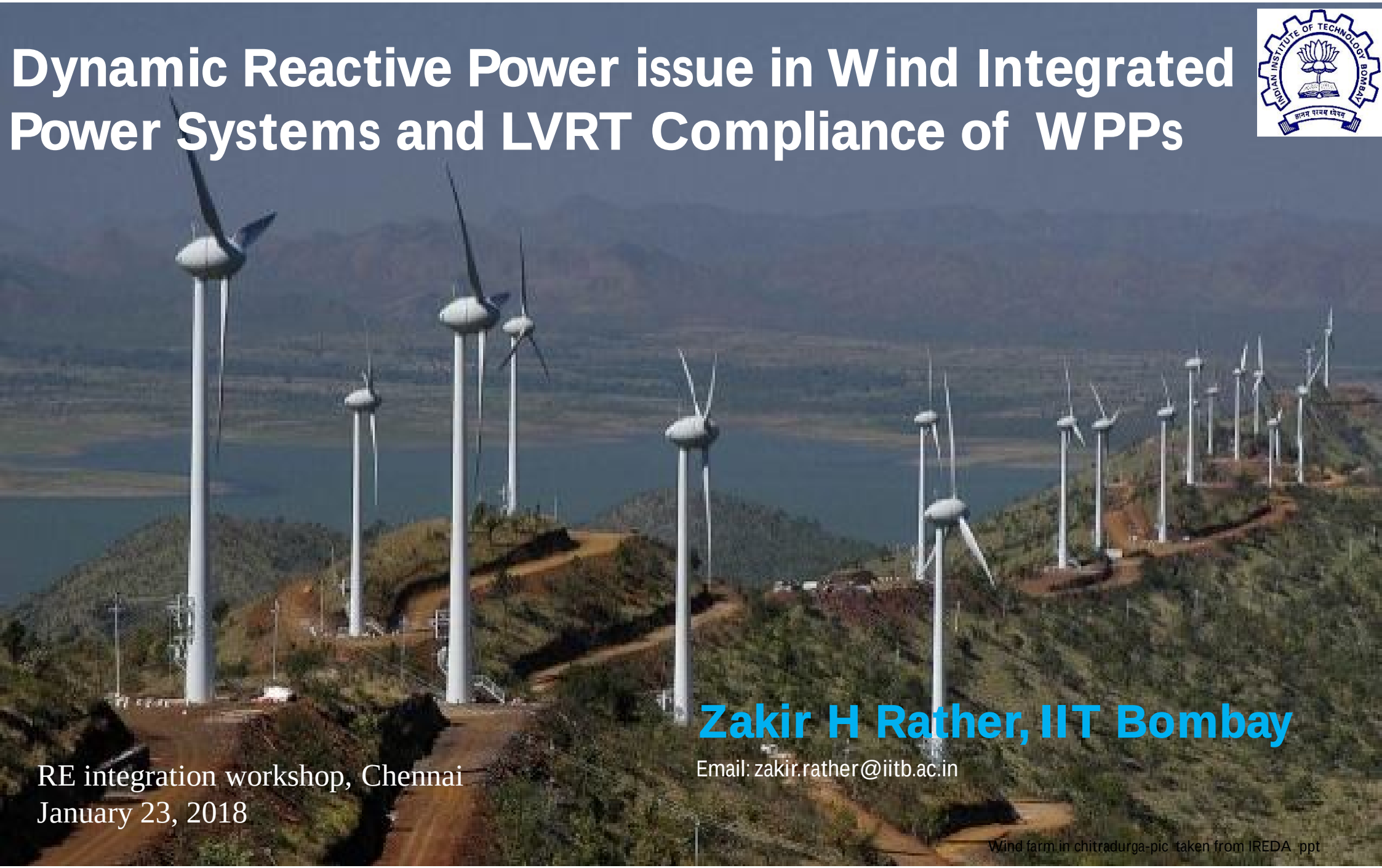
Dynamic Reactive Power issue in Wind Integrated Power Systems and LVRT Compliance of WPPs



