FREQUENCY PROVISION WITH LOW-INERTIA HYBRID POWER PLANTS: IDENTIFYING GAPS IN THE STANDARDS

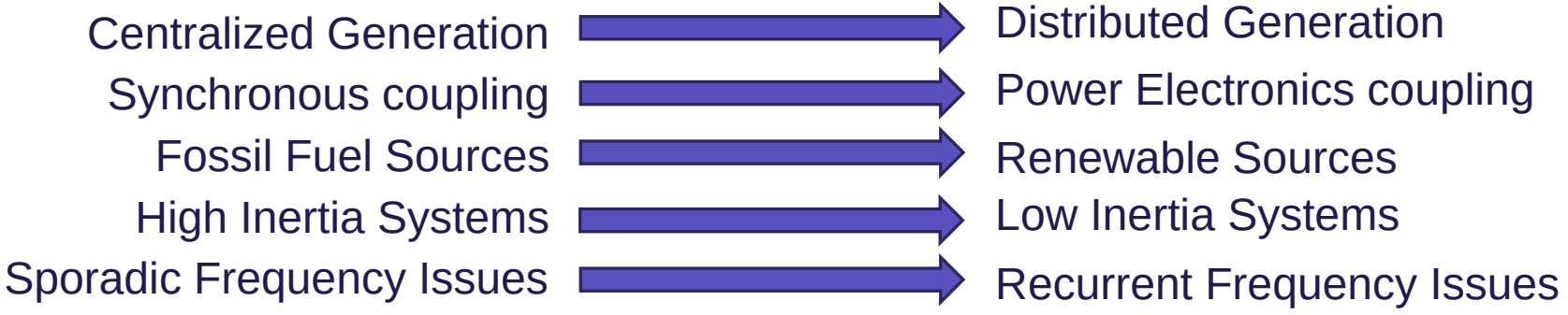
DANIEL VÁZQUEZ POMBO (DVP@ET.AAU.DK)
FLORIN IOV (FI@ET.AAU.DK)

AALBORG UNIVERSITY
DENMARK

Agenda

- Background
- ENTSO-E newest regulation
- Frequency and Inertia In Power Systems
- Proposed Method
- Tests Case
- Results
- Conclusion

Energy Transition



Frequency Blackouts

- Italy 2003: sudden load increase. Frequency reduced to 47,5 Hz during 2,5 minutes, causing the loss of 7,5 GW of DGs.
- Austria 2003: Plant tripped during tests. Load Shedding reduced the issue.
- Denmark-Sweden 2003: Short circuit left 2,5 million people without electricity.
- India 2012: Unnecessary tripping of a relay, load shedding was not enough.
- Australia blackout 2016: Line tripping, and sudden loss of wind production.

ENTSO-E newest regulations

- Supporting document for the network code on load frequency control and reserves – 2013.
- Frequency stability evaluation criteria for the synchronous zone of continental Europe – requirements and impacting factors. – 2016.
- High penetration of power electronic interfaced power sources – 2017.
- Need for synthetic inertia for frequency regulation – 2017.
- Establishing a guideline on electricity transmission system operation – 2017.

