GRID IMPACT ANALYSIS

HYBRID ENERGY STORAGE SYSTEMS

in PARTNERSHIP WITH

IEWT 2021
PARALLEL SESSION 5C: SPEICHER I
ROOM: VIRTUAL ROOM 3
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Introduction

The increase penetration of renewables energies in the grid poses a unique challenge for the power systems in the future. A major concern is the decrease of rotational inertial which has been a standard feature of traditional power grids. Integration of wind and PV to the AC grid requires inverters or power electronic interfaces to reliably interconnect these two distinct current sources. These devices do not exhibit an inherent inertia due to the lack of rotational mass during their operation. To solve this problem, other sources of inertia must be introduced to compensate this reduction.

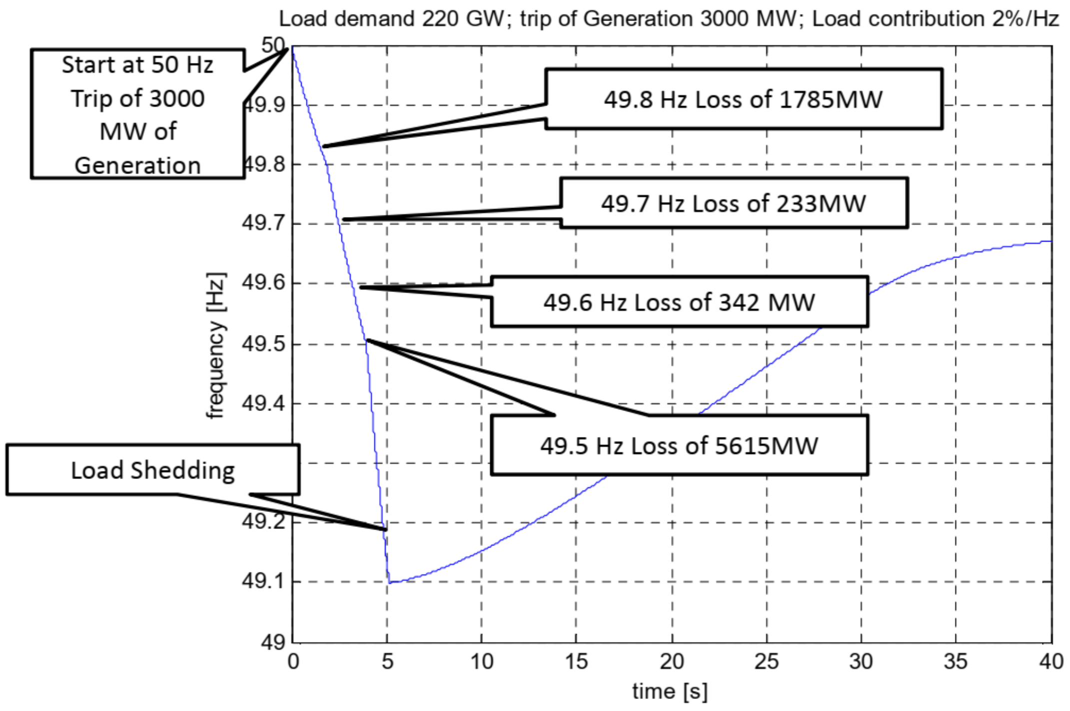
Goal and objectives

The aim of this study is to develop a simulation model to illustrate the integration, control and operation of energy storage systems at the system level of multi-area power systems during various conditions using the DigSILENT PoweFactory™ software. These will include:

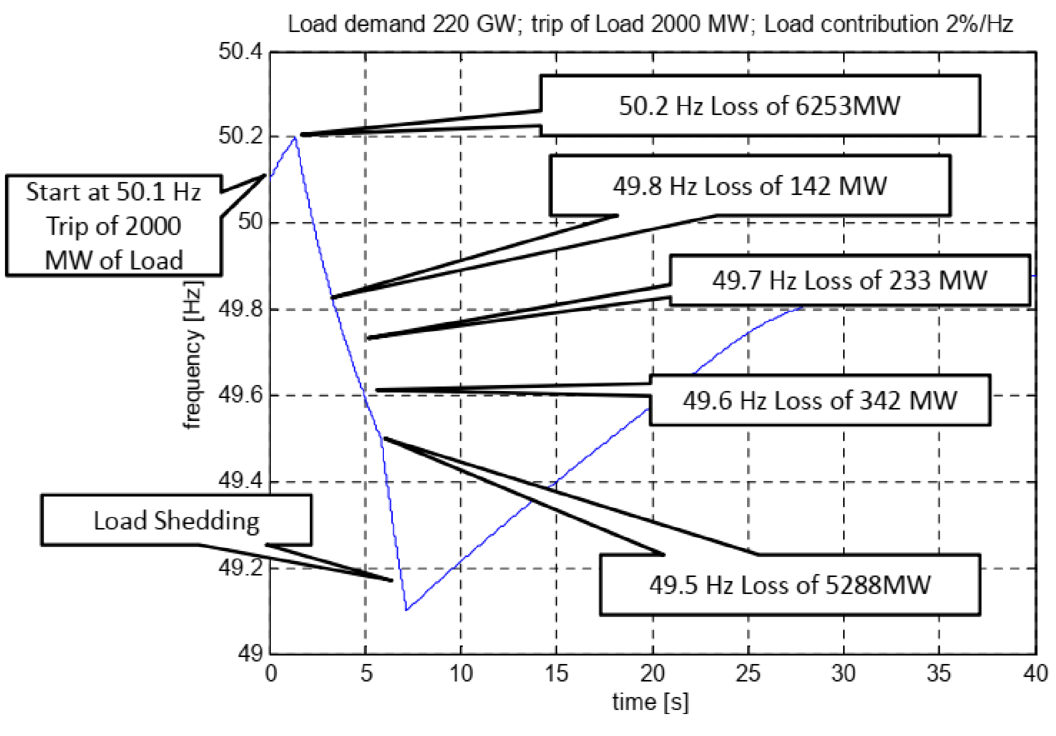
- grid compliance of the system at a high renewable energy penetration level
- system inertia requirements, capacity and size.
- estimated investment cost and comparison to legacy systems.

The Inertia conundrum

- Issue 1: Reduction of inertia



- Issue 2: RES overgeneration and participation



Tesla, Inc. Megapacks (1 GWh)

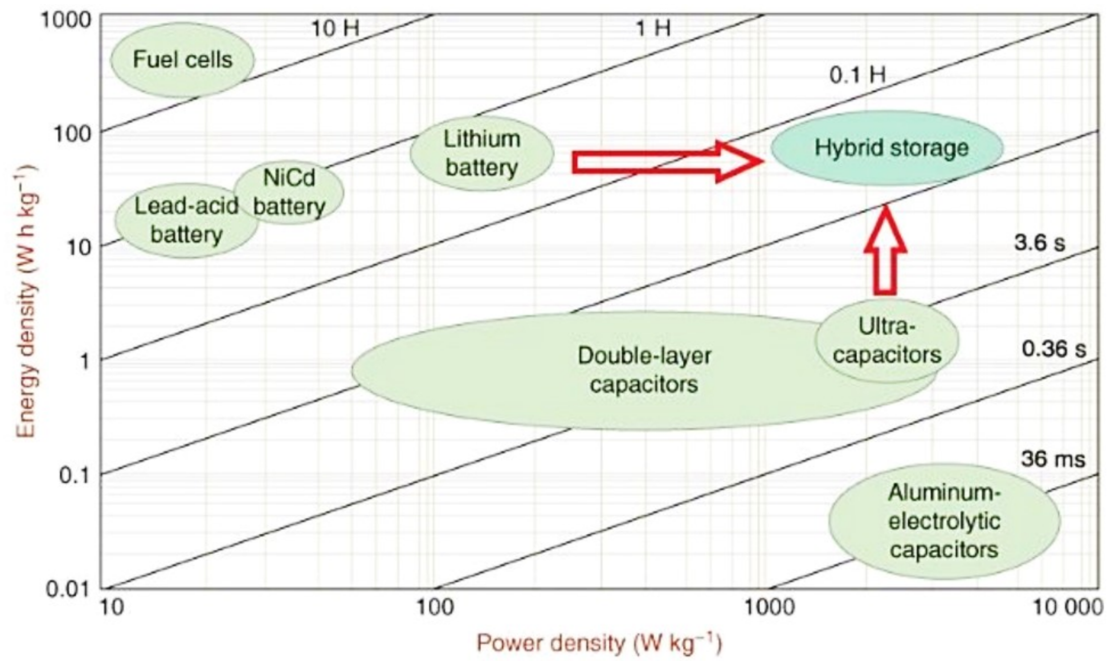
- The original system is normally separated in two partitions. The Hornsdale Power Reserve in South Australia has a 70 MW peaking capacity delivers 10 mins of around ~12 MWh reserves allocated for frequency containment and other grid regulation services. The remaining 30 MW/90MWh reserves are utilized for demand response and energy arbitrage. Their newest iteration , the MEGAPACK, consists of 3 MWh modules that can be scaled-up to a 1 GWh reserve. The system will be first implemented as a “peaker” power plant at Moss Landing in Monterrey Bay, California.