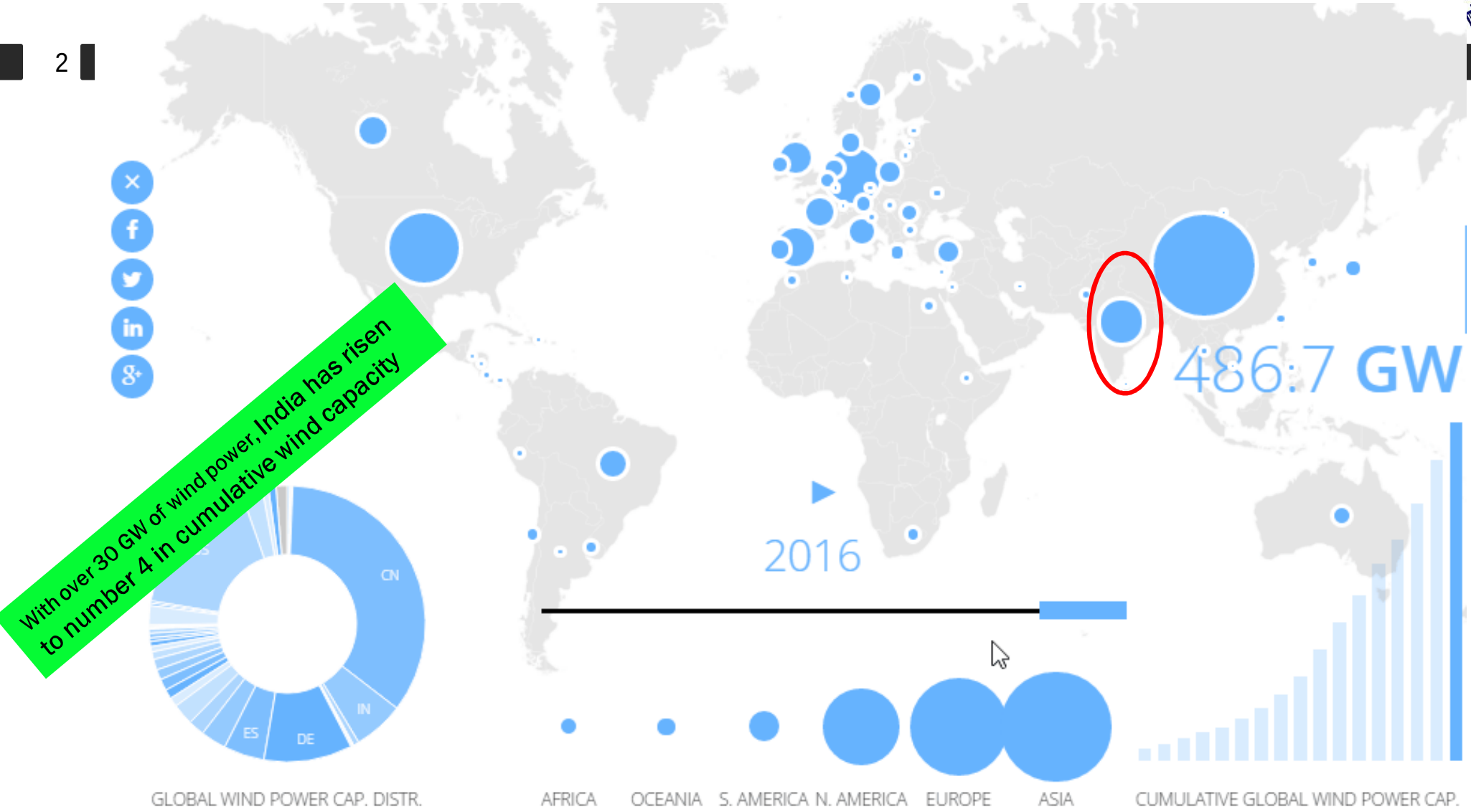
Zakir H Rather, IIT Bombay

Email: zakir.rather@iitb.ac.in

RE integration workshop, Chennai
January 23, 2018

Wind farm in chitradurga-pic taken from IREDA ppt

Journey of wind power at global level



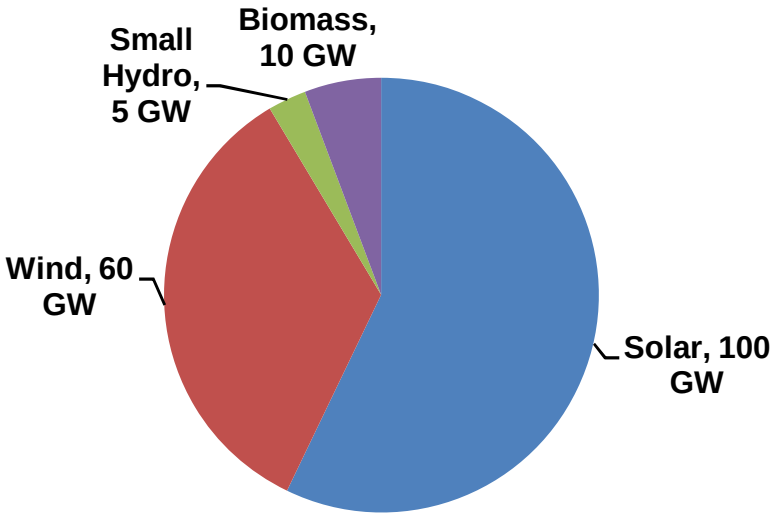
Source: GWEC

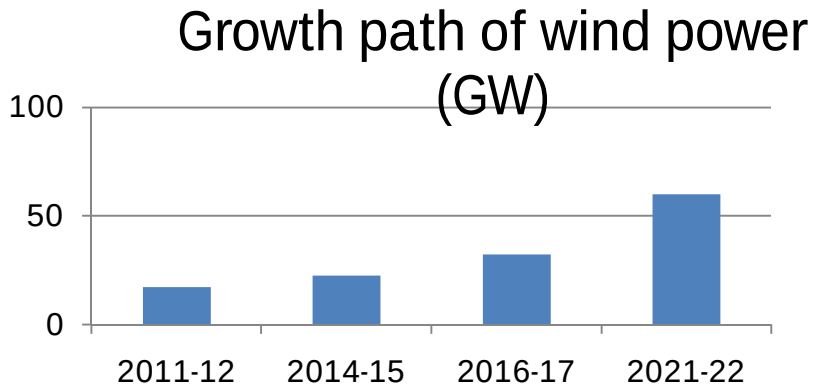
Indian Power System and 2022 RE target

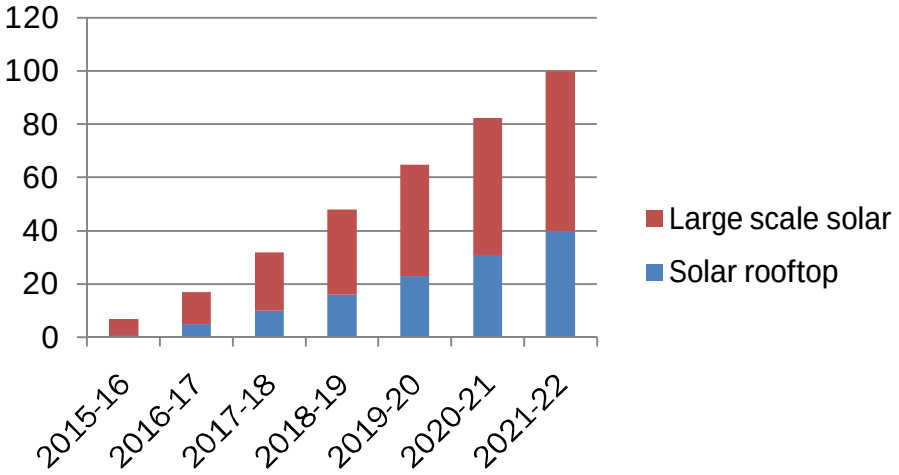
- Installed capacity≈330 GW (1.36 GW in 1947) ; Peak demand ≈ 150 GW
- ≈ 300 million people do not have access to electricity.

RE

- **302 GW at 100 m height**
- **Target by 2022 is 60 GW of wind and 100 GW of solar PV**
- 90% of wind potential is in the Southern and the Western region







Challenges of variable RE (vRE) integration

Technical

- Lack of transmission infrastructure, grid stability, variability of RE sources, weak grid, estimation of effective turbine capacity etc.

Regulatory

- Complexity of subsidy structure and involvement of too many agencies

Industrial barriers

- Lack of investment , skilled manpower

Wind resource data collection

- Wind potential calculation requires proper data of wind speed at site .

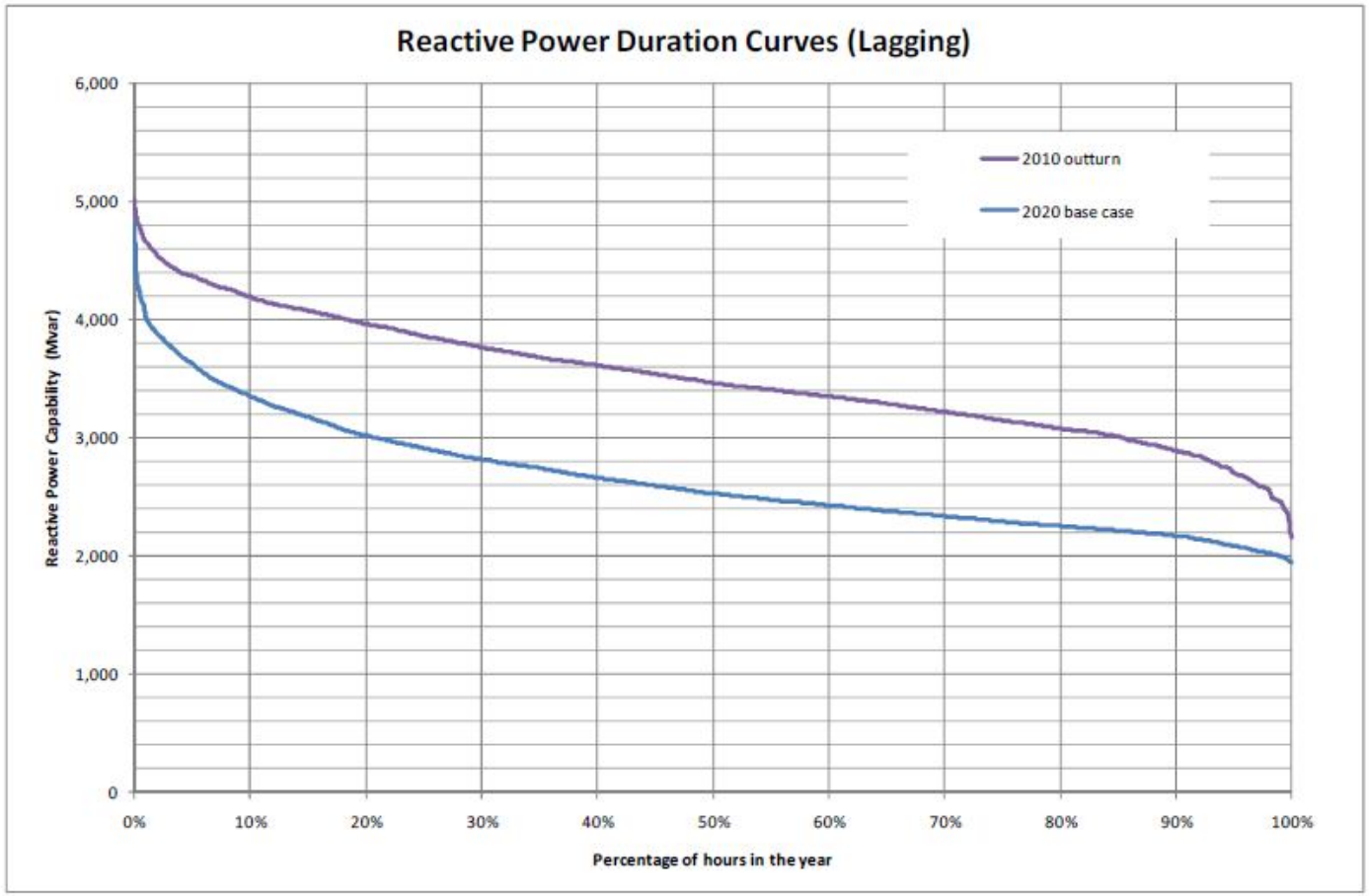
Social and environmental issues

- Noise pollution from wind farm affects the local region.
- Deforestation for carrying wind turbine and blades

vRE integration-Technical issues

- Increased Flexibility requirement (variability issue)
- Wind-driven displacement of conventional synchronous power plant
  - low synchronous inertia and possibly increased operating reserves
  - Diminishing reactive power reserve and short circuit power
- Renewable Energy curtailment
- Emerging issues: Post-fault delayed active power recovery from wind turbine/plant