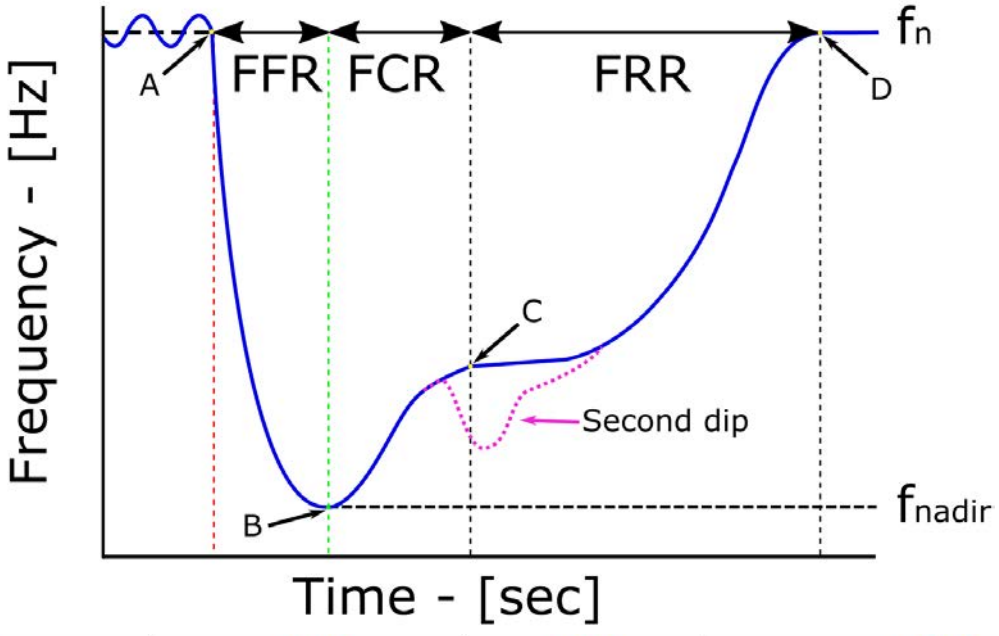
Frequency In Power Systems

$$P_G - P_L = \frac{2HS}{f_n}\frac{\Delta f}{\Delta t}$$

ROCOF

P_G : Power generated [W]
P_L : Power consumed [W]
S : System size [W]
H : Inertia [s]
f_n : nominal frequency [Hz]
Δf : frequency variation [Hz]
Δt : time variation [s]

Frequency In Power Systems



Stage	FFR	FCR	FRR
Interval	A-B	B-C	C-D
Origin	Virtual inertia	Reservoir	Generation adjustment
Similar To	IR	PFR	SFR

Vázquez Pombo, D., Iov, F., & Stroe, D. I. (2019). A Novel Control Architecture for Hybrid Power Plants to Provide Coordinated Frequency Reserves. *Energies*, *12*(5), 919.

The perfect frequency recovery

- Small Nadir
- Smooth recovery – No second dip

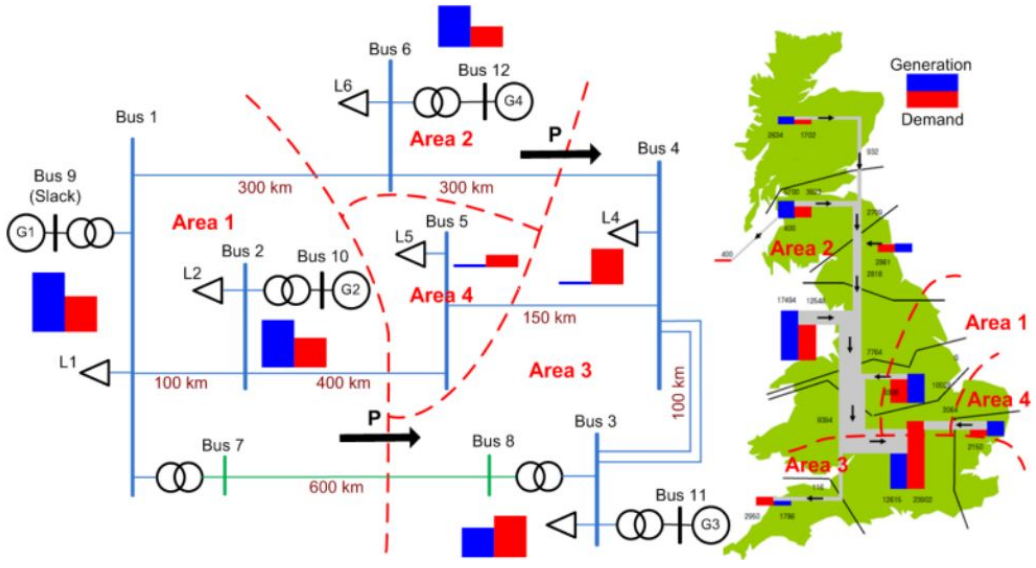
How?

