response time)
- **Suggest to issue guidelines to define compliance through simulation before commissioning**
- **Prove compliance with real fault post commissioning and allow fine tuning of parameters**

Low Voltage Ride Through (Wind, Solar, Storage)

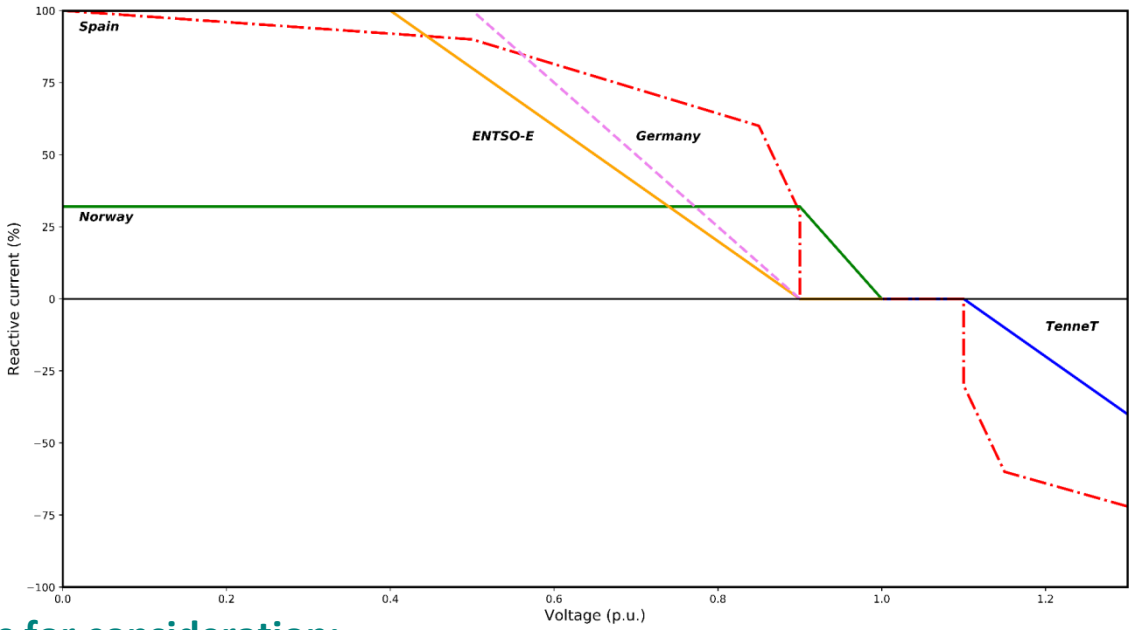
Standard requirement with varied performance



- **LVRT Testing of wind farm at point of connection not possible**
- To be adapted according to voltage level at connection point
- Define performance during low voltage condition (magnitude of active power & reactive power)
- **Compliance through simulation before commissioning of wind farm,**
- **Prove compliance with real fault post commissioning and allow fine tuning of parameters**

Performance during Fault Ride Through

Suggest to define magnitude of reactive current injection/absorption



Suggestions for consideration:

1. **Wind and solar park to operate in inductive power factor mode above 1pu Voltage**
2. **Above 1.1pu Voltage, feed inductive current proportional to voltage rise**

- To support grid voltage stability
- state of art Wind, Solar and storage converters capable to meet these requirements
- **We should define how Wind and Solar generators should behave considering Indian grid protection and operation philosophy and not according to certification agencies**

Consecutive LVRT or HVRT requirement

Suggest to consider indian national grid operational characteristics

Suggestions for consideration in IEGC revision:

- **Ride thorough atleast five consecutive LV or HV events**
- **Time duration between consecutive LVRTs: Minimum five minutes**
- **Tripping shall be allowed if thermal, integrity or safety limits are exceeded**

- Shall be possible for wind, solar and storage to ride through multiple consecutive faults
- Past expereince and data could help establish and refine this requirement
- **No testing possible at interconnection point, but to be proven by simulations**