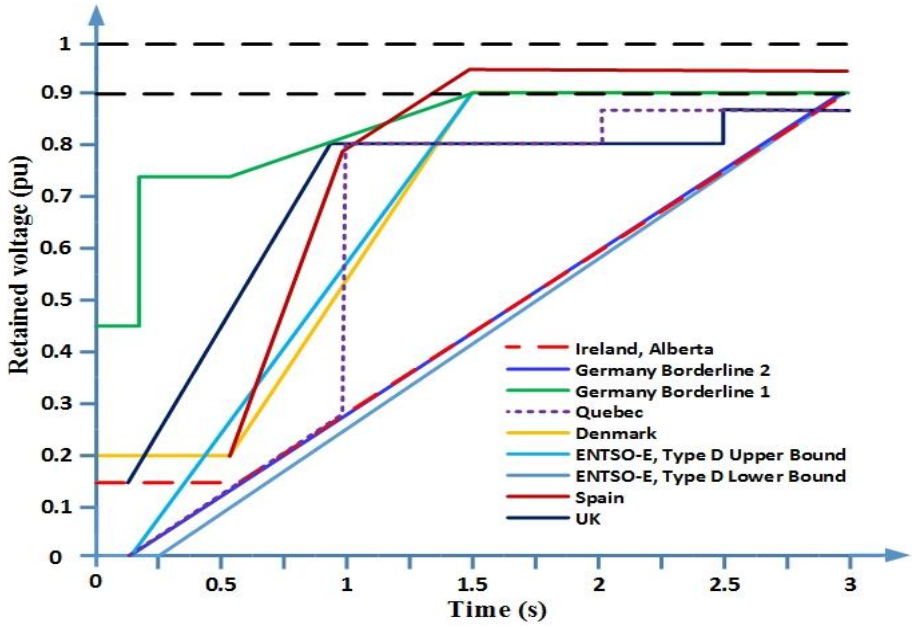
Impact on reactive power capability: Ireland



Evolution of LVRT

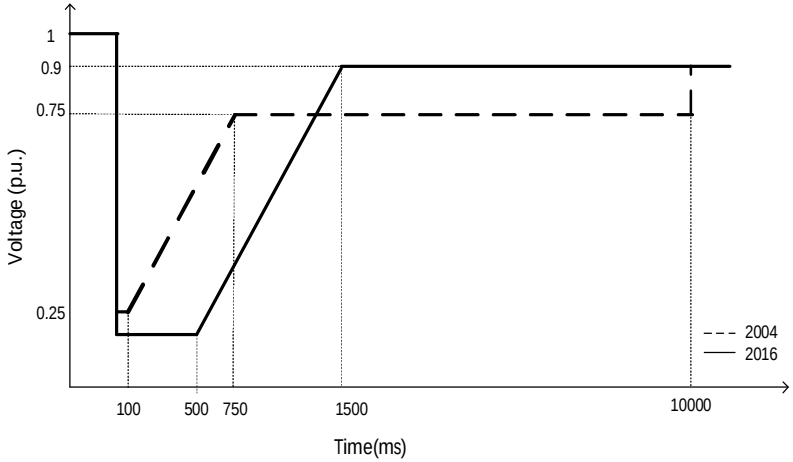
LVRT curve is representative of worst case realistic voltage recovery profile that may occur once a power system recovers from lowest voltage point. Factors affecting LVRT requirements:

- Current and anticipated wind penetration levels
- Strength of grid
- Type of load in the system (predominance of induction motor load leads to poor voltage recovery)
- Islanding of system
- Dynamic voltage support devices in the system and plant reactive power headroom

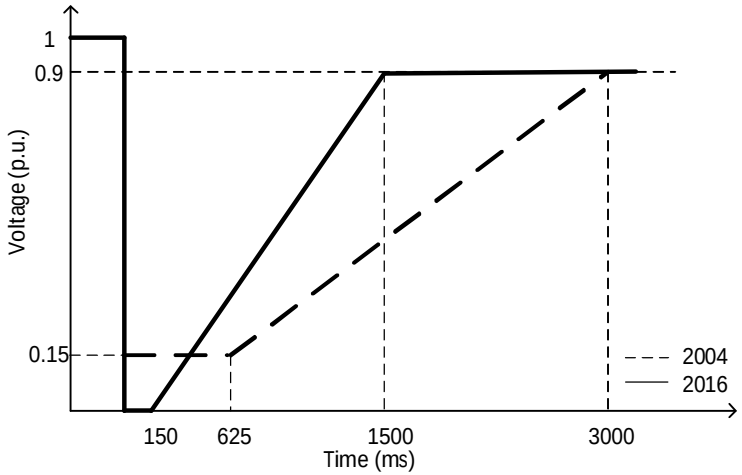


LVRT requirement

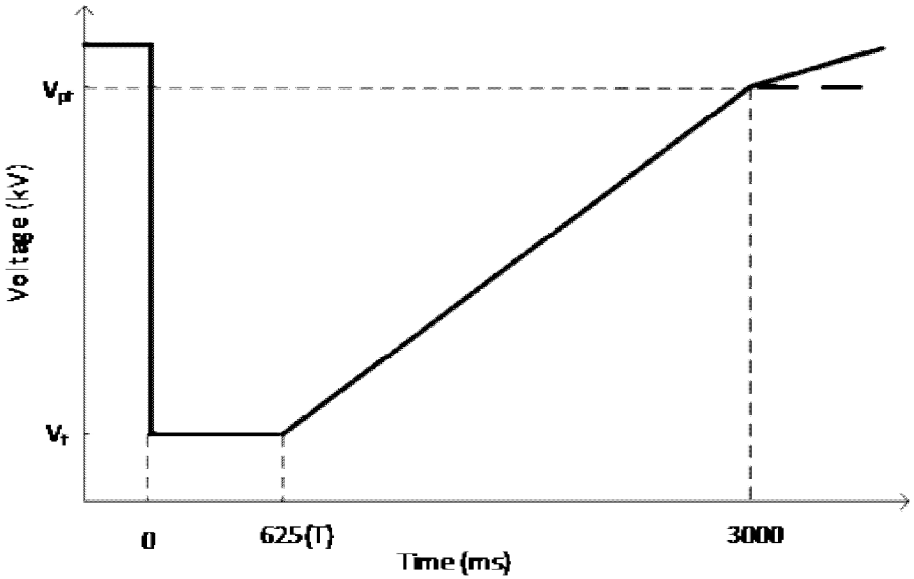
LVRT priority



LVRT curve for Energinet.dk, Denmark



LVRT curve for Tennet TSO, Germany



LVRT curve as per EirGrid and Indian wind grid code

EirGrid: T= 625 ms, Vpf=0.9 pu; Vf= 0.15 pu
IEGC (CERC): T =table below, Vpf= 0.8 pu; Vf= 0.15 pu

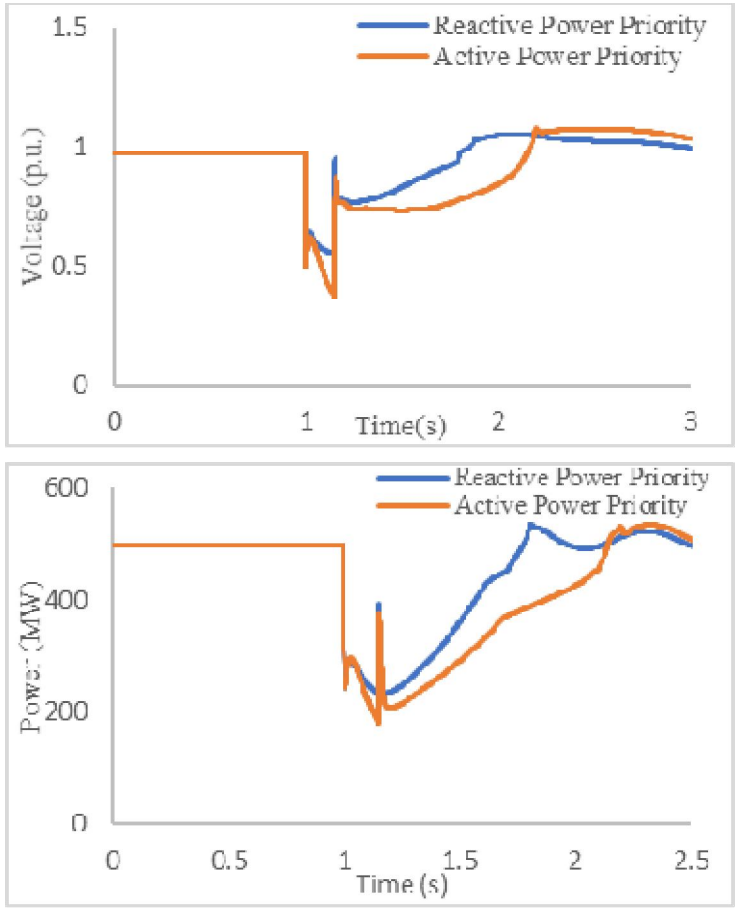
Table: T for various voltage levels in India