Hybrid Energy Storage Systems FCR/aFRR

200MW/
10MWh

Supercapacitor/Ultracapacitors

2MWh (SOC)



100MW/800MWh
Supercapacitor/Ultracapacitors

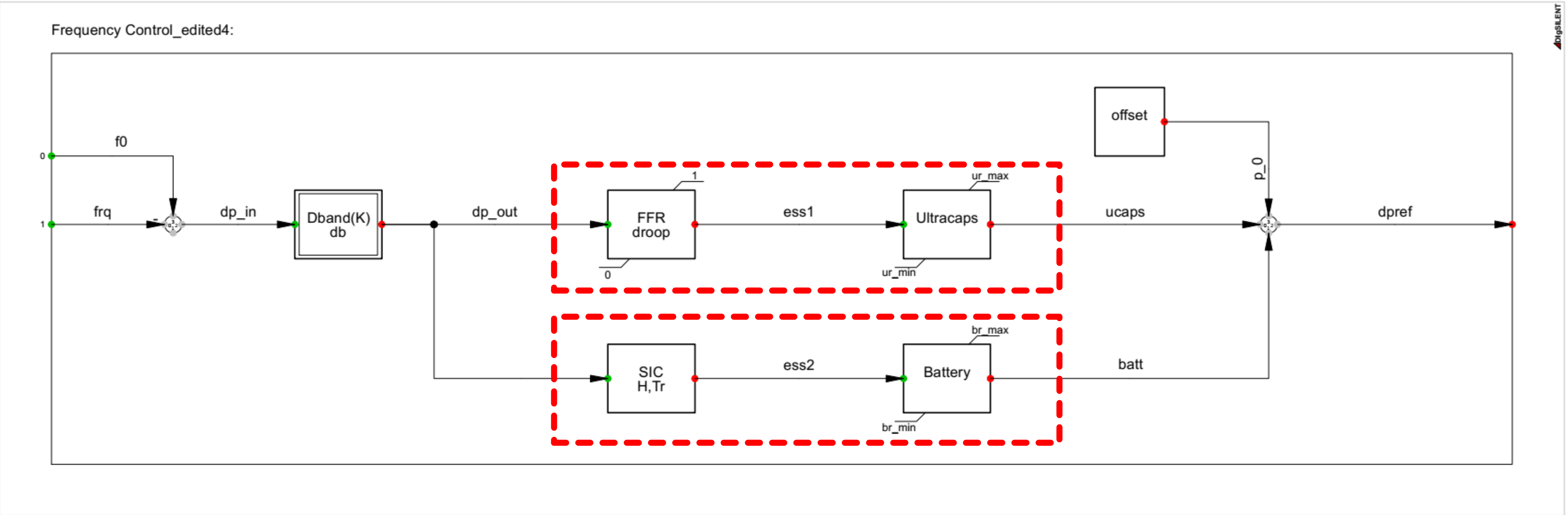
200MWh
(SOC)

+

Parameters for an effective FCR +aFRR

- **Delivery speed** – This refers to how fast energy can be injected after an event. It also describes the sensitivity of the system to abnormal RoCoF and the set threshold.
- **Peak power** – The magnitude of power delivered within a specific time frame. It addresses the resulting nadir of the system after an event.
- **Effective usable energy** – The pre-qualified reserve for dispatch to mitigate the overall contingency.

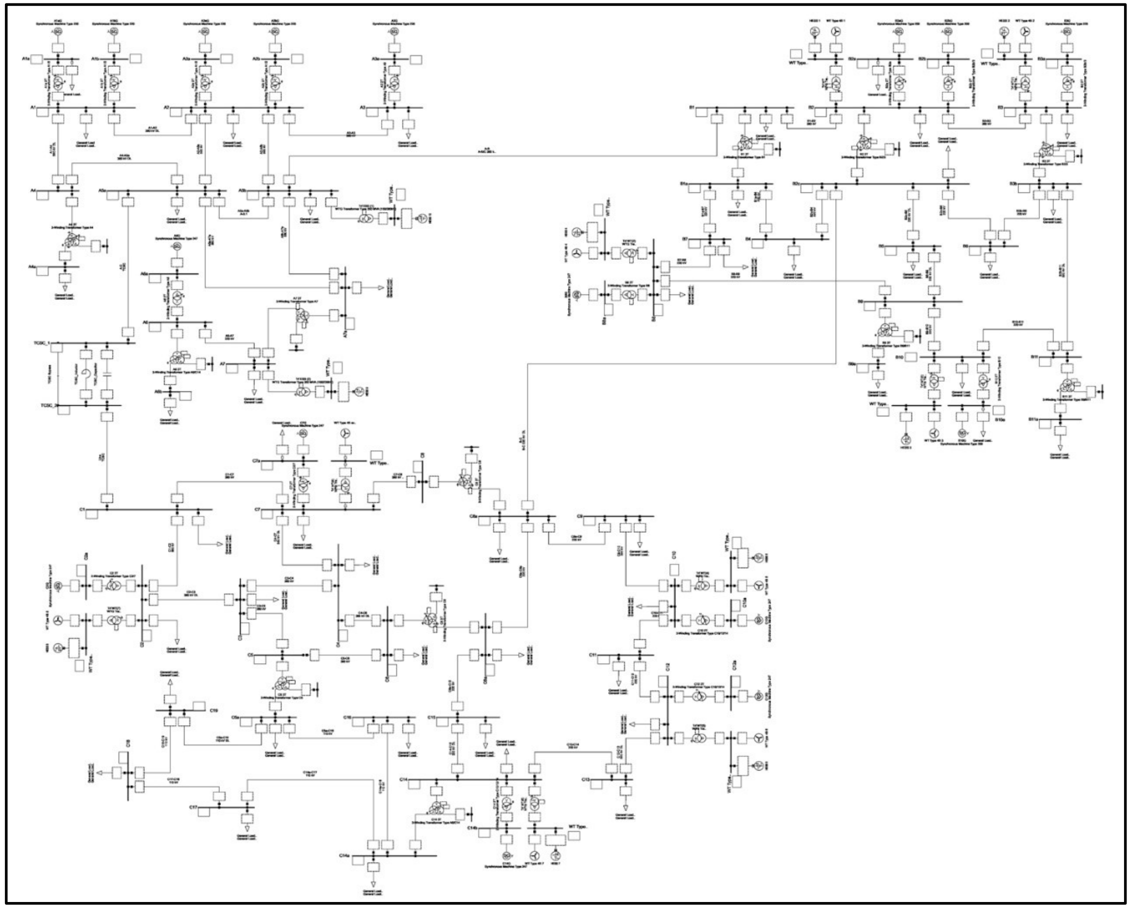
Control method



*The control method uses a combination of droop and swing method (RoCoF) to form a virtual synchronous machine. A ramp or 2nd Order Transfer Function represents the various ESS technologies to mimic their response as per their allowable discharge/charge rates. The ultracapacitor provides the main droop response while the battery delivers the ancillary energy based on the RoCoF.