LVRT test facility

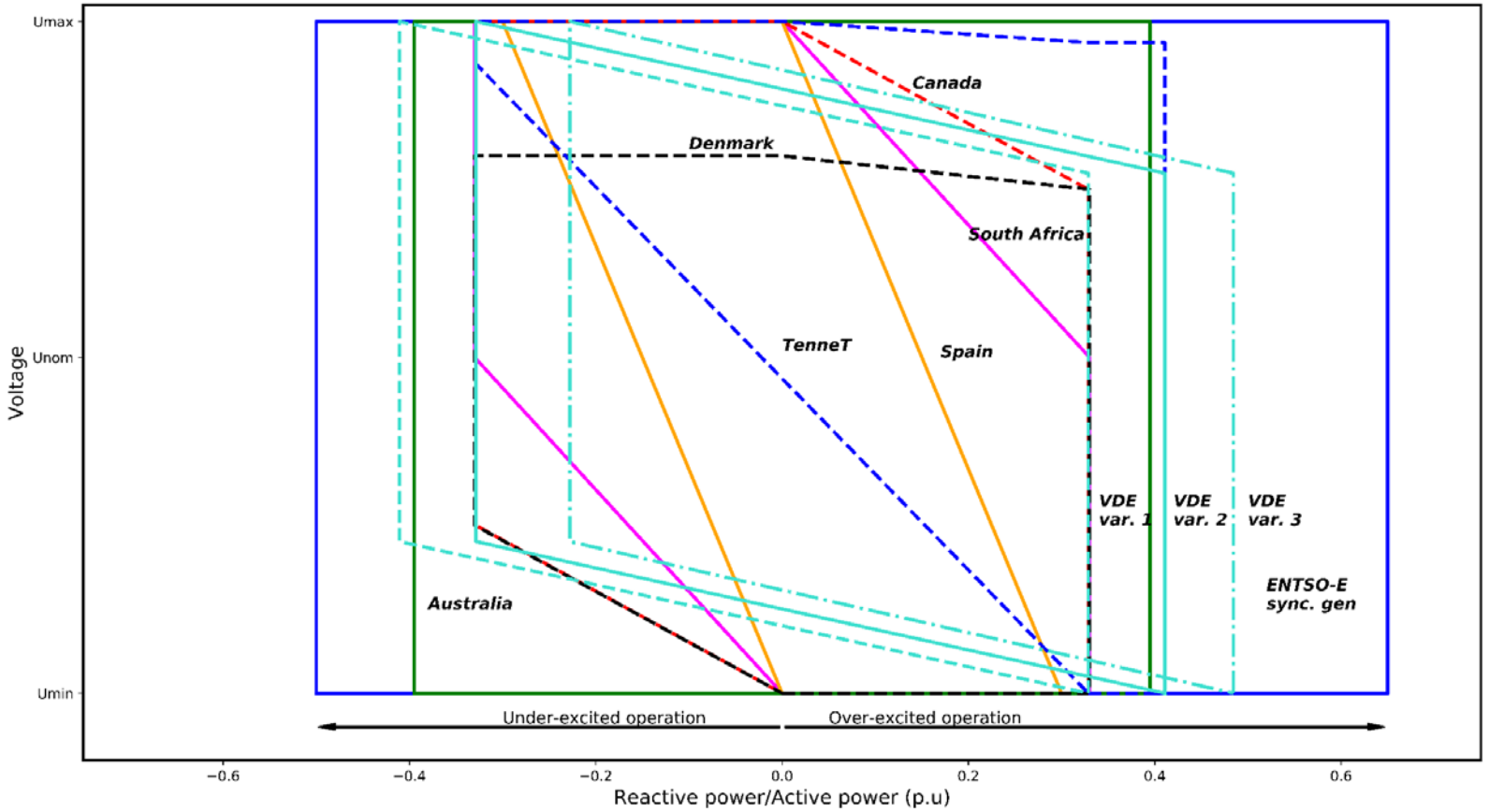
Suzlon mobile LVRT Laboratory at site in India

Suzlon Wind turbines extensively tested at 33KV voltage level, with direct connection to Indian grid

Timeline for testing needs to consider wind season

Reactive power capability requirement

Suggest to be voltage dependent and in +/- 5% range



- **Suggest to define as function of voltage at PCC, SCR at point of connection, size of generating station and grid operating philosophy**
- Reactive capability of wind and solar could be utilised to regulate grid voltage , hence improve stability
- **This regulation feature should be considered as Ancillary Service with suitable commercial settlement mechanism**

1

Grid Frequency Regulation

Worldwide Overview, Frequency response critical to ensure reliable power system operation

Country	Applicability	Droop range	capability	Market driven
ENTSO-E, Europe (36 countries, 46 TSO)	yes	2-12%	yes	Yes, vary country to country, under adoption phase
ERCOT, USA	yes	5%	YES (reserve headroom)	YES
Ontario IESO	yes	2-7%	Yes, additional synthetic inertia	
PJM	yes	5%	yes	
California ISO	yes	5%		yes
National Grid, UK	Yes, conditional	3-5%	Yes, enhanced frequency response	Yes, procured from batteries
AEMO, Australia	yes		yes	yes
Spain	yes	1.5%	yes	yes
Brazil	yes	2-8%	yes	
Singapore	yes	3-5%	yes	yes
Switzerland	yes	2-12%	yes	yes
India	yes	3-6%	yes	in discussion

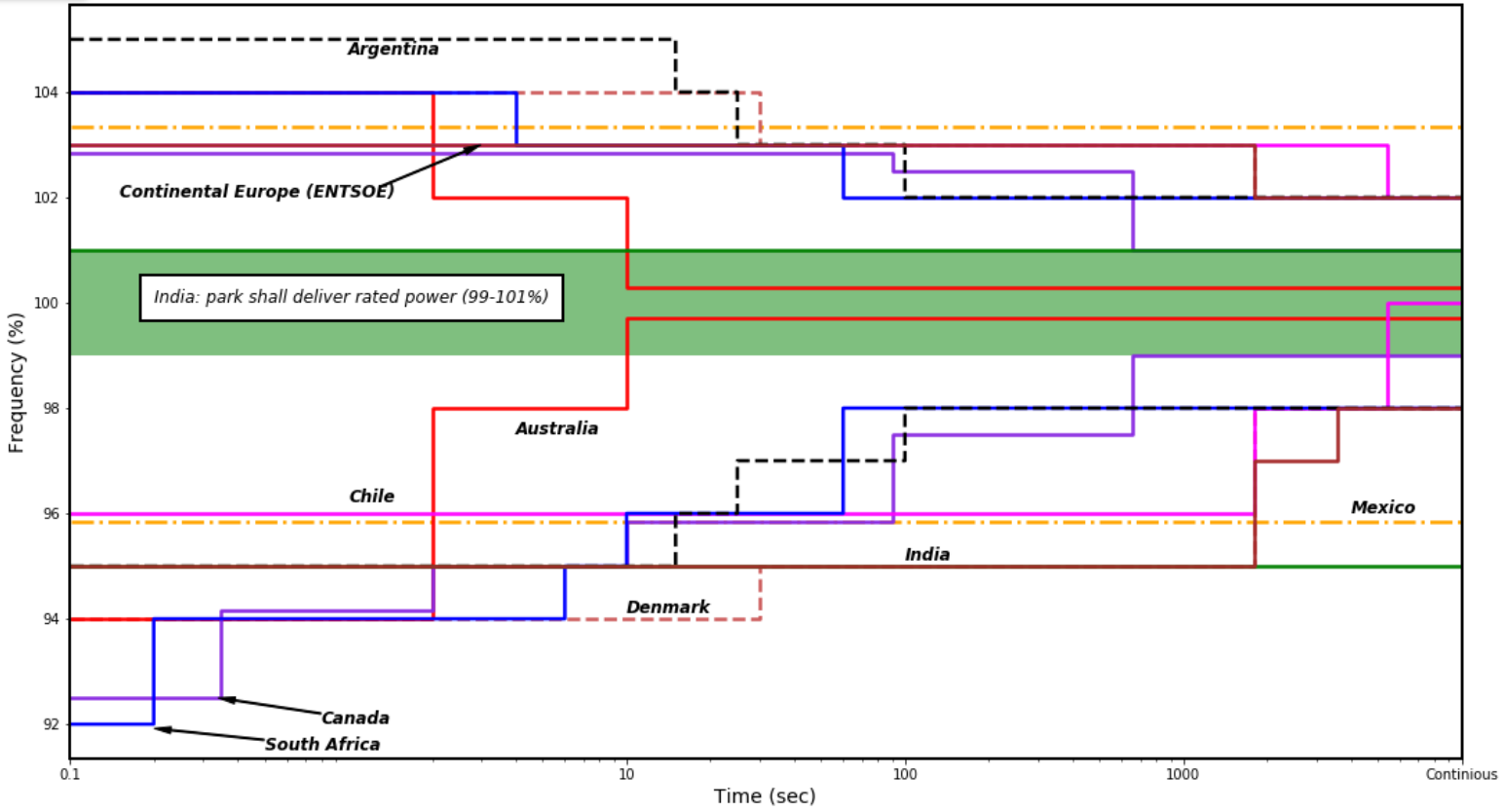
Frequency response and regulation requirements included in grid codes of most countries with different performance parameters with separate commercial settlement mechanism