- Detect the event as soon as possible – frequency vs ROCOF
- Start acting since detection – FFR
- Ensure a smooth transition between stages – Coordination

Frequency Event Definition

Characteristic	ENTSO-E	Proposed
Event Detection	Frequency $\notin$ (50±0,2 Hz)	Frequency $\notin$ (50±0,2 Hz) ROCOF $\notin$ (±0,2 Hz/s)
Frequency Deadband	50±0,5 Hz	None
ROCOF Deadband	None	±0,2 Hz/s

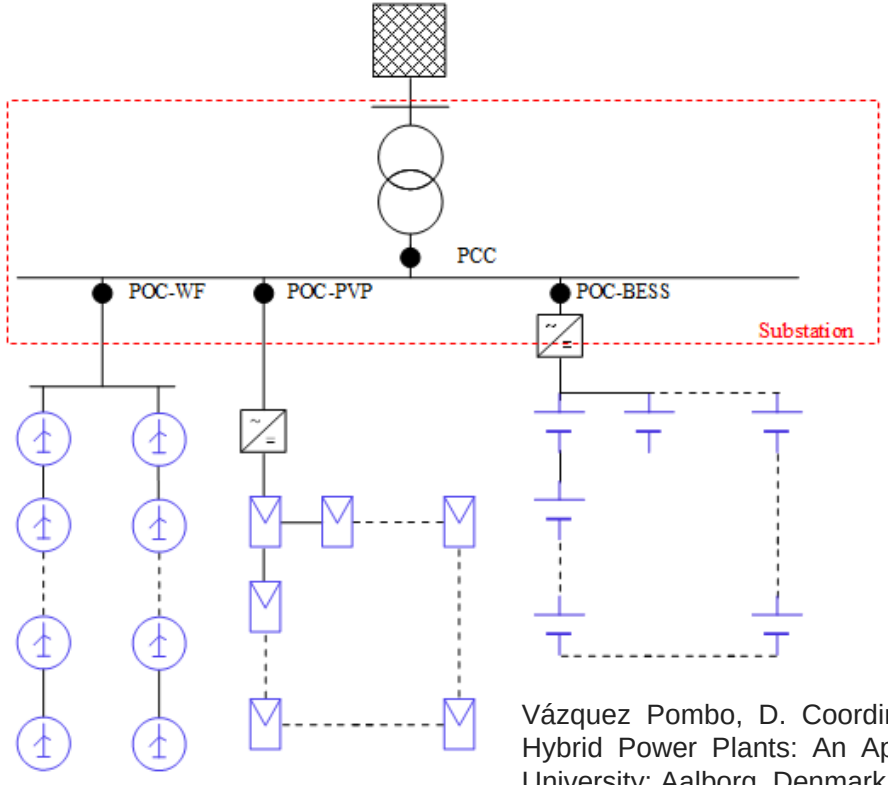
IEEE 12-bus system



Plant	Size [MW]	Ratio [%]
SG:G1	750	21,75
SG:G2	640	18,56
SG:G3	384	11,14
SG:G4	474	13,75
Hybrid	1200	34,8

Adamczyk, A., Altin, M., Göksu, Ö., Teodorescu, R., & Iov, F. (2013, September). Generic 12-bus test system for wind power integration studies. In 2013 15th European Conference on Power Electronics and Applications (EPE) (pp. 1-6). IEEE.

Hybrid Power Plant – Balance of Plant



Plant	Size [MW]
Wind Farm	1200
PV	378
Battery	336
Hybrid	1200

Vázquez Pombo, D. Coordinated Frequency and Active Power Control of Hybrid Power Plants: An Approach to Fast Frequency Response; Aalborg University: Aalborg, Denmark, 2018.