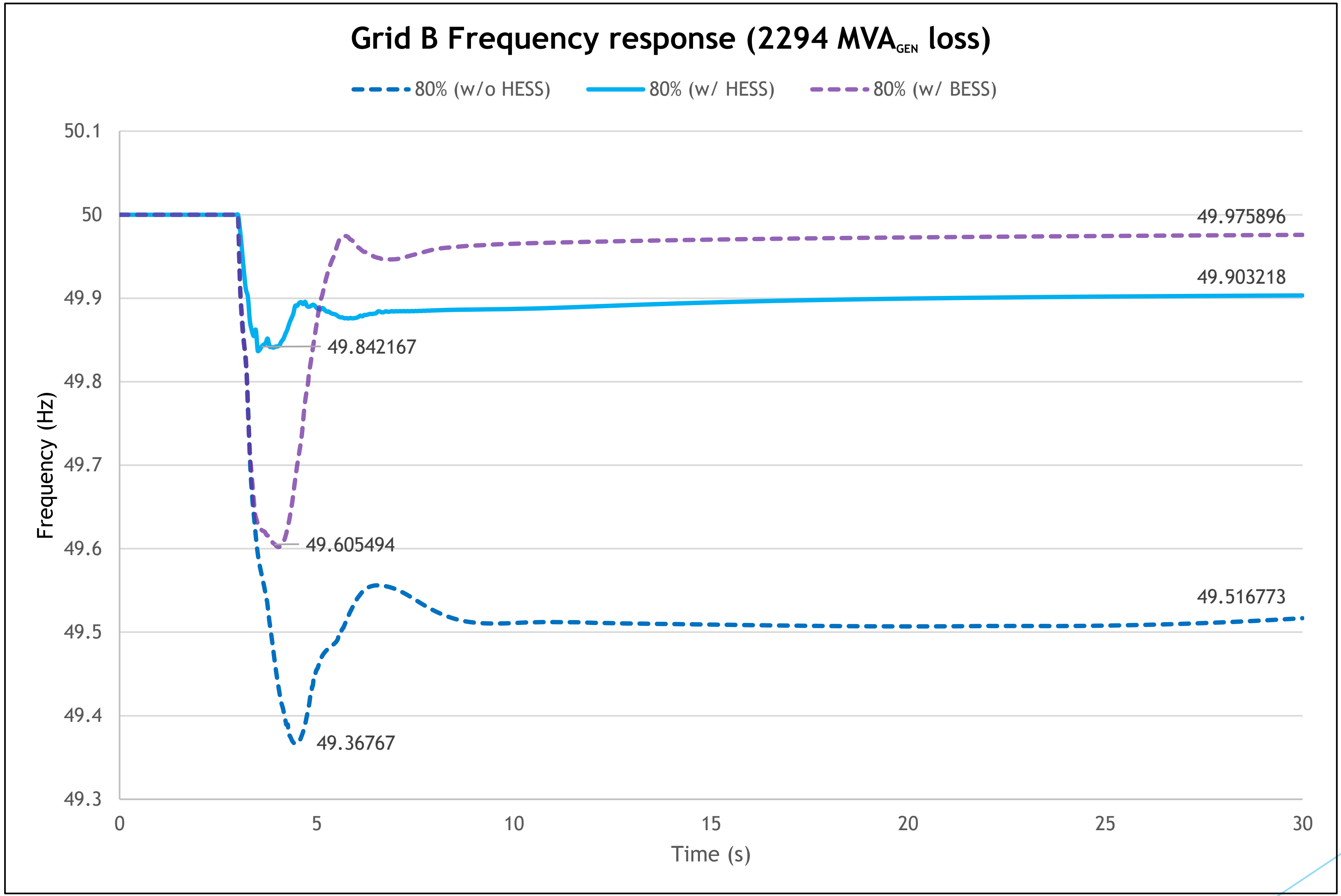
$$P_{VSG} = K_D \Delta\omega + K_I \frac{d\Delta\omega}{dt}$$

PST 16 benchmark and test metrics

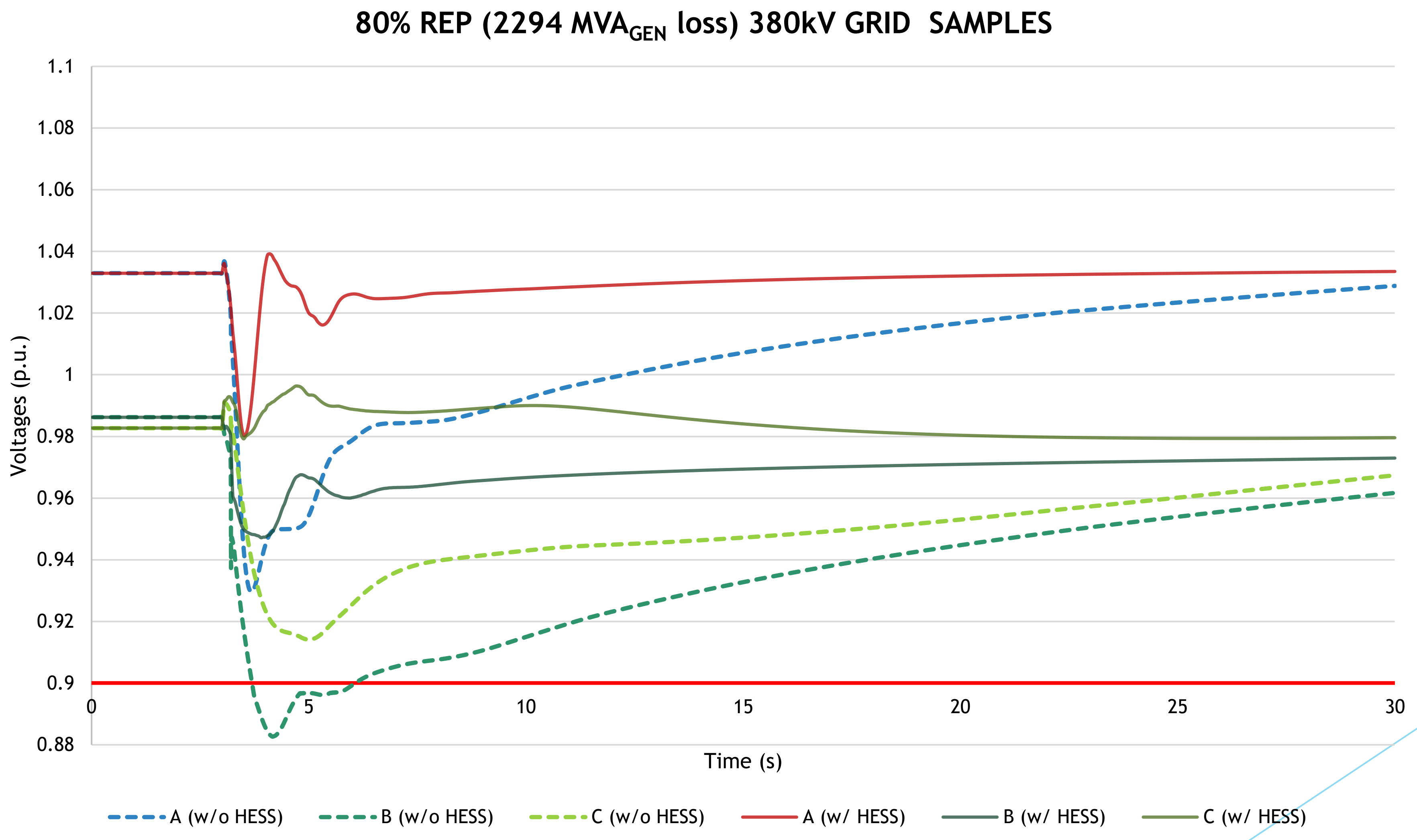


- **LFSM-O/U** (Limited frequency sensitive mode)
- **Voltage stability**
- **Islanding**
- **Fault-ride through**