Grid Frequency Range

Wind and Solar generators can support frequency stabilisation

CEA 2019 Requirement

"(2) The generating unit shall be capable of operating in the frequency range 47.5 to 52 Hz and be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz:



Frequency operating range should be reduced for wind and solar generators to 49.5-50.5Hz considering the actual measured grid frequency and future improvement initiatives.

Grid Frequency Variations

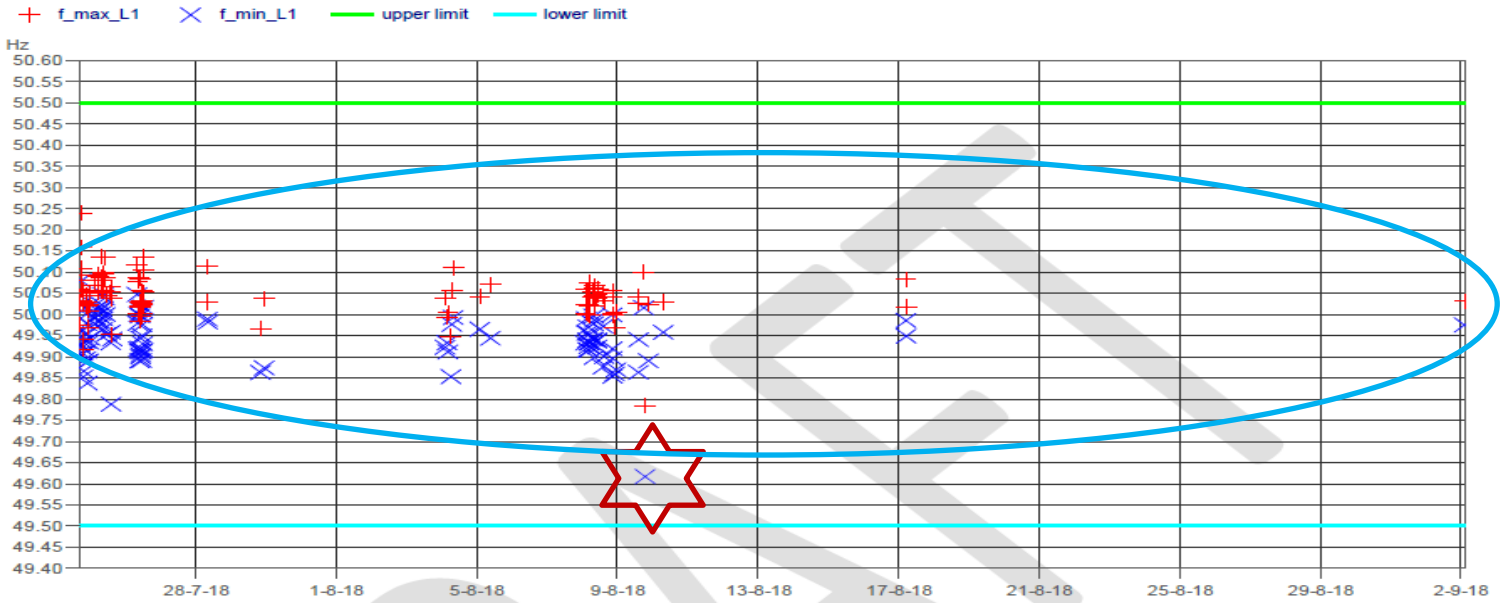
Jamanwada, Gujarat, India (measurement: 13.7 - 02.09.2018)

CEA 2019 Requirement

"(2) The generating unit shall be capable of operating in the frequency range 47.5 to 52 Hz and be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz:

Provided that in the frequency range below 49.90 Hz and above 50.05 Hz, or, as prescribed by the Central Commission, from time to time, it shall be possible to activate the control system to regulate the output of the generating unit as per frequency response requirement as provided in sub-clause (4):

Provided further that the generating unit shall be able to maintain its performance contained in this sub-clause even with voltage variation of up to ± 5% subject to availability of commensurate wind speed in case of wind generating stations and solar insolation in case of solar generating stations.

