Limitations on the virtual inertia provision from grid-forming-connected renewable energy sources

Jaume Girona-Badia*, Vinícius Albernaz Lacerda, Eduardo Prieto-Araujo and Oriol Gomis-Bellmunt

*jaume.girona@upc.edu

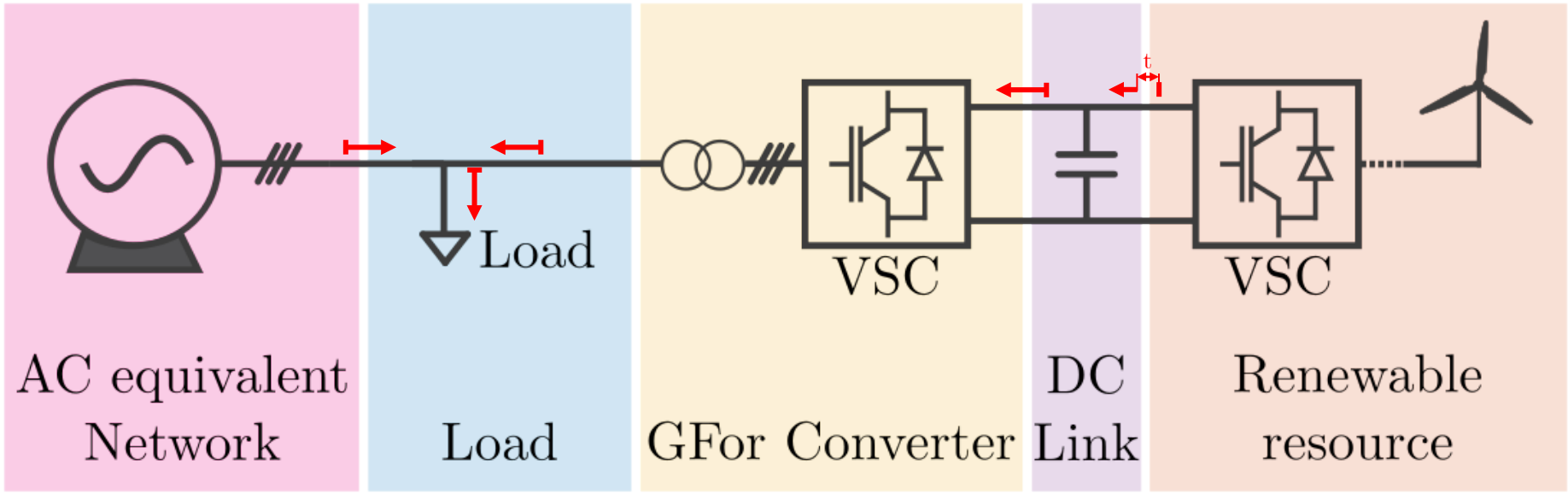
CITCEA, Universitat Politècnica de Catalunya, Barcelona, Spain

Motivation

- The share of **RES is increasing** in the electrical power system, **decreasing** the amount of SG and the **inertia** of the system and its **stability**.
- The GFor control is desired to behave as a **voltage source** improving the AC **network stability**.
- The GFor control can provide **virtual inertia = instant power** to the AC network.
- This **power** is provided by **DC bus capacitor** and the **renewable resource**.

How much virtual inertia a GFor RES can provide?

System description



AC equivalent Network

- ↓SG → ↓H
- H 2030[1] → 2~4s

GFor Converter

- Virtual inertia

DC Link

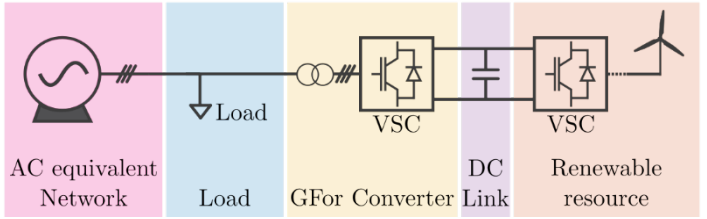
- Smooth the DC voltage oscillations
- Adequate DC voltage control
- Active power buffer