Test Case

Plant	Steady-State Power Output [MW]	Steady-State Share in Total Generation [%]	Steady-State Power Output [%]
SG:G1	300	20,0	40,0
SG:G2	200	13,3	31,3
SG:G3	100	6,7	26,0
SG:G4	300	20,0	63,3
Hybrid	600	40,0	50,0

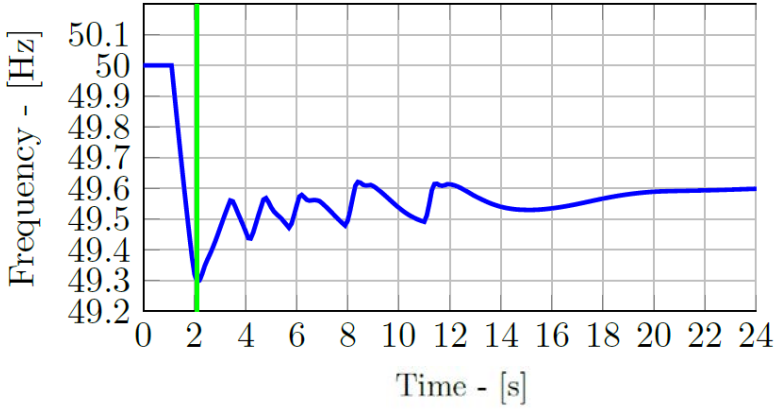
- SG:G2 sudden disconnection – (N-1 contingency)

Scenarios

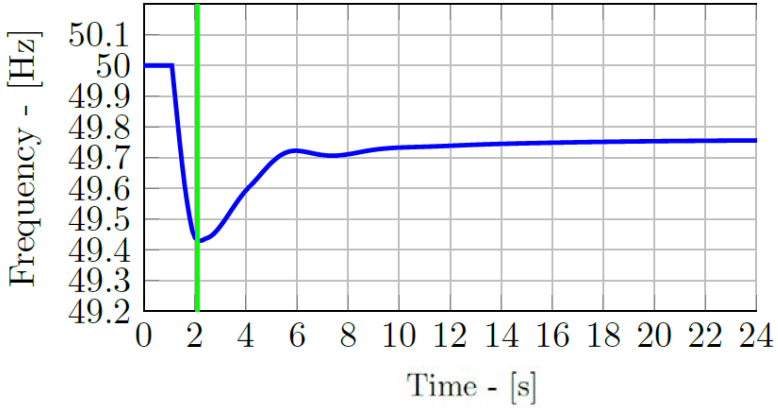
Characteristic	ENTSO-E	Proposed
Event Detection	Frequency ∉ (50±0,2 Hz)	Frequency ∉ (50±0,2 Hz) ROCOF ∉ (±0,2 Hz/s)
Frequency Deadband	50±0,5 Hz	None
ROCOF Deadband	None	±0,2 Hz/s