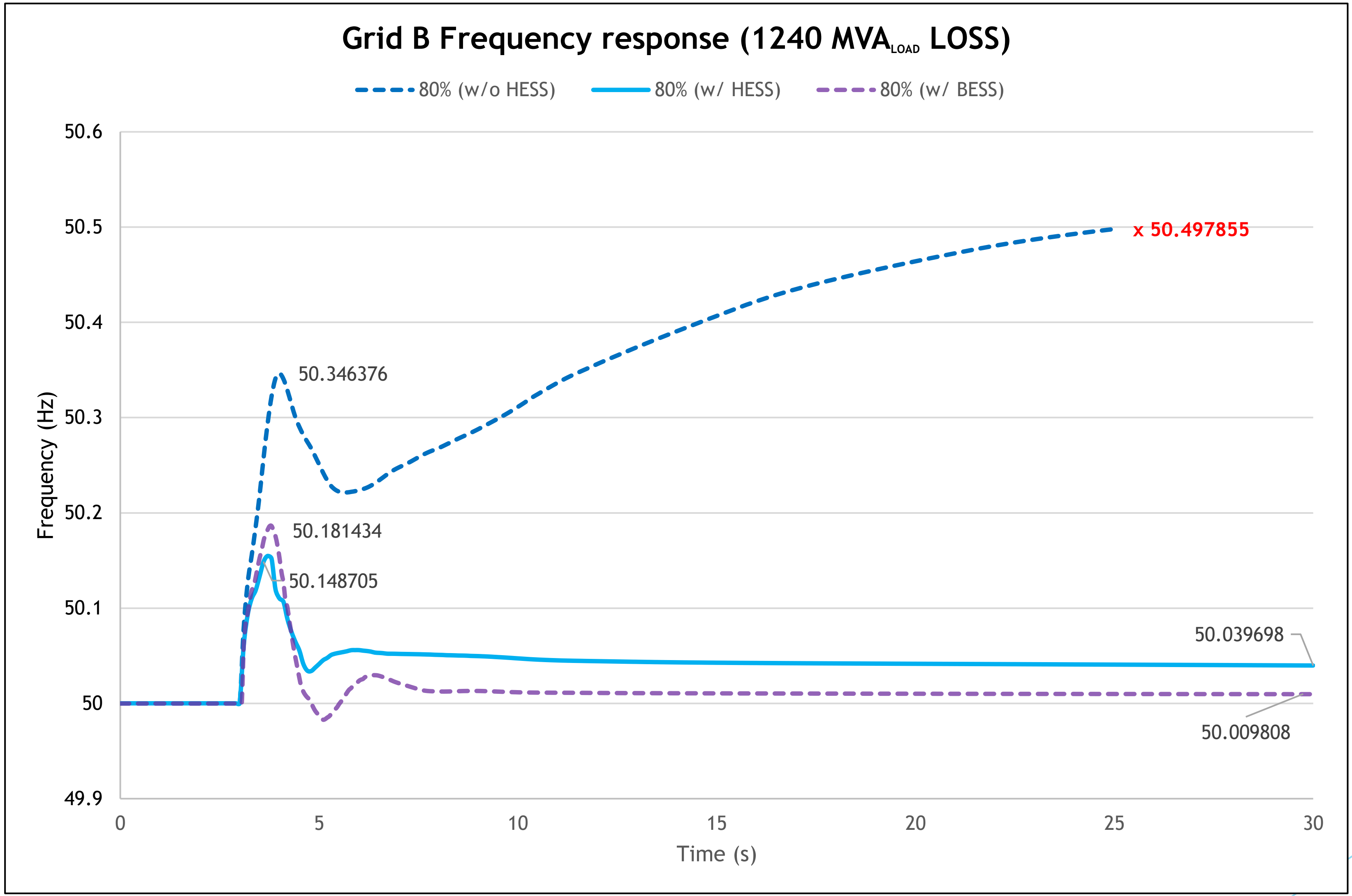
LFSM-U Compliance



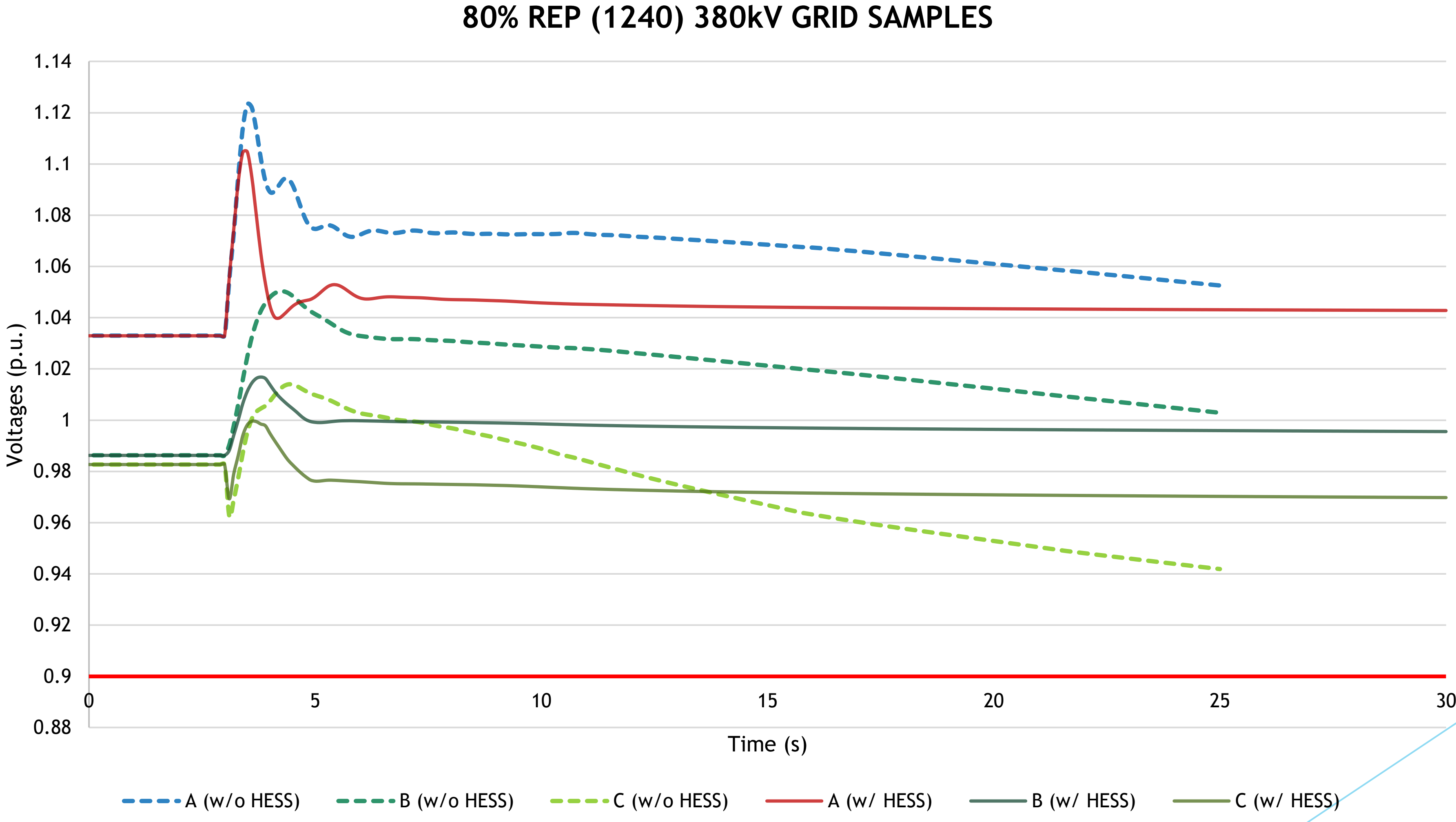
Voltage stability GEN LOSS



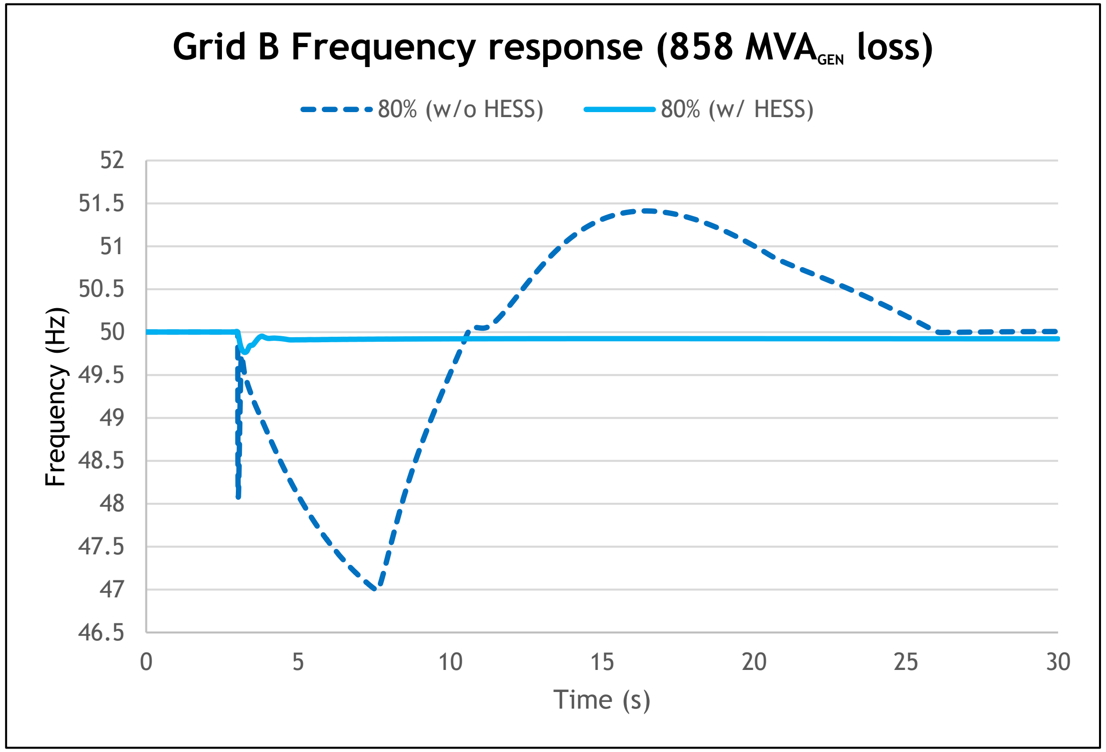
LFSM-O Compliance

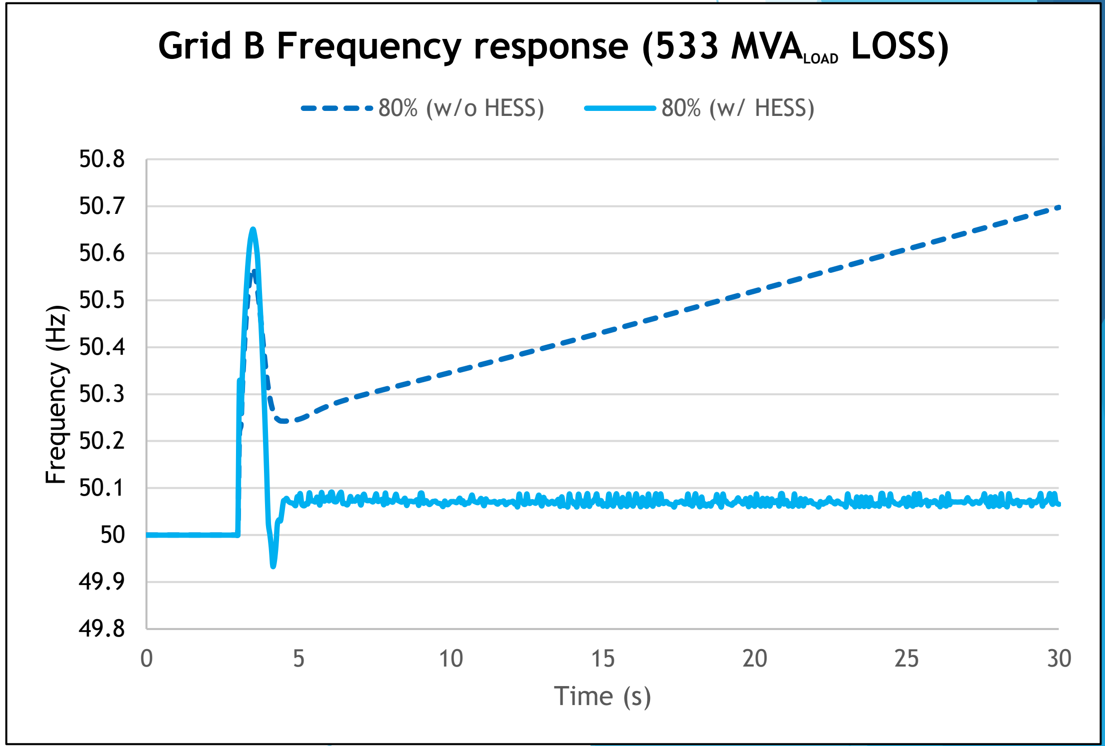