Renewable source

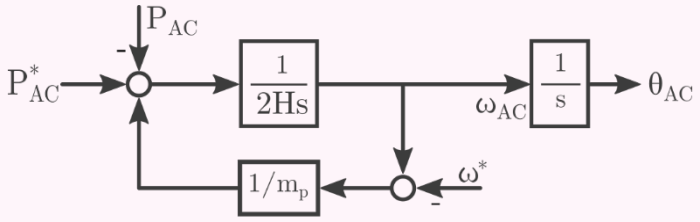
- Deloaded manner
- Delay to provide power

[1] ENTSOE 'Completing the map Power system needs in 2030 and 2040', January 2021

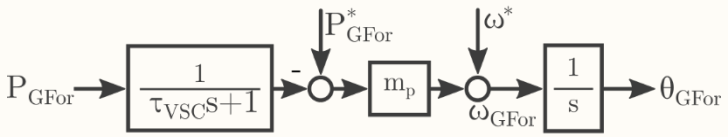
System modelling



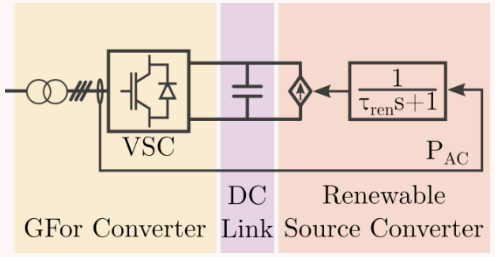
AC equivalent Network



GFor Converter



Renewable source



Power transfer

$$P_{GFor} \simeq \frac{U^2}{X_{Trf}}(\theta_{GFor} - \theta_{load})$$

$$P_{AC} \simeq \frac{U^2}{X_{AC}}(\theta_{AC} - \theta_{load})$$

- Constant voltage
- Inductive network
- Small phase variation

Load

Conservation of power

$$P_{load} = P_{GFor} + P_{AC}$$

Used equation:

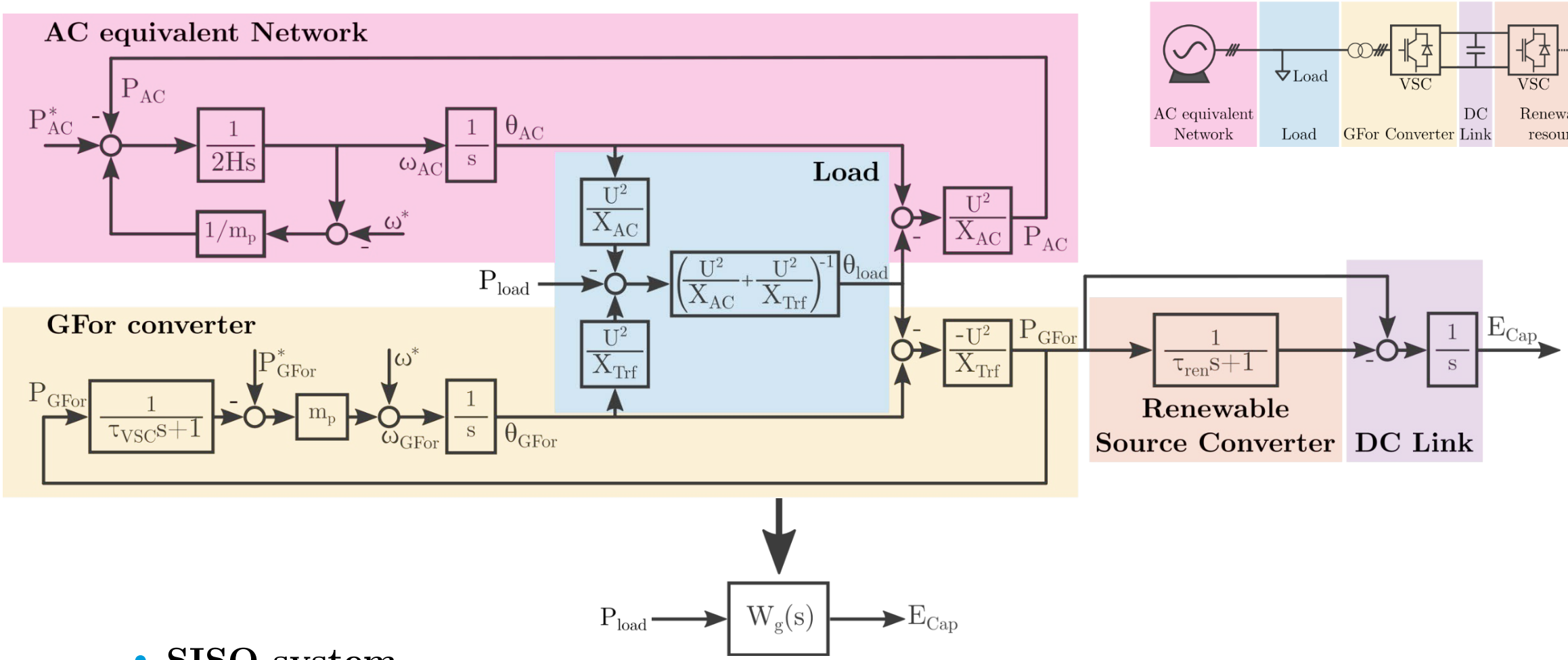
$$\theta_{load} = \frac{-P_{load} + \frac{U^2}{X_{AC}}\theta_{AC} + \frac{U^2}{X_{Trf}}\theta_{GFor}}{\frac{U^2}{X_{AC}} + \frac{U^2}{X_{Trf}}}$$