Results

ENTSO-E

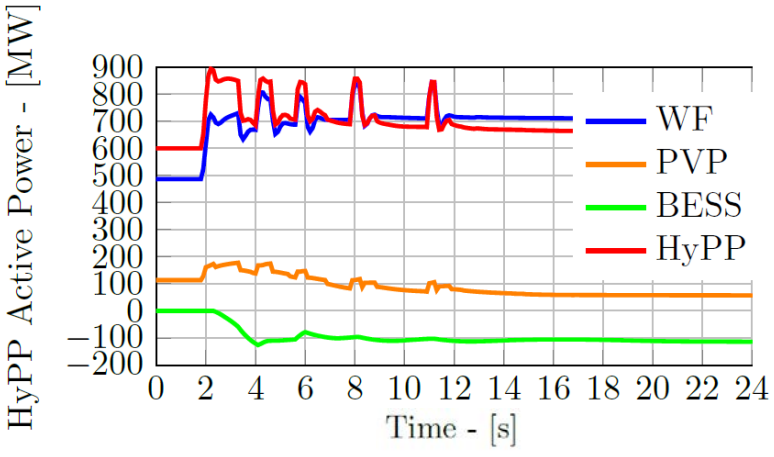


Proposed

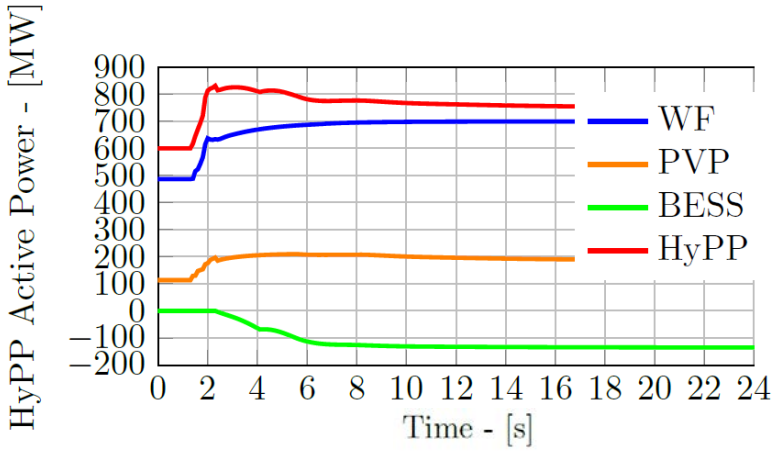


Results

ENTSO-E

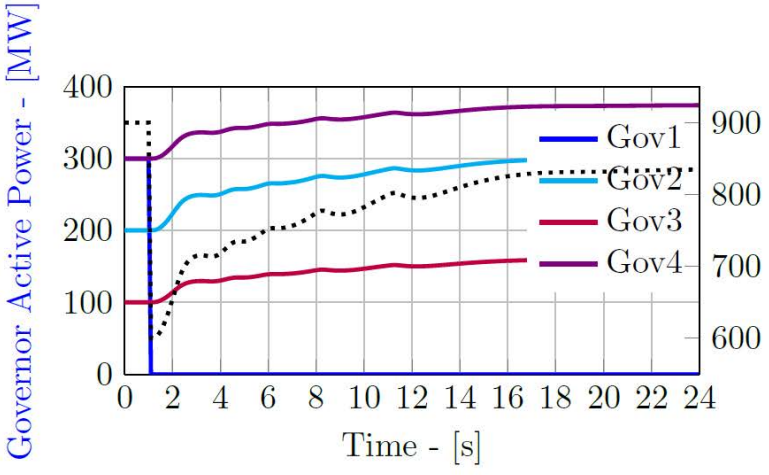


Proposed

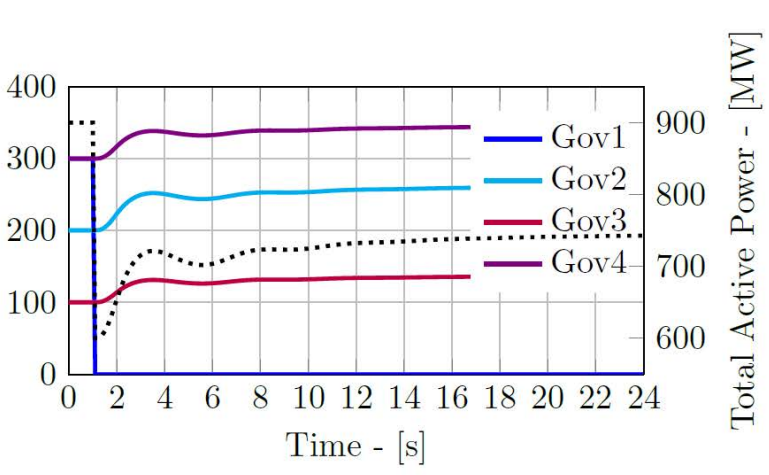


Results

ENTSO-E



Proposed



Conclusions

- ENTSO-E guidelines need further assessment
- Modern Renewable plants are capable of supporting frequency
- The proposed event detection greatly improves the response

Willing to learn more?

1. Coordinated frequency and active power control of hybrid power plants. MSc thesis, Aalborg university. (2018)

2. A Novel Control Architecture for Hybrid Power Plants to Provide Coordinated Frequency Reserves. Energies, 12(5), 919. (2019)

Thank you for your attention

Any questions?