Voltage stability LOAD LOSS

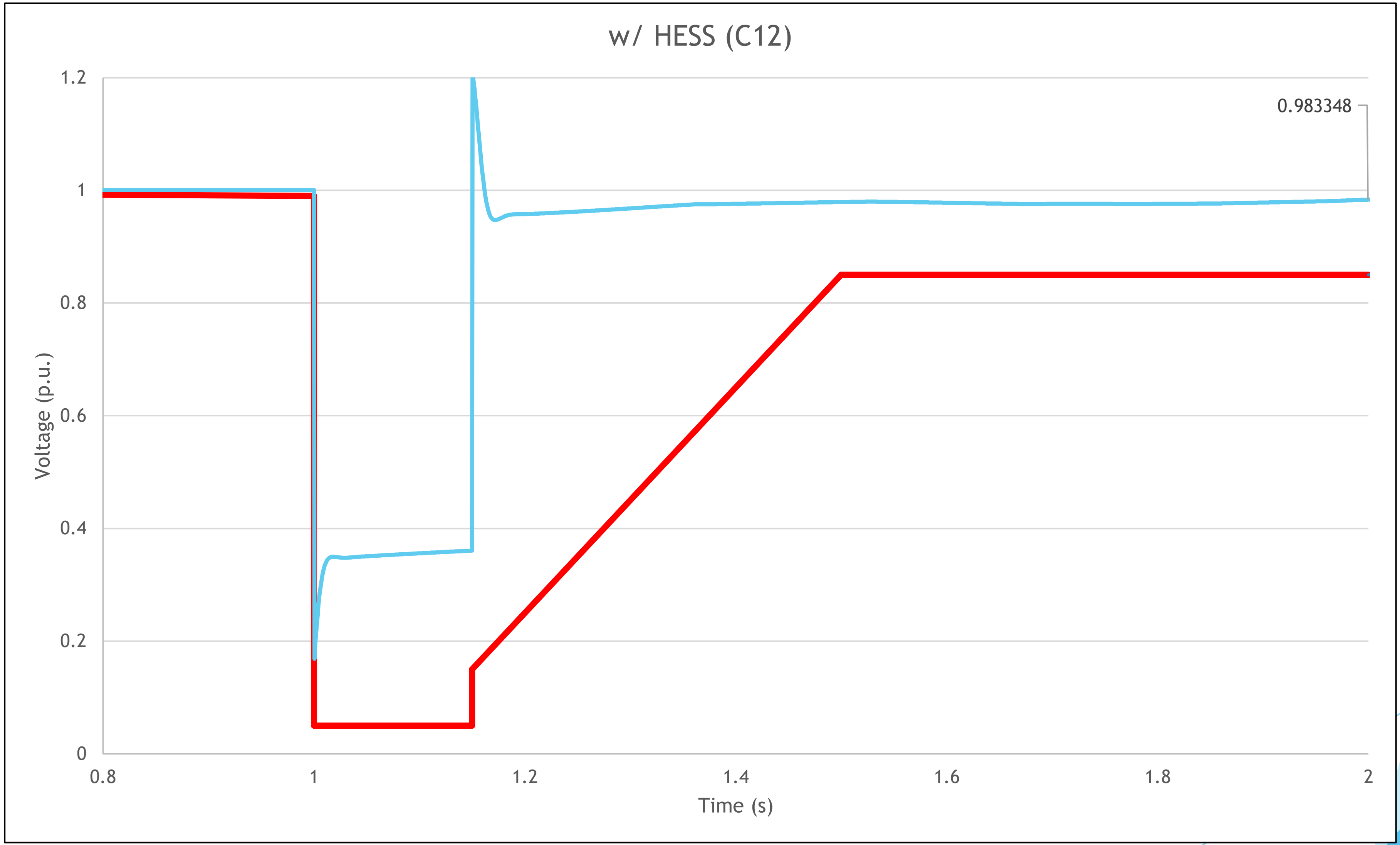


Islanding


Grid B Frequency response (858 MVA_{GEN} loss)
80% (w/o HESS)
80% (w/ HESS)
Frequency (Hz)
52
51.5
51
50.5
50
49.5
49
48.5
48
47.5
47
46.5
0
5
10
15
20
25
30
Time (s)