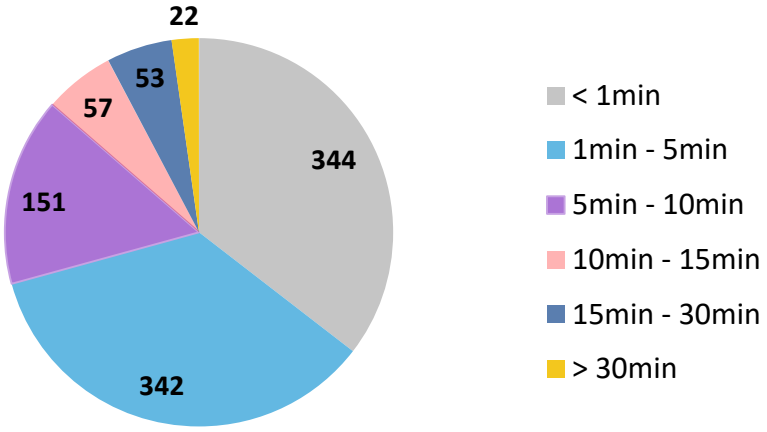


- Grid frequency deviations of several seconds to minutes, could occur at any power production level,
- Require frequent active power increase/decrease
- **The operating range for wind and solar generators should be redefined as 49.5 - 50.5Hz**

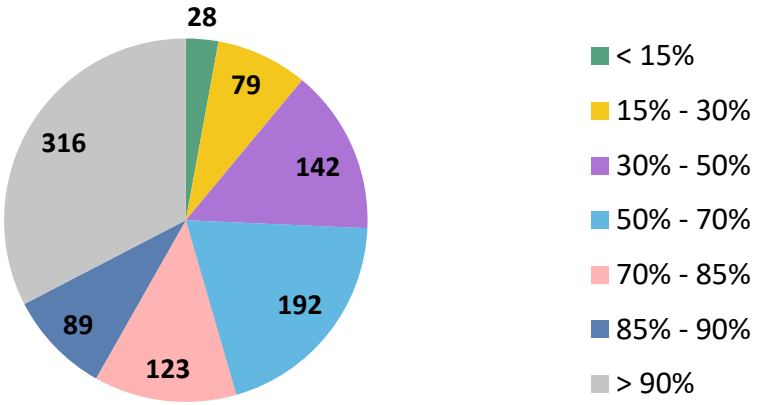
Over/under Grid Frequency Events

Tejuva Wind Farm, India (measurement: 01 - 15.06.2018)

Duration of over/under frequency events: f<49.9 or f>50.05



Active power [in % of Prated] during the events
Rated power: 200 [MW]



Analysis: total 969 under/over frequency events recorded:

- **71.3% over frequency (generation curtailment)**
- **28.7% under frequency (generation increase, requiring headroom)**

- Measurement example show continuous governor action required
- **Is frequency regulation from wind and solar best and economical solution?**

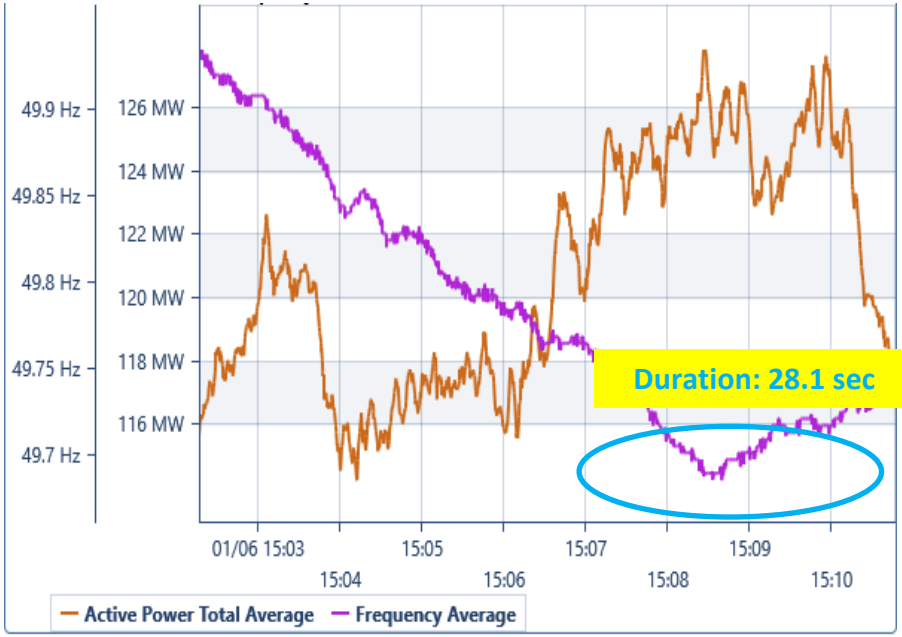
Grid frequency Events less than 49.7Hz

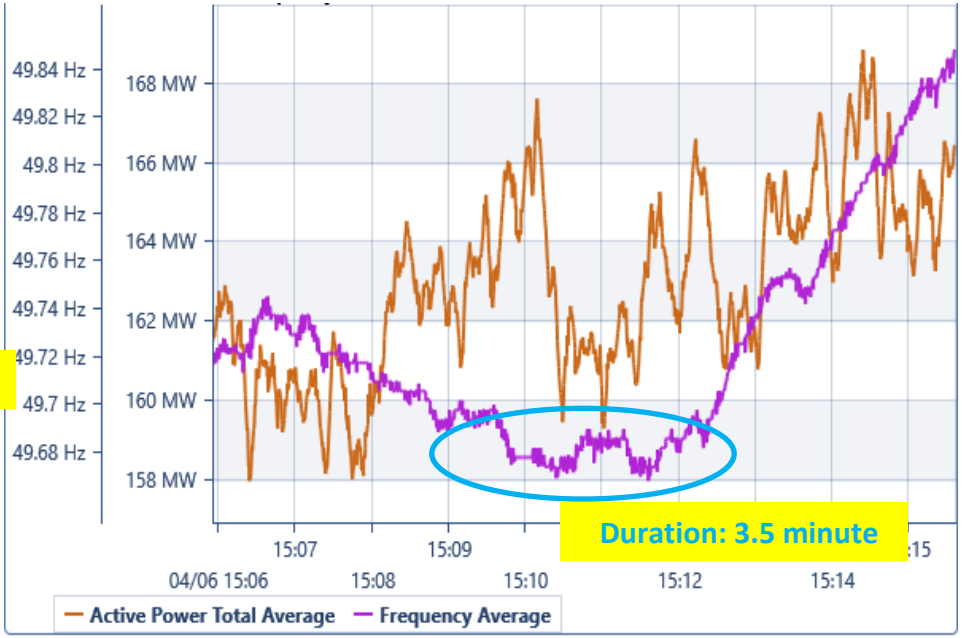
Tejuva Wind Farm, India (measurement: 01 - 15.06.2018.)