DC Link

$$E_{Cap}(s) = \frac{1}{s}(P_{GFor}(s) - P_{ren}(s))$$

- No specific capacitor
- $E_{cap}[s] = \frac{E_{cap}[Ws]}{P_{nom}[W]}$
  - Easily extrapolated to different power ratings

System modelling



- **SISO system.**
- The transfer function relates the capacitor energy with the active power load.
- It allows for **a decrease** in the **computational time.**

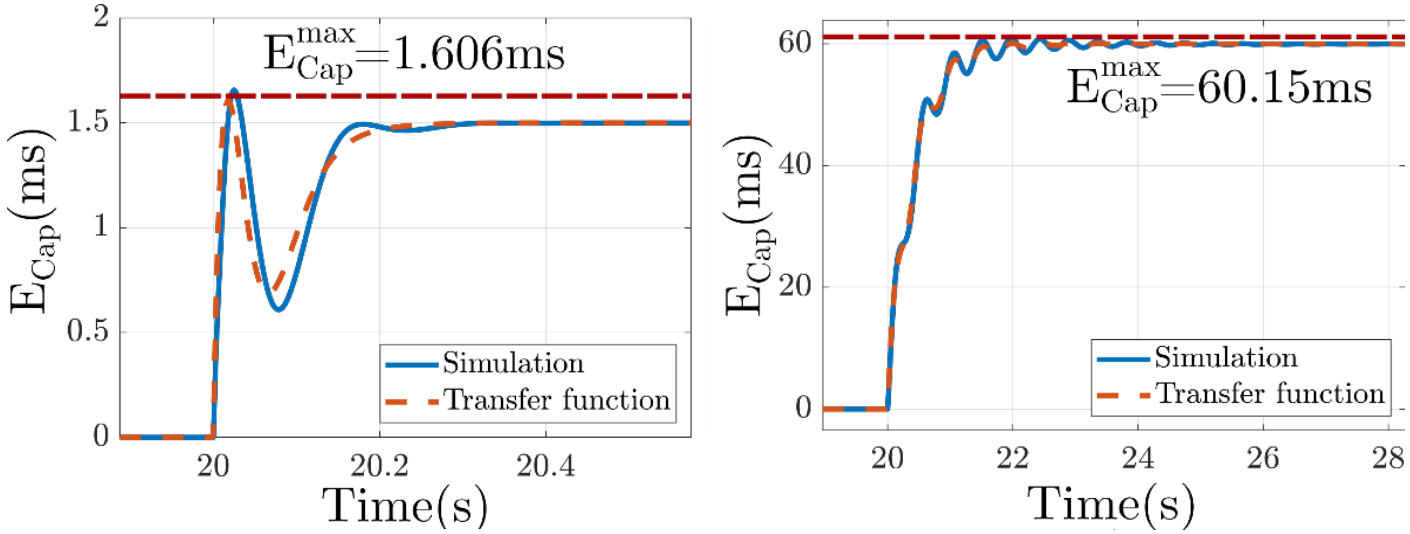
System modelling - validation

Simulation

- **MATLAB SIMULINK** simulation
- To **validate** the **hypothesis**

Validation test