Grid B Frequency response (533 MVA_{LOAD} LOSS)
80% (w/o HESS)
80% (w/ HESS)
Frequency (Hz)
50.8
50.7
50.6
50.5
50.4
50.3
50.2
50.1
50
49.9
49.8
0
5
10
15
20
25
30
Time (s)

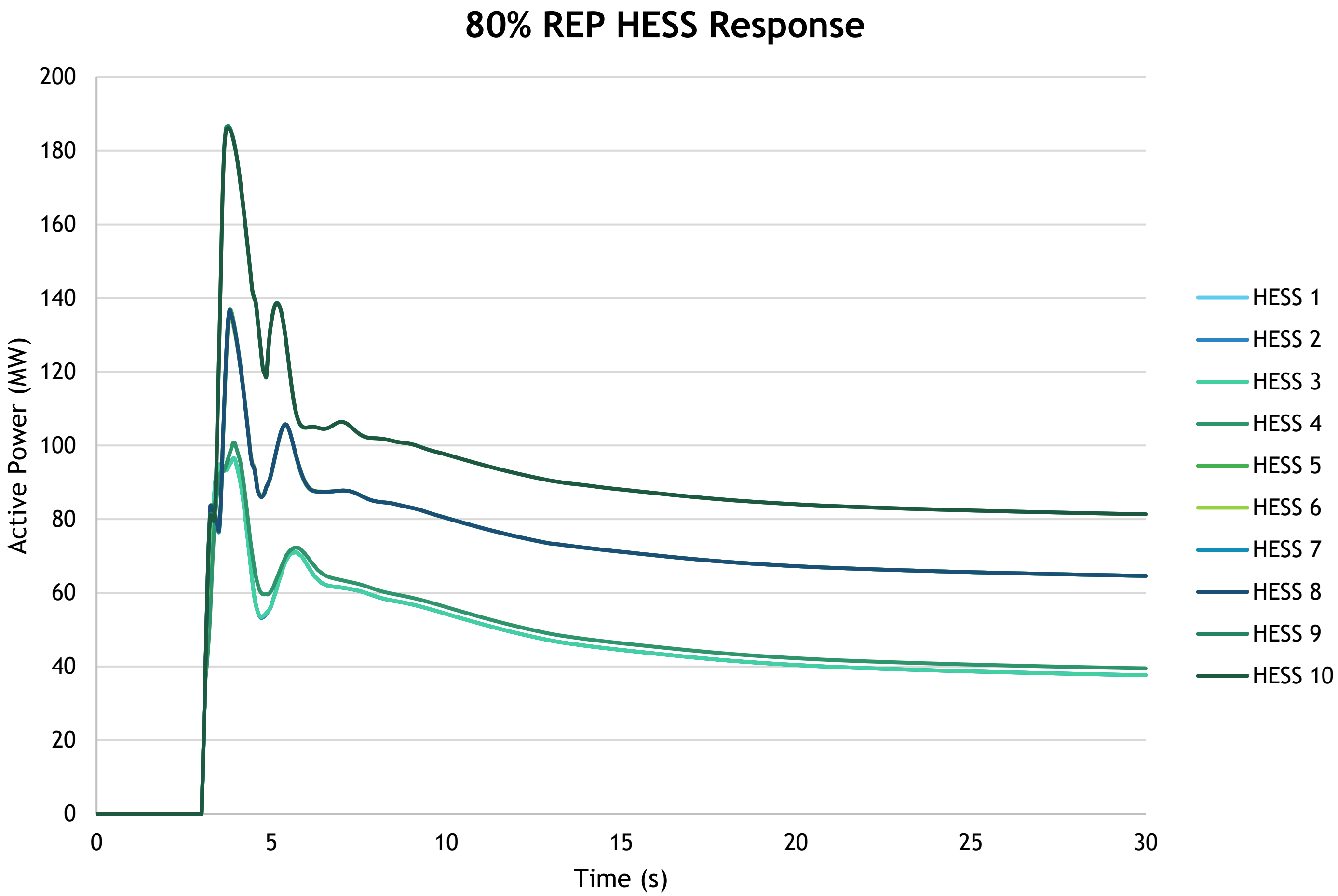
Fault-ride through (FRT)