CEA 2019 Requirement

(ii) shall have governors or frequency controllers of the units at a droop of 3 to 6% and a dead band not exceeding ±0.03 Hz:

Provided that for frequency deviations in excess of 0.3 Hz, the Generating Station shall have the facility to provide an immediate (within 1 second) real power primary frequency response of at least 10% of the maximum Alternating Current active power capacity;



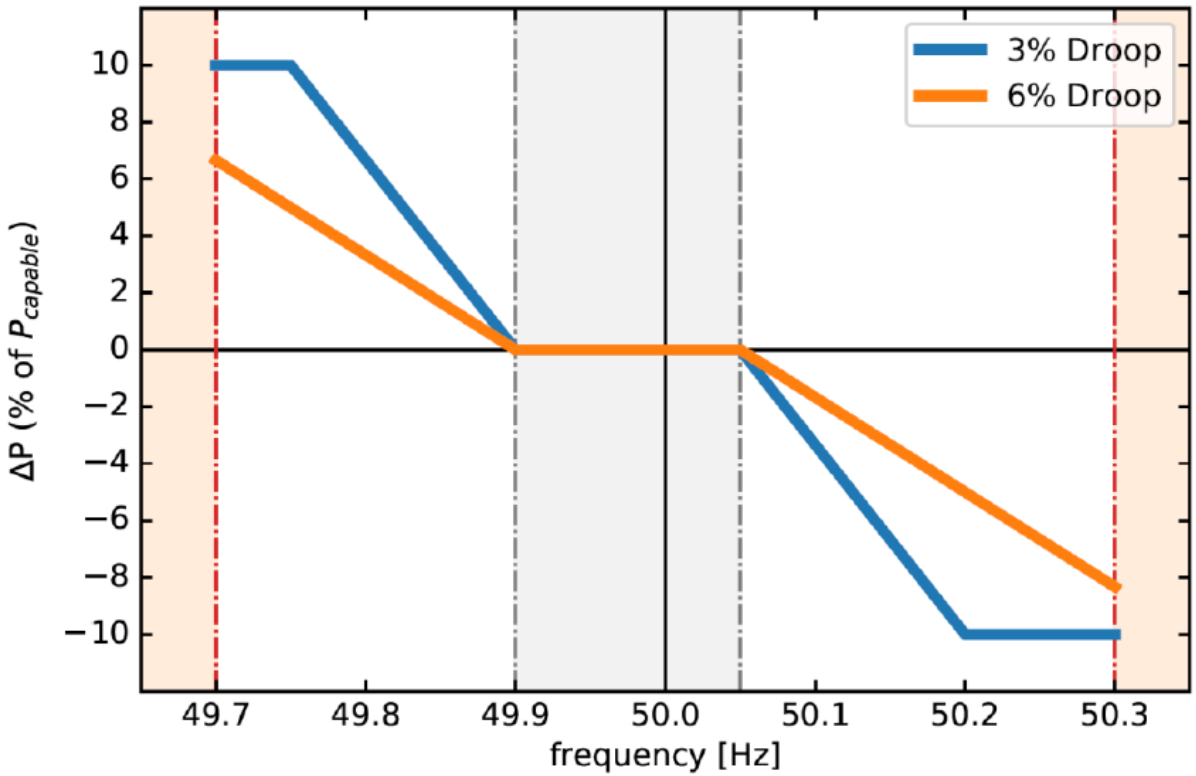


- Frequency deviations >0.3 Hz could range from few second to several minutes
- **Suggest duration of fast frequency response of 5 minutes duration commensurate to wind speed or solar insolation**
- Fast frequency response of various duration (based capability of RE parks) should be considered as separate Ancillary Service and suitable commercial mechanism to compensate for this service to be provided

Grid Frequency Regulation as Ancillary Service

Under frequency and primary response

Example: Droop implementation (wind farm, CEA 2019)