The validation has been carried out for different τ_{VSC} and H [1]



Validation conclusions

- **Acceptable match** even though the simulation presents few more oscillations.
- **The maximum value** (red dashed line) **is well captured**, which is the key magnitude of interest.

1 More validations in the paper

Objective

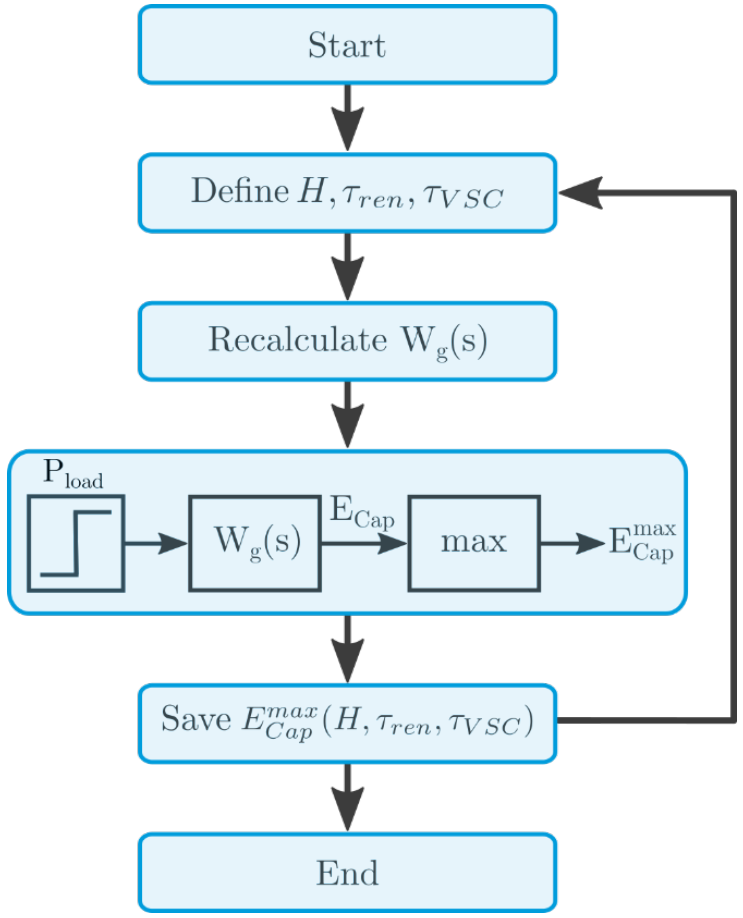
Assess the **maximum virtual inertia** that the GFor interfaced renewable energy sources can provide, based on a defined **DC link energy**, an **AC network inertia** and a **renewable source time response.**