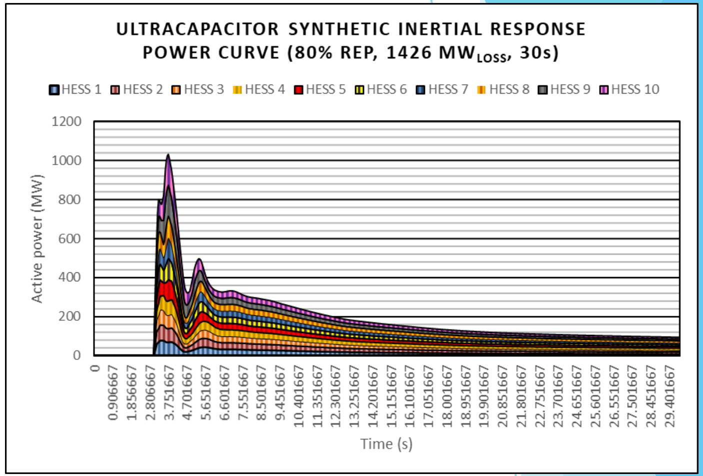


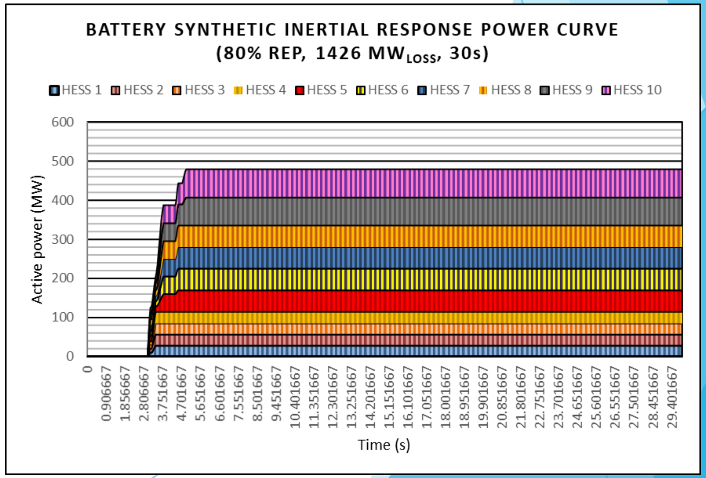
ENTSOE-E compliance checklist

Regulations		Compliance measures
Requirements for grid connection of generators [COMMISSION REGULATION (EU) 2016/631]		
General requirements	Article 13	Simulating various load profiles and preset frequency conditions for over or underfrequency events. This is by establishing the prescribed dead bands, setting up the RoCoF and nadir limits for auto load shedding. This also include generation curtailment procedures to maintain frequency stability. A test scenario with different active power levels with respect to a given set of frequency deviations.
	Article 14(a)	Simulating a fault-ride through (FRT) scenario to assess the capability of the system to operate without disruption while clearing the fault
	Article 15 and Article 21	Testing synthetic inertia and fast active power response capability by simulating a major contingency under various Frequency Sensitive Modes. A preset topology of the grid benchmark will be established with all the appropriate ESS and RES settings at 80% integration. A test case wherein substantial amount of rotational inertia is lost and power park modules help facilitate energy frequency restoration.
	Article 16 and Article 22	Fulfilling the technical requirements on the specific installed capacity.
Simulation requirements	Article 54	Fulfilling the technical simulation requirements for type B power park modules.
	(2) With regard to the LFSM-O response simulation	Simulating an over-frequency scenario and creating a control methodology for active power modulation with high-frequency steps or ramps until reaching the minimum regulating level as stipulated from the code.
	Article 55	Fulfilling the technical simulation requirements for type C power park modules.
	(2) With regard to the LFSM-U response simulation	Simulating an under-frequency scenario and creating a control methodology for active power modulation with low-frequency steps or ramps until reaching the minimum regulating level as stipulated from the code.
	(4) With regard to the island operation simulation	Simulating an island operation of a control area wherein the active power output is regulated from an operating point without disconnection of the power park module from the island due to over- or underfrequency.
	(5) With regard to the simulation of the capability of providing synthetic inertia	Simulating a low frequency event and proposing a control methodology for a synthetic inertial response during very fast frequency deviations.
	(7) With regard to the power oscillations damping control simulation	Simulating active power oscillations and devising a control method to provide control.

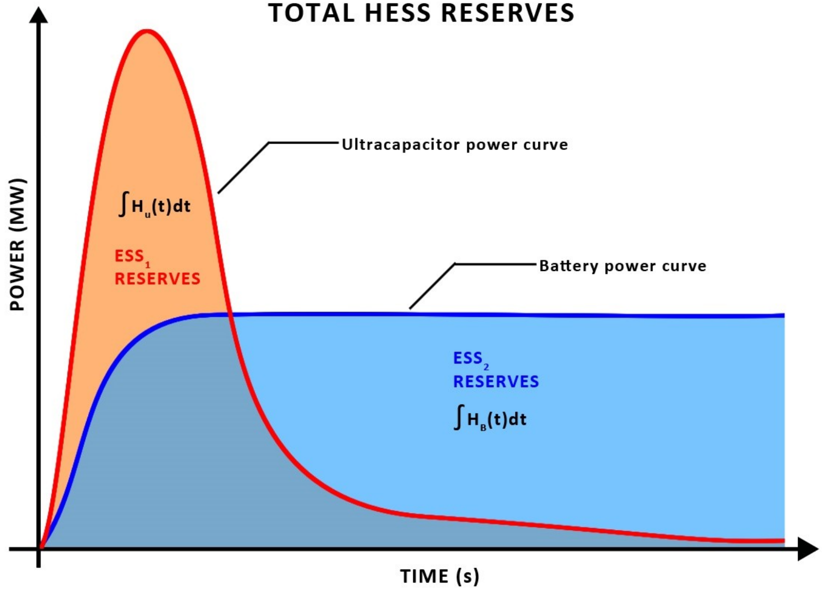
Sample inertial response







Total emulated inertia



$$H_{SI} = \int_{t_n}^{t_{n+1}} H_u(t)dt + \int_{t_n}^{t_{n+1}} H_b(t)dt$$

where:

H_{SI} – total synthetic inertia requirement (MWs)

$H_u(t)$ – ultracapacitor active power curve (MW)

$H_b(t)$ – battery active power curve (MW)

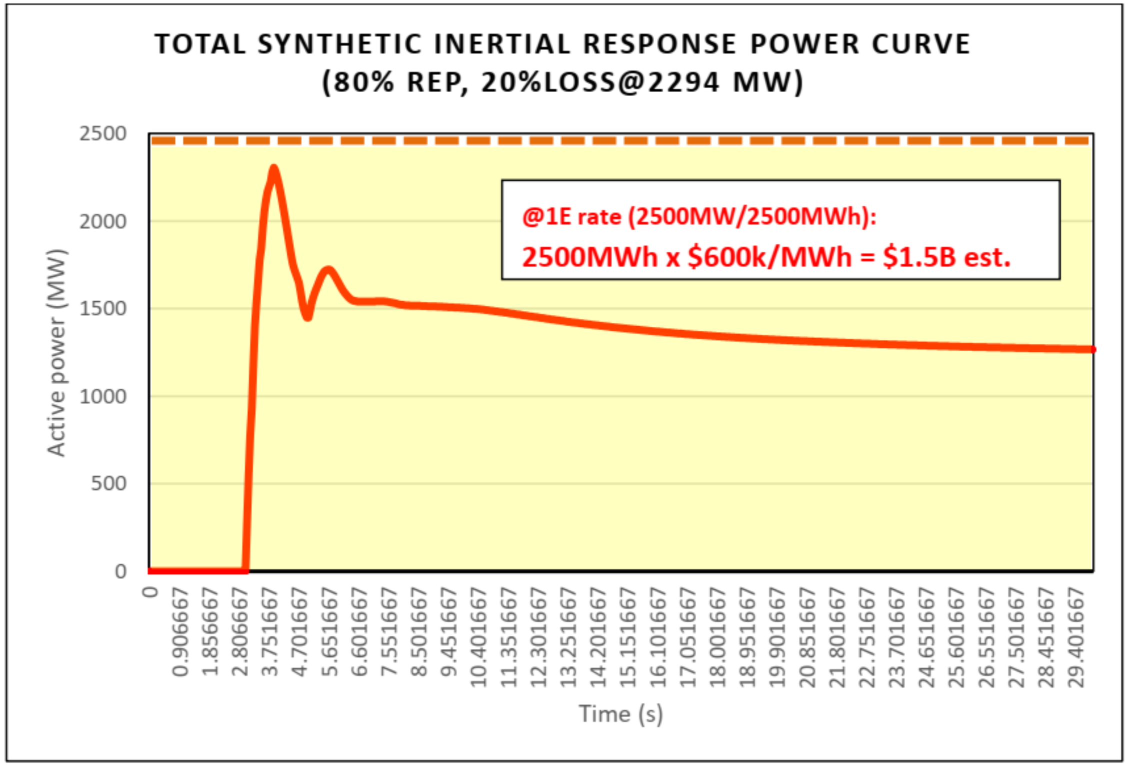
dt – time interval of measurements (s)