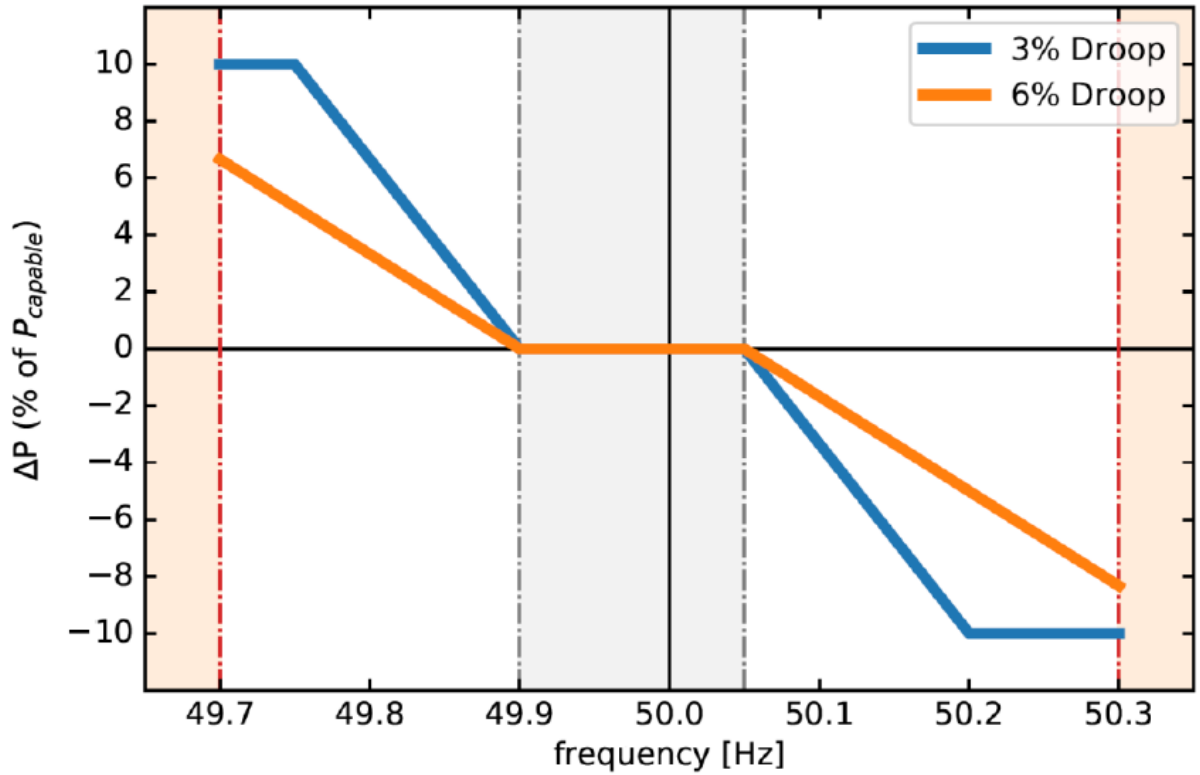


- Under frequency response from wind, solar, storage technically possible with the provision of Headroom, there is no test procedure in IEC standard
- **This should not be mandatory requirement for wind and solar parks**
- The under frequency response should be considered as Ancillary service and suitable commercial settlement mechanism to be provided
- Should be applicable at PCC and not at generating unit
- **Regulation range should be 50-100%, for wind /solar park of size more than 50MW**

Grid Frequency Regulation as Ancillary Service

Over Frequency Response

Example: Droop implementation (wind farm, CEA 2019),



- Over frequency response from wind and solar technically possible
- **Should not be used for normal frequency regulation, but only in case of contingency**
- A detailed technical description with accuracy, response, curve should be provided to have uniform regulation characteristics
- **Should be applicable at PCC and not at generating unit**

Synthetic Inertia as Ancillary Service

Suggested to incoprrpare if RE penetration expected to be very significant

- The medium to large sized RE plants should provide frequency stability capability through synthetic inertia/fast frequency response during very fast grid frequency deviations.
- This feature could help to arrest rate of change of frequency.
- **The applicability of this technical capability and performance parameters should be specified considering real benefits and associated costs by SLDC, the grid operator should make contract with plant owner to deliver this ancillary service**.

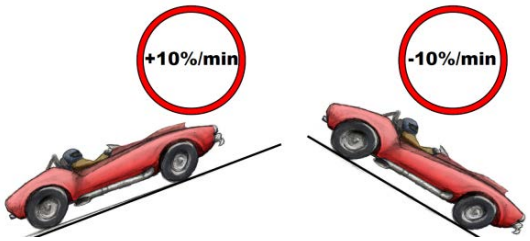
:

Power Ramp up/down rate control

Requirement for wind, solar generators

CEA 2019 Requirement

(iv) shall be equipped with the facility for controlling the rate of change of power output at a rate not more than ± 10% per minute.

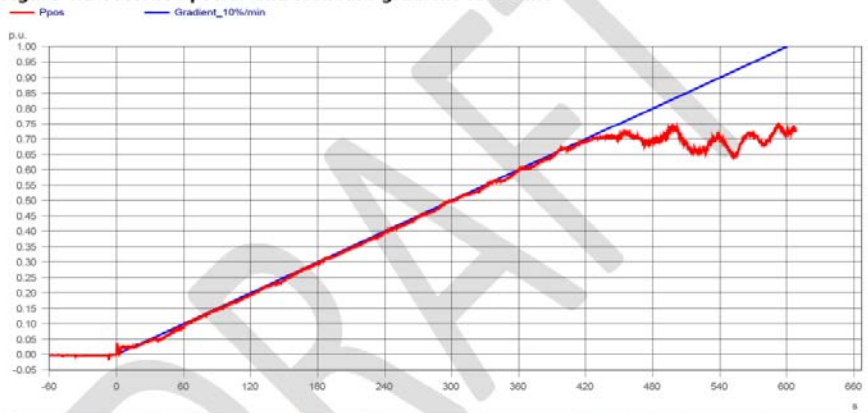


Example: power ramp up test as per IEC standard

Table 4.1-5: Evaluation of active power gradient after loss of grid

Mean gradient in % of P_n per minute	Maximum gradient in % P_n per minute
7.01	10.04