Nominal rated voltage (kV)	Fault clearing Time (millisecond)	$V_{post\ fault}$ (kV)	V_{fault} (kV)
400	100	360	60
220	160	200	33
132	160	120	19.8
110	160	96.25	16.5
66	300	60	9.9

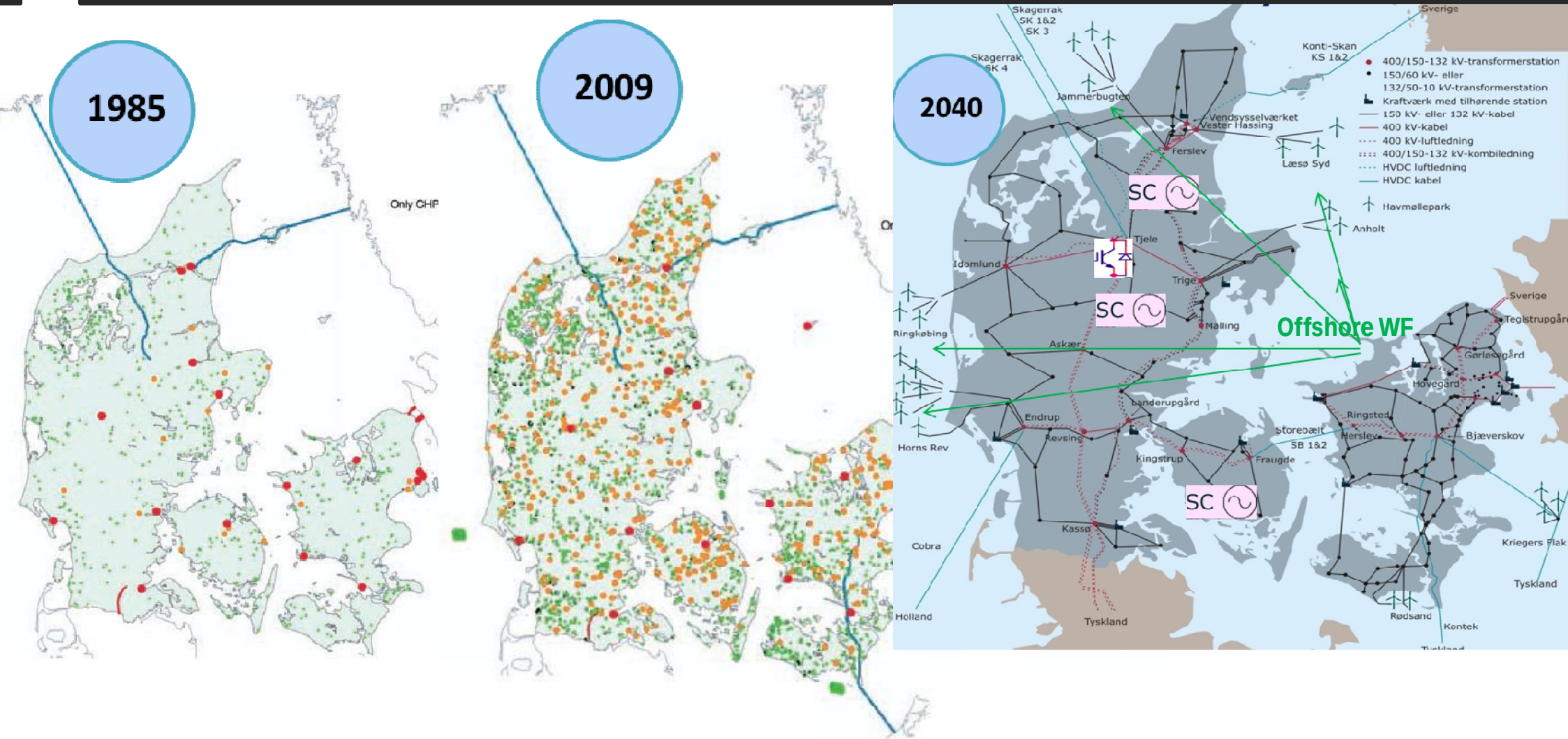
LVRT Issues

- IEC 61400-21/IEC 61400-21-1
  - Field testing?
- What about old WTGs?
- How to ensure WTGs are LVRT compliant after a period of operation?
- How to monitor LVRT compliance?

Which LVRT priority?

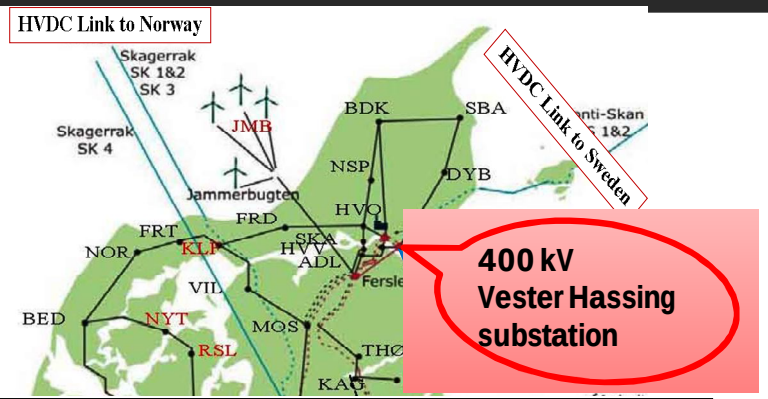


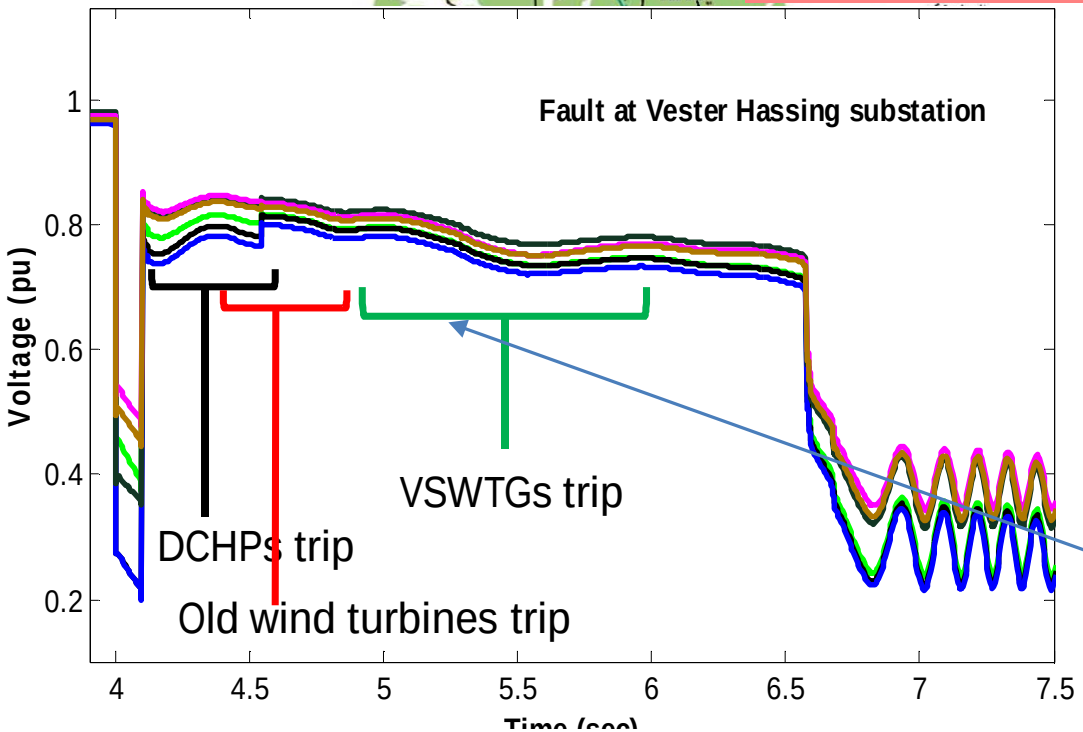
Wind driven displacement of Conventional Power Plants (CPPs)-Danish power system