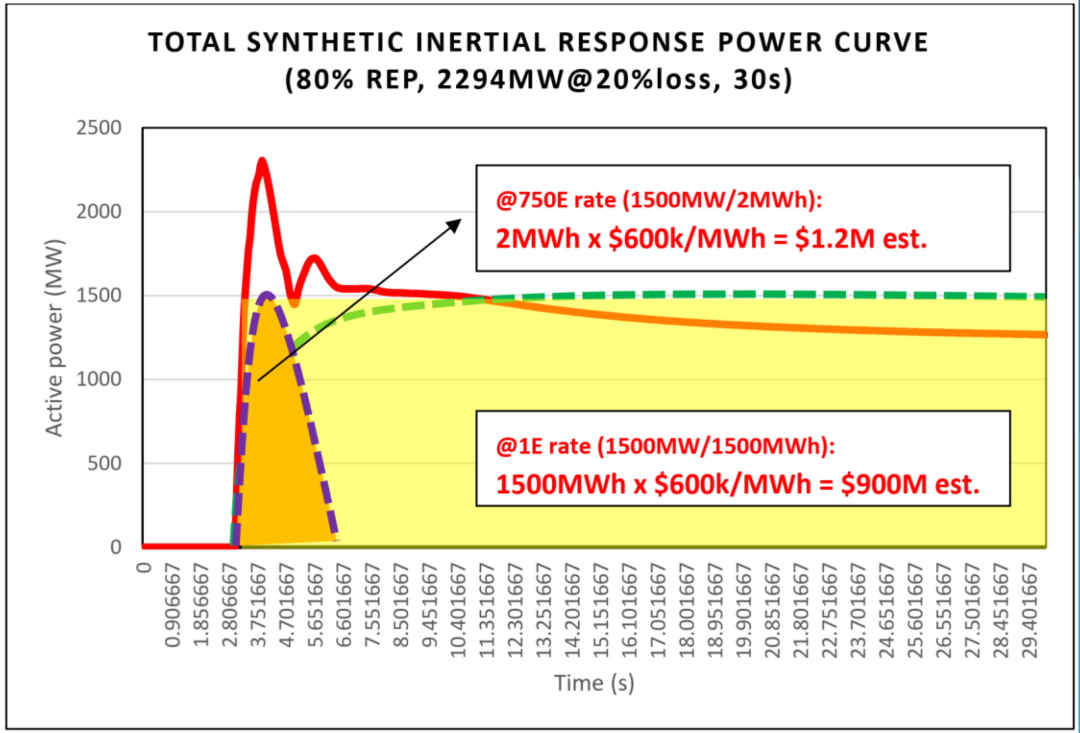
t_{n+1} – required inertial response duration

t_n – frequency event

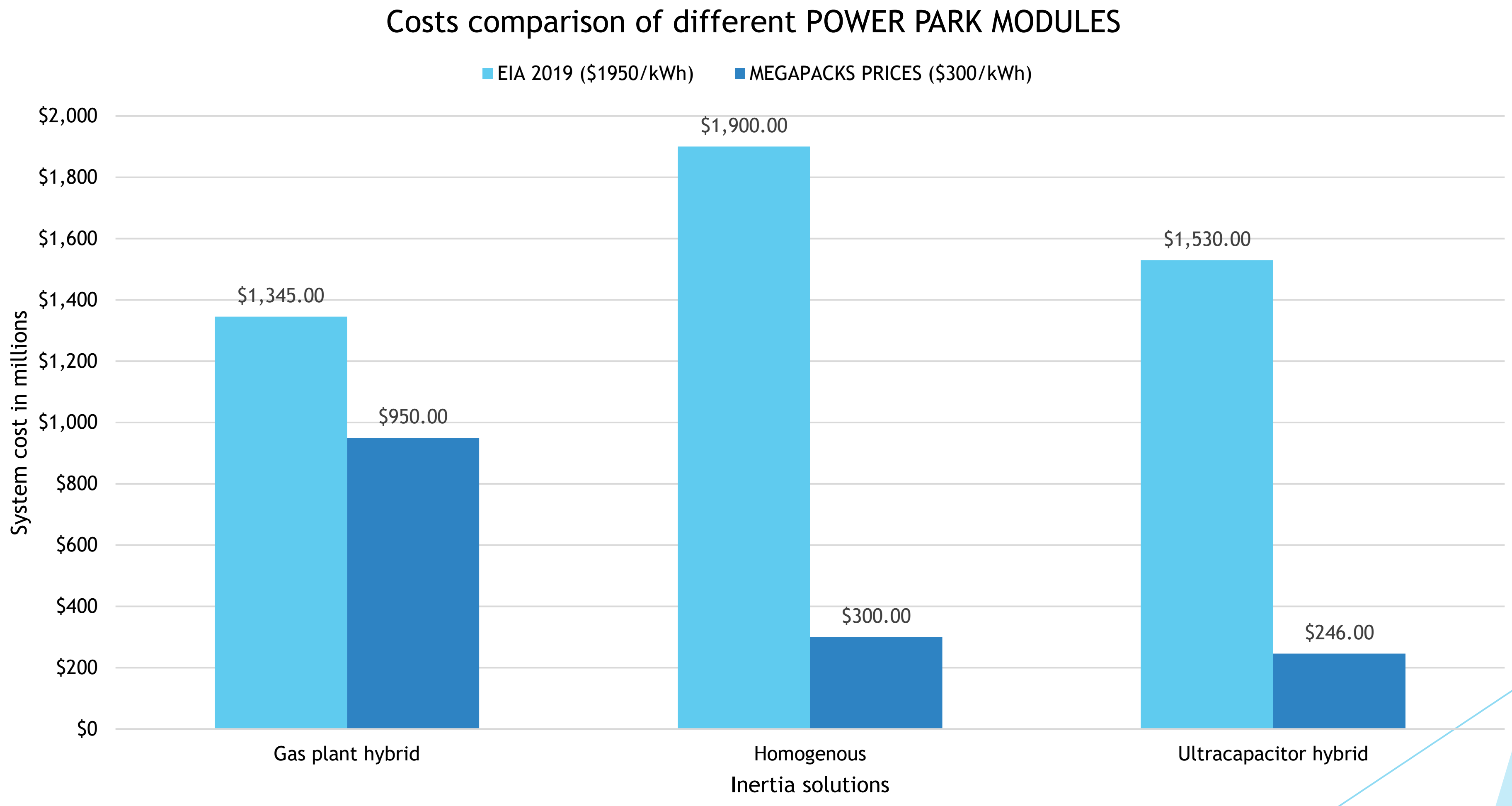
Contingency	Inertia requirements (MWs)		
	Ultracapacitor	Battery	Synchronous
11% Loss	6000 MWs	13000 MWs	16000 MWs
20% Loss	20850 MWs	15000 MWs	18000 MWs

Compared to a homogenous solution





Compared to other solutions…



Conclusion

It can be seen from this simulation the significance of a hybrid energy storage system provides cost-effective synthetic inertia. It also meets the grid requirements set by ENTSO-E even at higher %REP. Through this technology and control method proposed in this research, a feasible and practical facility can be further developed for grid implementation. Moreover, synchronous generators still play a decisive role in supporting frequency restorations. Future power systems will still rely on these platforms for stability regardless of the amount of synthetic inertia available. Renewable energies and storage systems have its limits. Thus, the grid of tomorrow will be a diverse mix of fewer old and more new technologies.

Future challenges

- Grid implementation, TSOs or Markets?
- Market integration and contingency role
- Ultracapacitors and batteries supply
- Inertial anomalies across different grids

E N D

"Nothing is as powerful as an idea whose time has come."

-Victor Hugo

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