Parameters

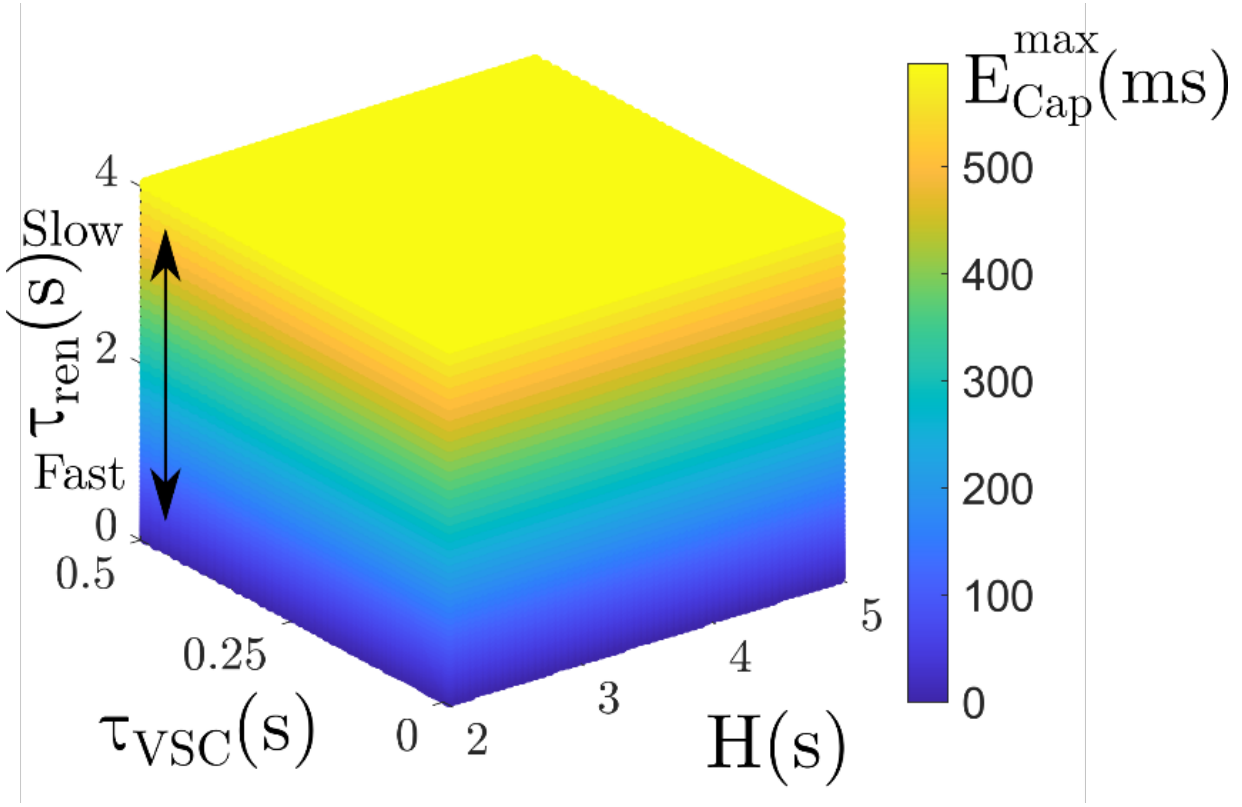
Parameter	Value	Units
n	60	
τ_{ren}^{min}	0	s
τ_{ren}^{max}	4	s
τ_{VSC}^{min}	0	s
τ_{VSC}^{max}	0.5	s
H^{min}	2	s
H^{max}	5	s