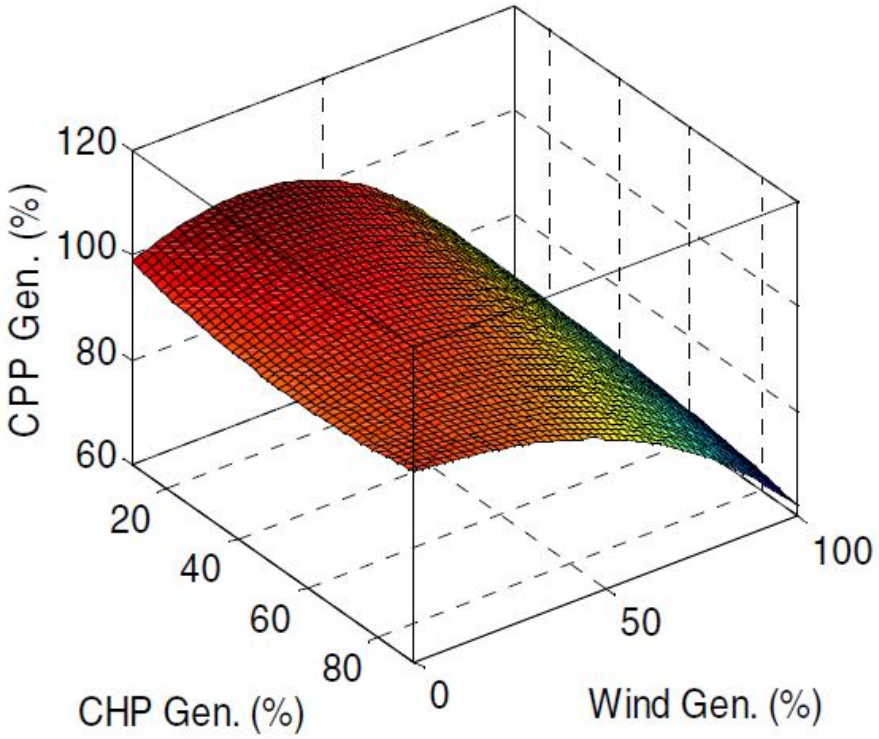


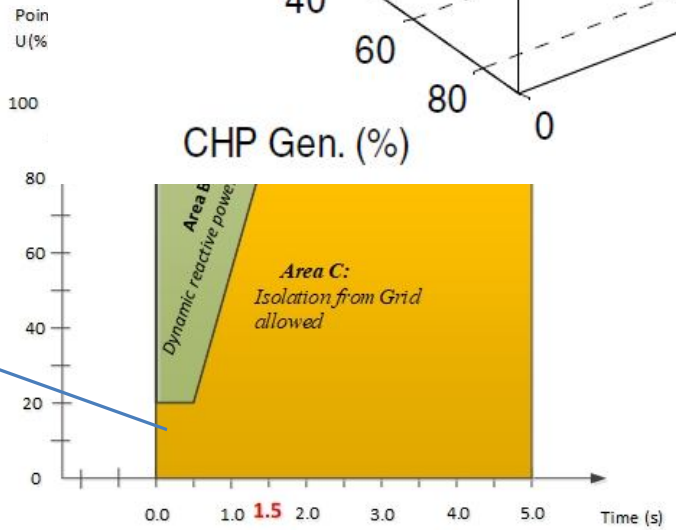
Source: Energinet.dk

Impact on grid security: Danish case study







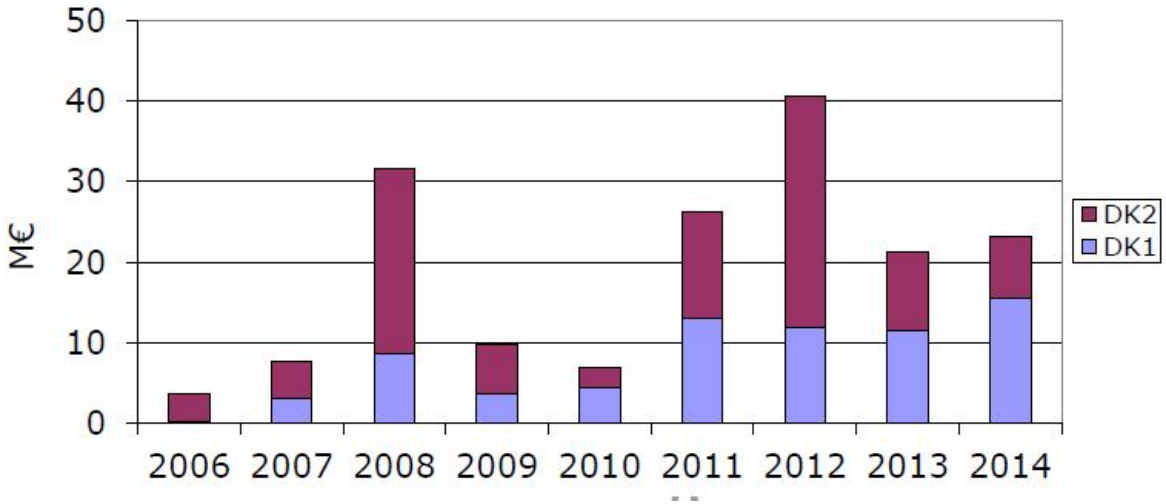


Reactive power support from must run CPPs in the Danish grid

- Short circuit power
- Dynamic voltage control
  - Reactive power consumption by old wind turbines and commutation of HVDC LCC
- Continuous voltage control

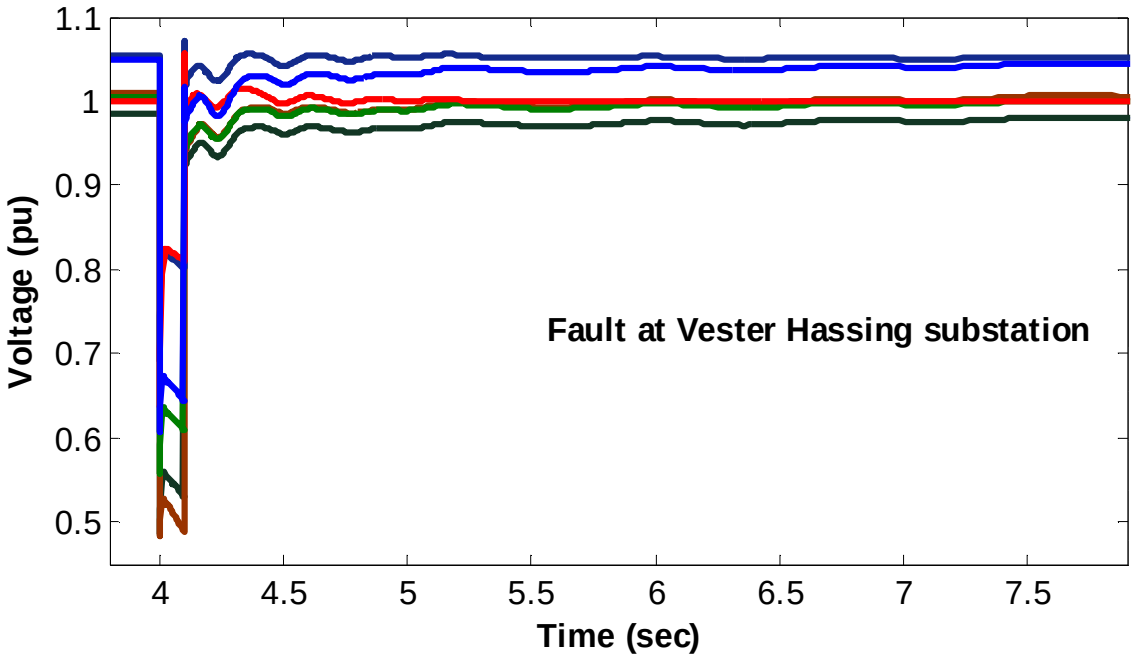
(Active power reserves are bought in separate markets and do not give rise to must-run)