Figure 4.1-7: Active power and standard gradient over time



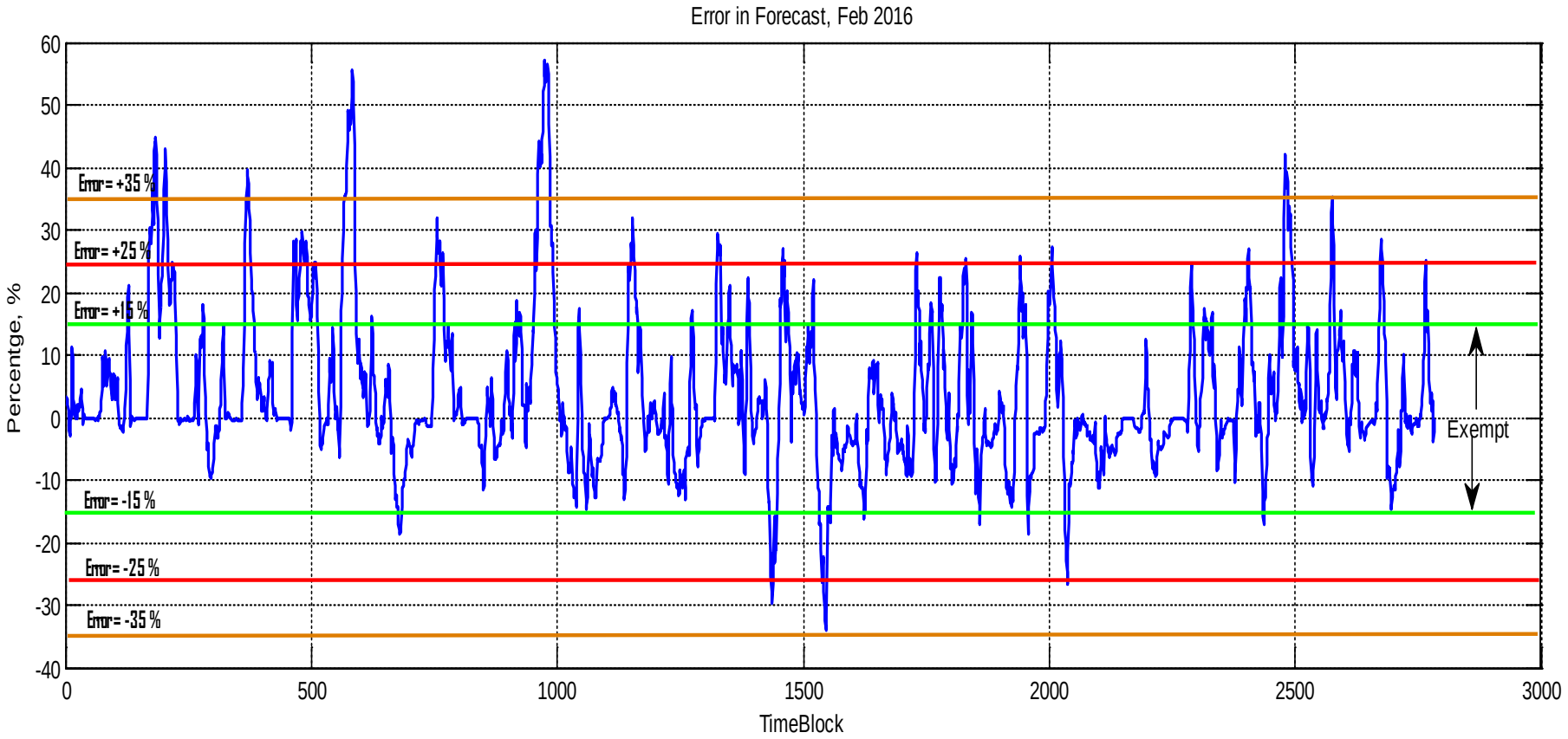
Re-connection time in s	0.00	End time of analysis in s	606.91	Average gradient in %/min	7.01
Start mean time before re-connected in s	60	Active Power at end in kW	1659.50	Max. gradient in %/min	10.04

- **Controlled ramp up/down possible only under stable operating conditions**
- Grid code to consider variability of primary energy source and accordingly define requirements, test procedures and compliance guidelines
- **The ramp rate control facility would cause revenue loss to generating company but benefit grid and hence should be suitably compensated**
- **Should be considered as Ancillary Service**

Power Generation Forecast

Not accurate at individual park level

Ex.: Wind farm in Madhya Pradesh, 2016



- It is a challenge to accurately forecast power generation at park or pooling substation with current technology
- However, forecast accuracy can be significanlty improved if done at state or regional level

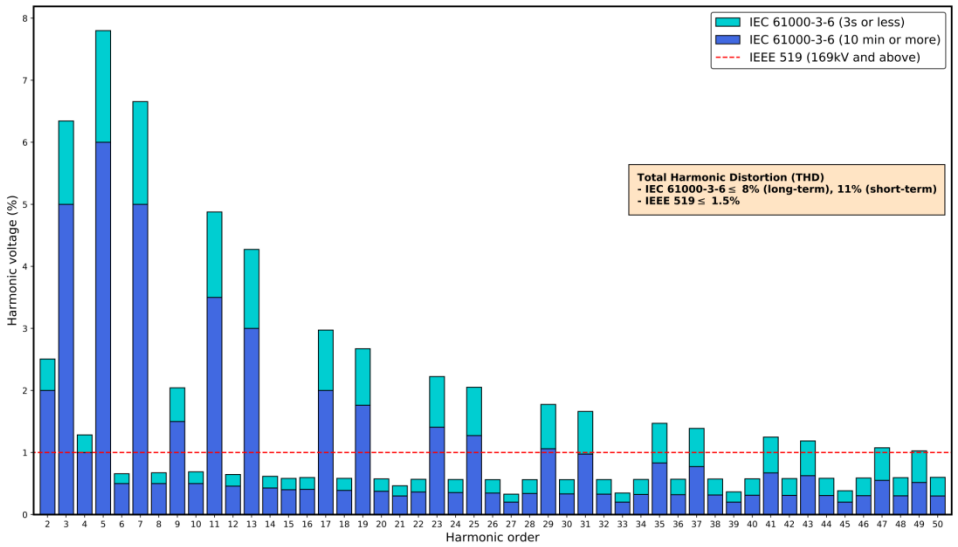
Harmonic current from RE Generating Station

Suggest IEGC to define limits at generating station level

CEA 2019 Requirement

(1) Harmonic current injections from a generating station shall not exceed the limits specified in Institute of Electrical and Electronics Engineers (IEEE) Standard 519.