$$2H_{VSC} = \frac{\tau_{VSC}}{m_p}$$

Algorithm



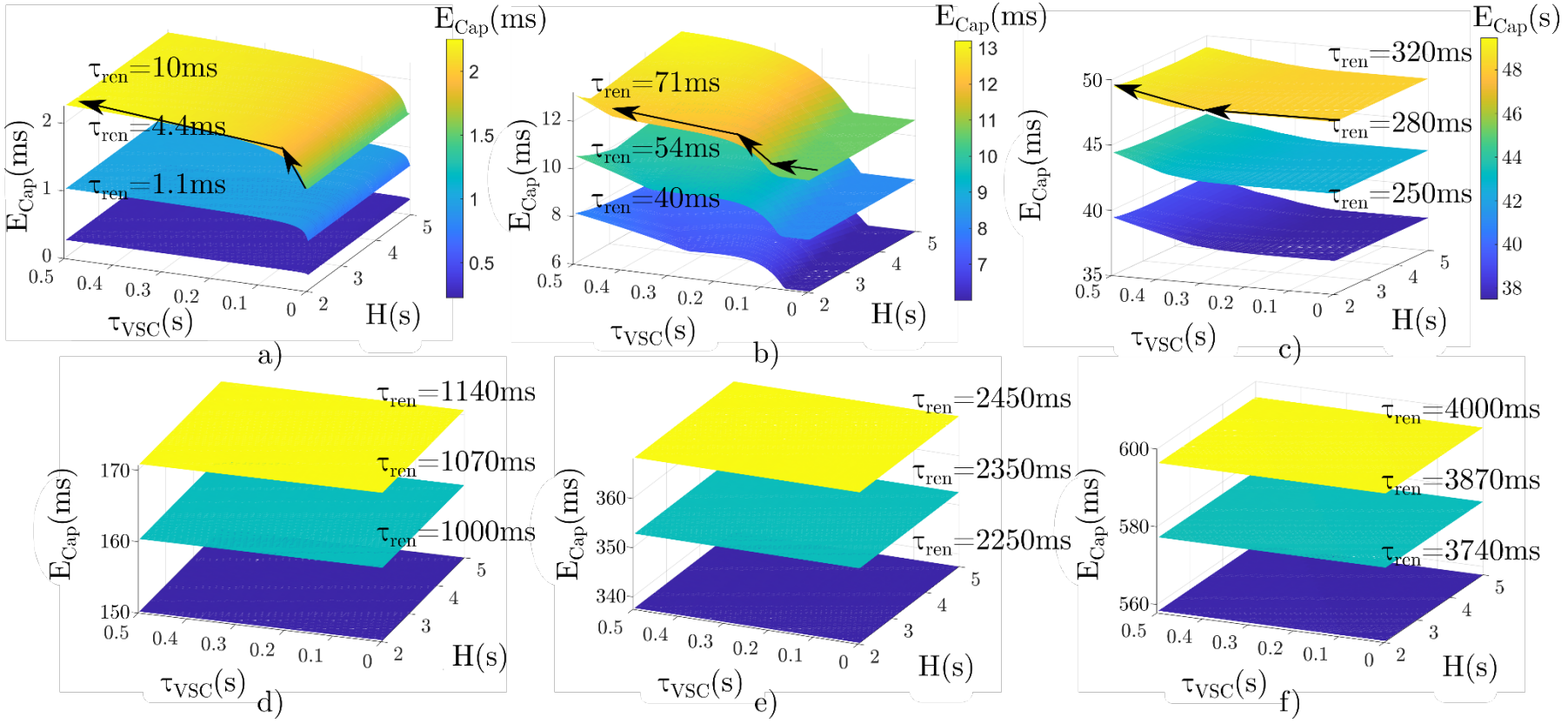
General results



- The DC link energy is mainly affected by renewable time response.
- The actually the E_{Cap} is around 10 ms.

Results and discussion

Different τ_{ren}



- The influence of virtual inertia depends on the renewable source speed response.
  - Slow renewable sources no influence can be observed.
  - If τ_{VSC} and τ_{ren} have the same order of magnitude an interaction appears.
- H has a low impact in the DC link energy.

Conclusion

- We presented an **analysis of the maximum virtual inertia** that a GFor RES can provide.
- A **modelling approach** capable of representing the system as a **simple transfer function** was proposed.
- The most **crucial parameters** to provide virtual inertia from RES are the **DC energy** and the **renewable source time response**.
  - Only **fast renewable sources** will be **able to operate in grid-forming**.
  - **Future** converter designs should consider **increasing the DC link storage** to enable the operation in grid-forming mode.
  - One potential approach to enable operation in grid-forming mode is to either **limit the frequency response** or introduce **new control structures**.

Thanks for your attention

Jaume Girona-Badia*, Vinícius Albernaz Lacerda,
Eduardo Prieto-Araujo and Oriol Gomis-Bellmunt

jaume.girona@upc.edu