Must-run was costly

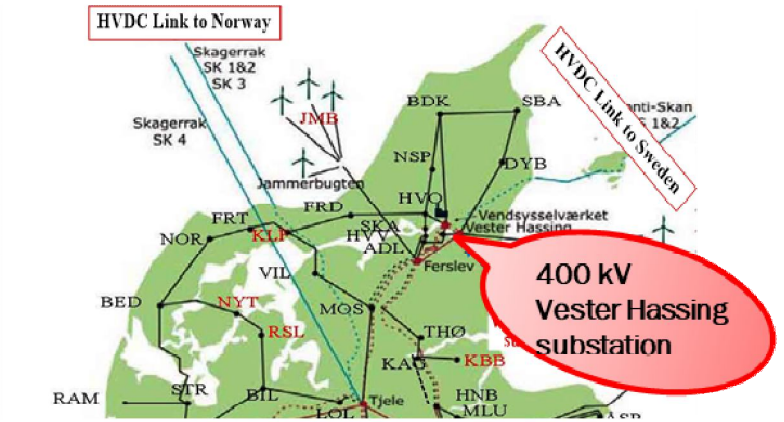


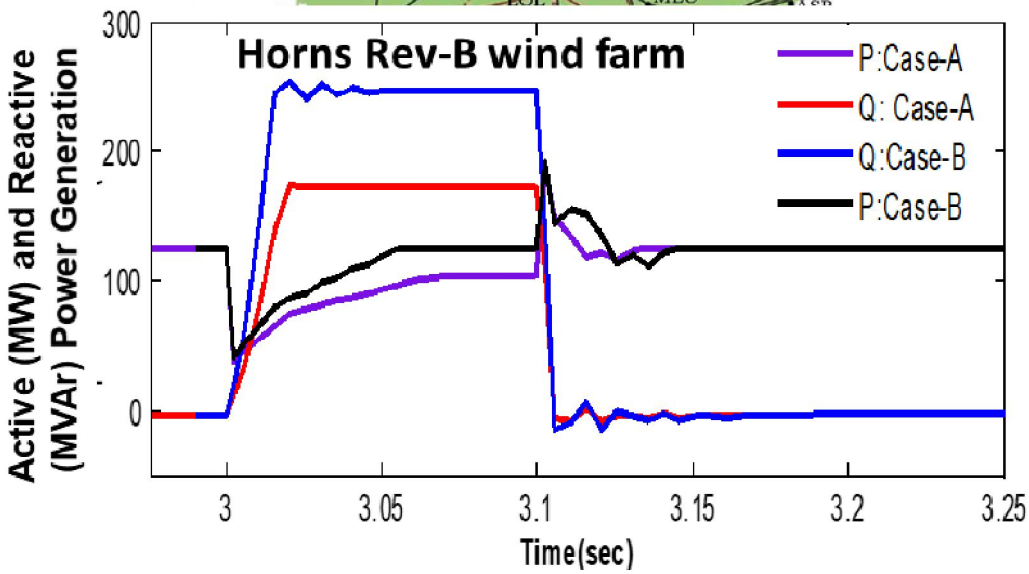
Source: Energinet.dk (Danish TSO)

Voltage stability considering dynamic reactive power compensation in 2030 Danish grid



Rather et al., 2015

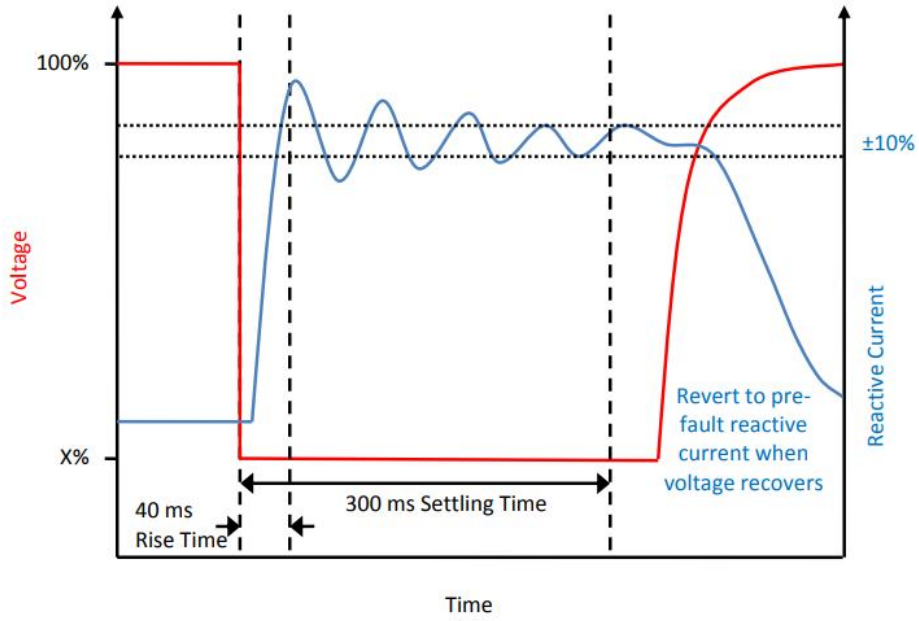




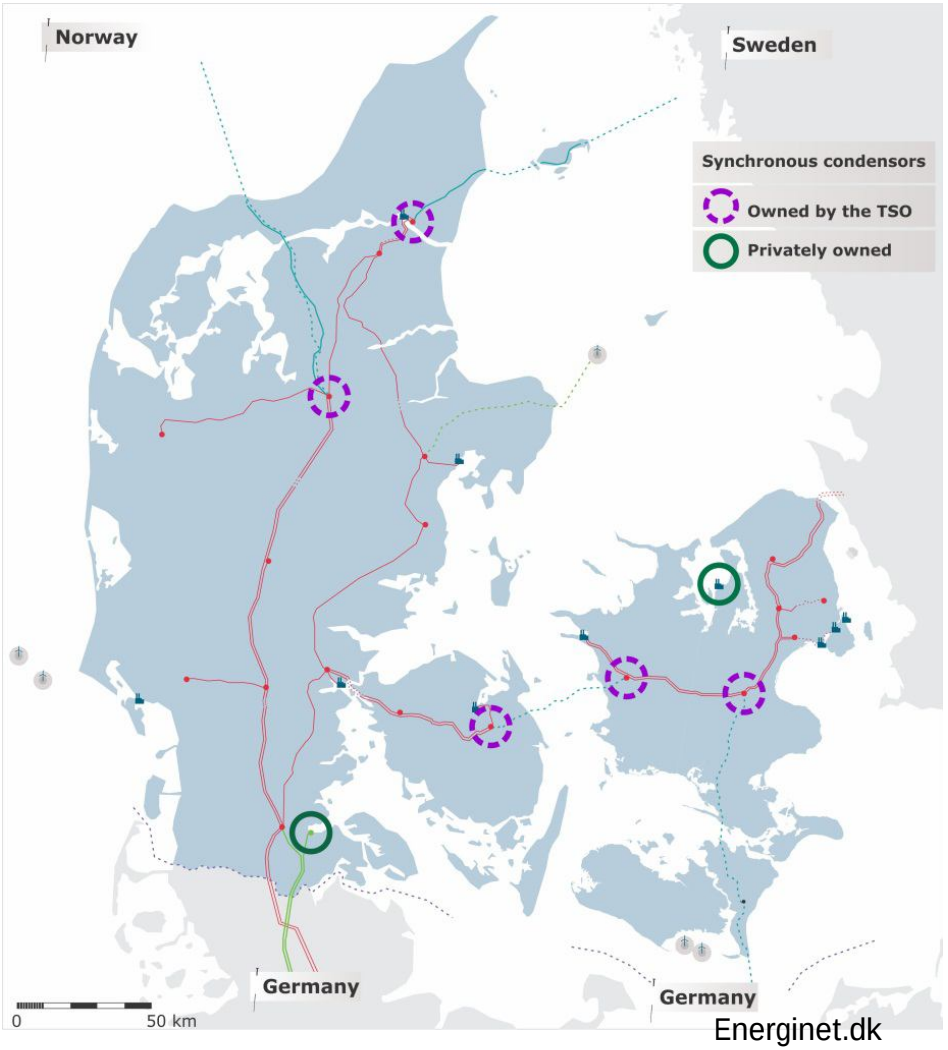
Potential solutions to address lack of dynamic reactive power reserve in RE integrated system