(2) The Generating station shall not inject DC current greater than 0.5 % of the full rated output at the interconnection point.



- Harmonic emission limits should be defined based on PCC strength, size of park, voltage level
- The harmonic emission evaluation method and acceptance criterion should be defined either using IEC or CIGRE or any other defined method

Energy Storage Integration with Wind & Solar Stations

Suggest to define more detailed technical requirement for grid integration

The electrical energy storage could be integrated with wind and solar plants to further enhance grid security, reliability and stability by providing one or more of the following functions:

1. **Energy shifting**
2. **Fast frequency response**
3. **Spinning reserve support**
4. **Frequency regulation support**
5. **Ramp rate control support**

- All above should be considered as Ancillary service
- Separate technical connectivity and operating requirements should be defined
- A suitable commercial settlement mechanism for using services during charging and discharging should be defined

Black Start as Ancillary Service

Suggest to define more detailed technical requirement for grid integration

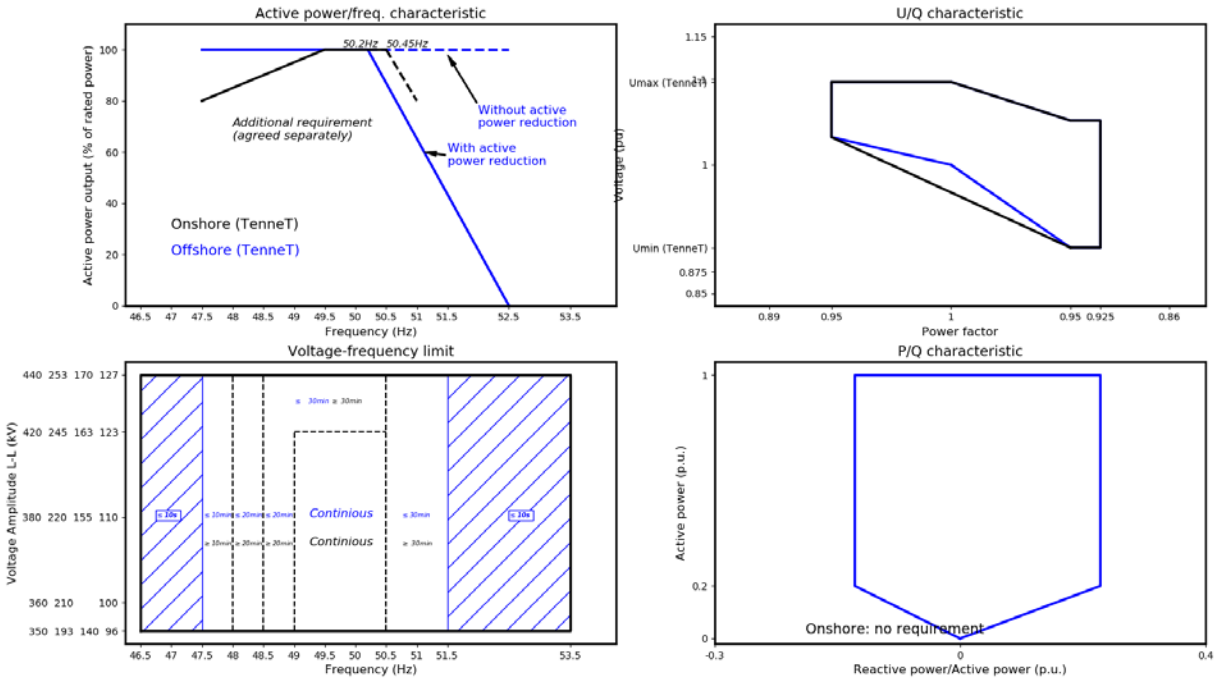
- **RE plants with black start capability should be capable of starting from shutdown without any external electrical energy supply within a specified time frame**
- **black start capability should not be mandatory, and to be considered if RE penetration is expected to exceed at least 60-70% of**
- **The RE owners should present techno commercial offer, based on its capability, for providing black start capability.**
- **The grid operator or SLDC could procure this capability/service if there is system security risk due to inadequate black start capability or due to superiority of technical capability.**
- **The technical requirements should be defined such that black start could work within defined grid voltage and frequency limits.**

Technology under development

Technical Capabilities for Offshore Windfarms

Suggest to define detailed technical requirements for grid integration

- In view of government vision to set up large offshore windfarms, **It is suggested that regulation regarding frequency stability, voltage stability, fault ride through capability, restoration capability etc should be laid down considering technology of ac connection, size of plants, pooling station location.**



Suggestions for Consideration

- Mechanism to update grid code/connectivity standard quickly based on field learnings (Eg. Australia black out)
- *Test specifications and compliance procedures for wind and solar generating stations to be issued by CEA/CERC/NIWE/POSOCO/PGCIL*
- Testing and compliance as per published IEC standard only
- *All technical requirements to be applicable at point of interconnection*
- Detailed explanation/interpretation of requirements and acceptance criterion *to be issued by CEA/CERC/NIWE/POSOCO/PGCIL*
- The technical features such as ramp rate control, frequency regulation, would cause revenue loss to generating company and hence should be considered as ancillary service

Suggestions for Consideration (continue)

- The expected technical performance or capabilities from RE plants should be based on their size, voltage level connection, and considering their effect on the overall power system stability, security and reliability
- The technical capabilities should not be applied for existing RE plants
- Technical requirements for offshore wind farms should be defined separately
- More detailed and clear technical requirements for storage should be defined considering potential large storage application in grid for various applications, and should be considered as Ancillary service

Thank you

for your attention