- Infrastructure reinforcement:
  - synchronous condensers,
  - FACTS devices such as SVC, STATCOM, TSSC

Procurement of dynamic reactive power through ancillary service market

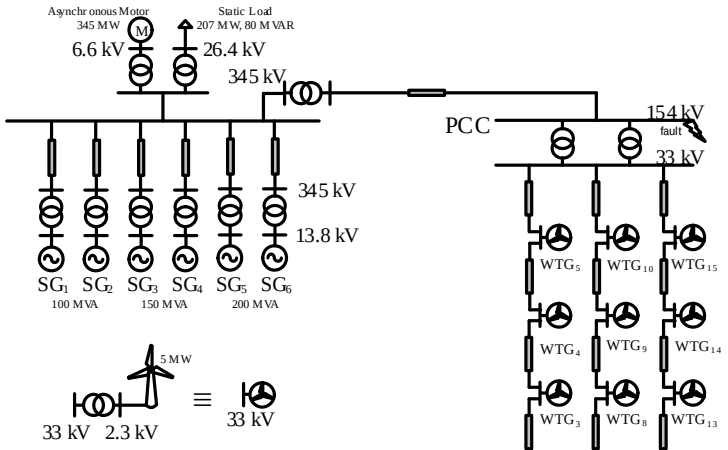


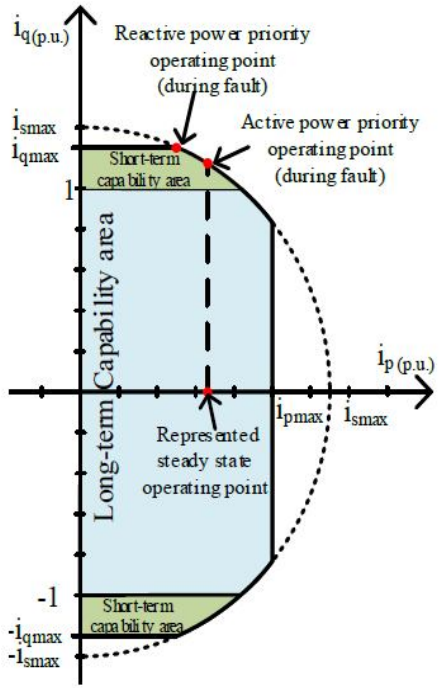
EIRGRID semo SONI

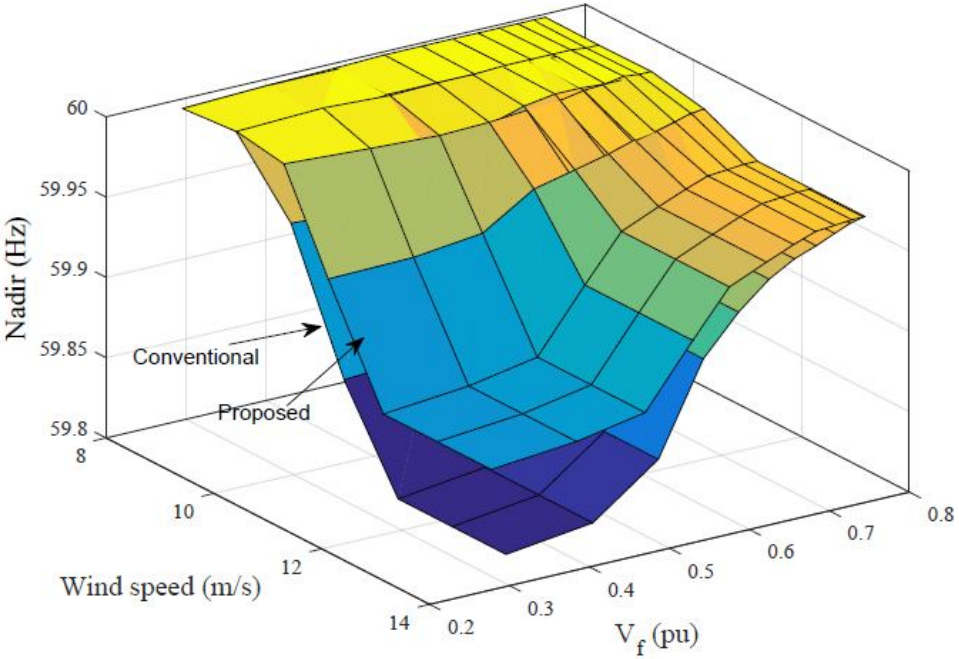


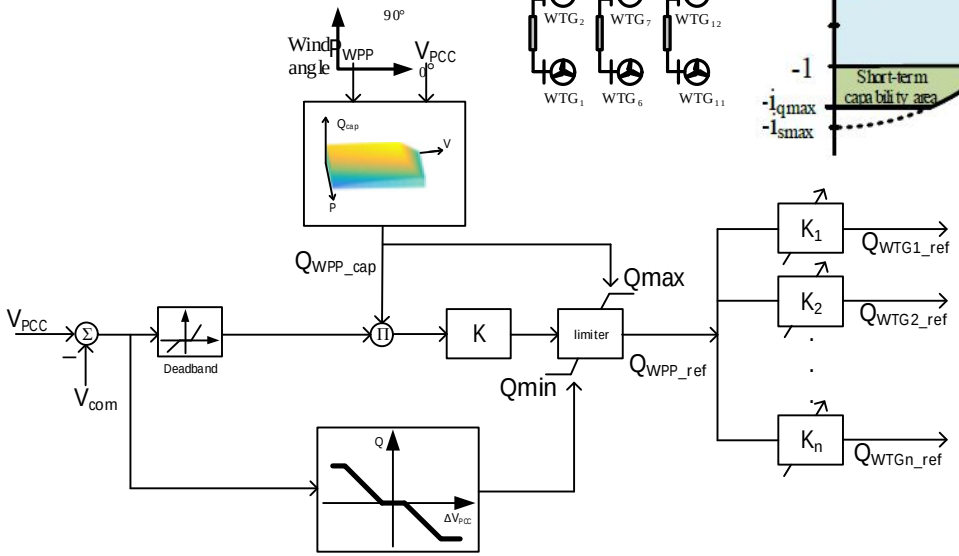
Energinet.dk

Operating WPP beyond grid code requirement

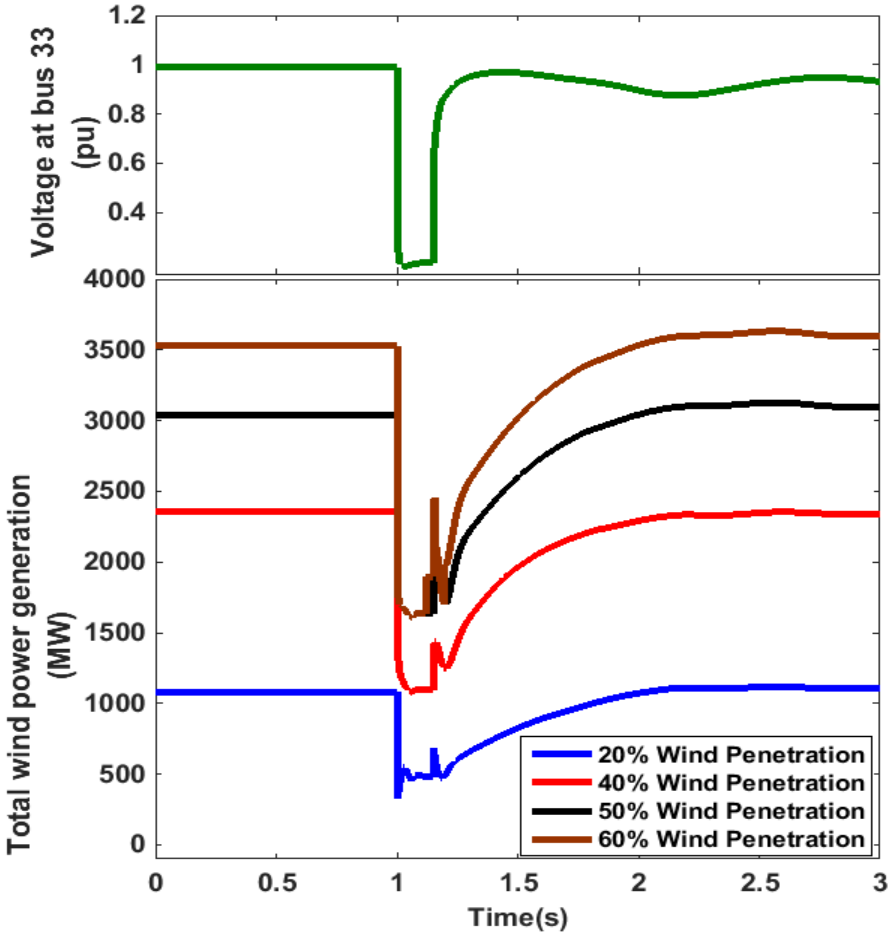




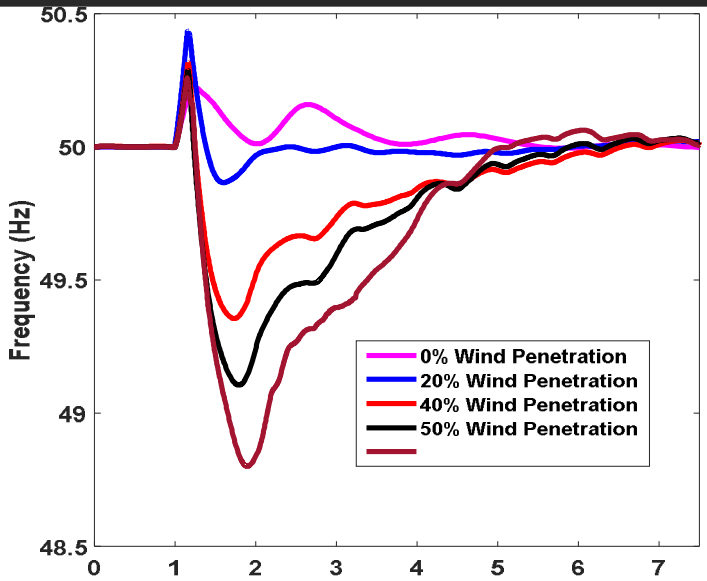


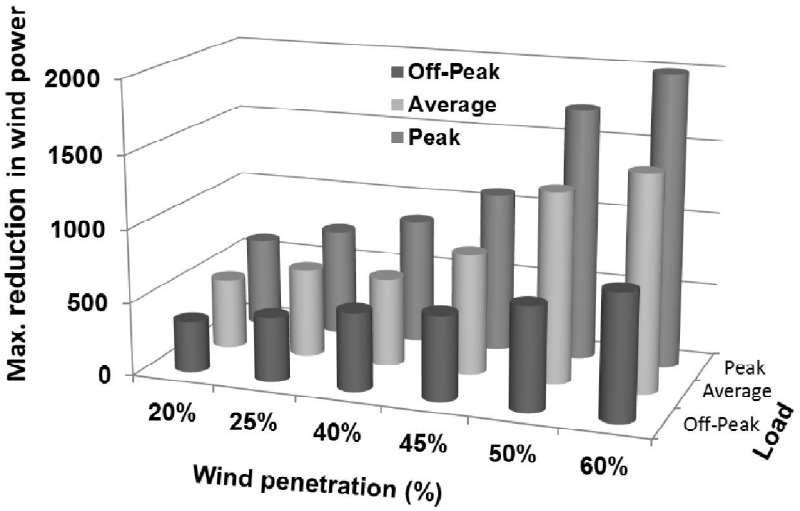


Post-fault delayed active power recovery



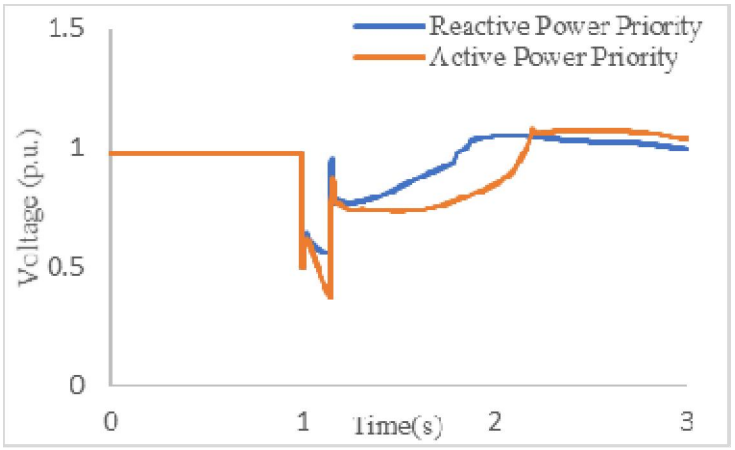
Rather et. al, 2017



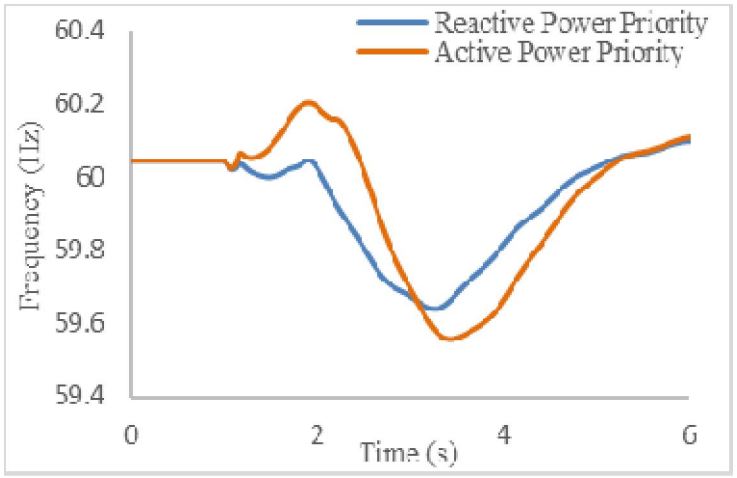



THANK YOU
FOR YOUR
KIND ATTENTION

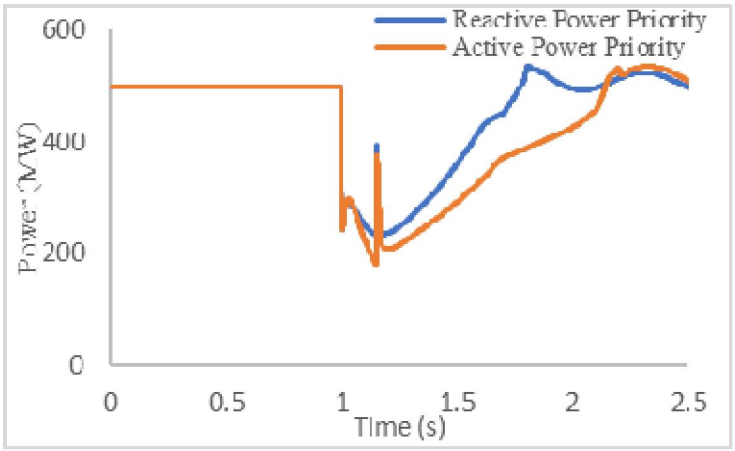
LVRT priority: active or reactive power?



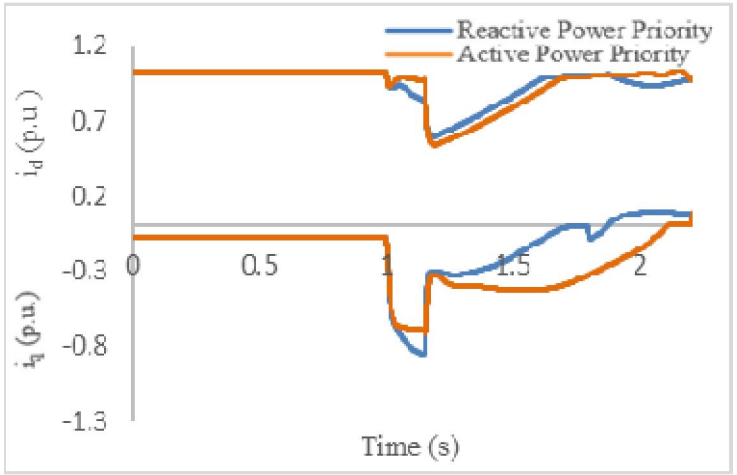
Voltage at TW1(WPP1 terminal)



Grid frequency



Active power from WPP



Active and reactive current