

IBR Grid Connection Studies – Lessons Learned

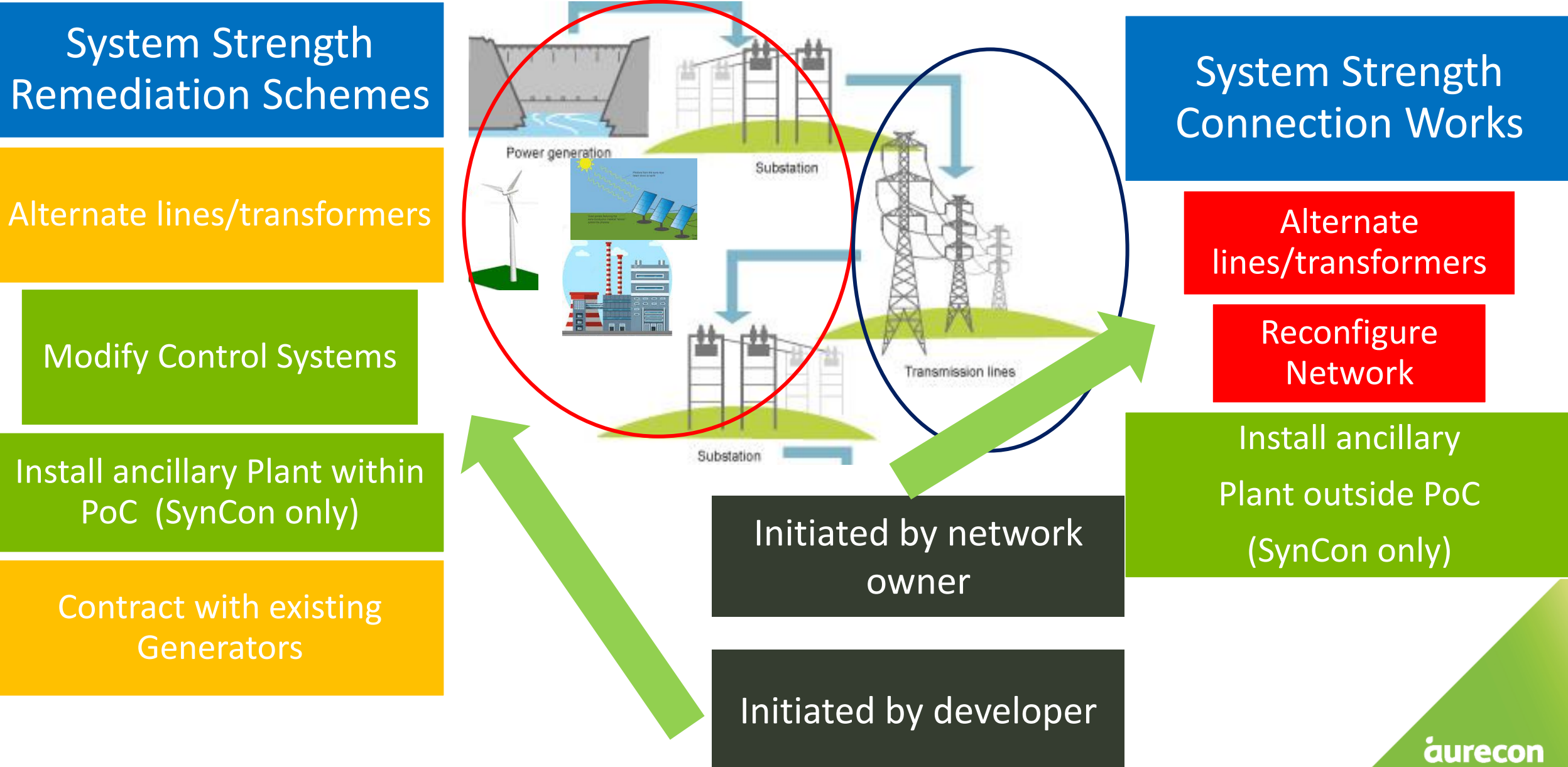
Babak Badrzadeh

24 October 2023

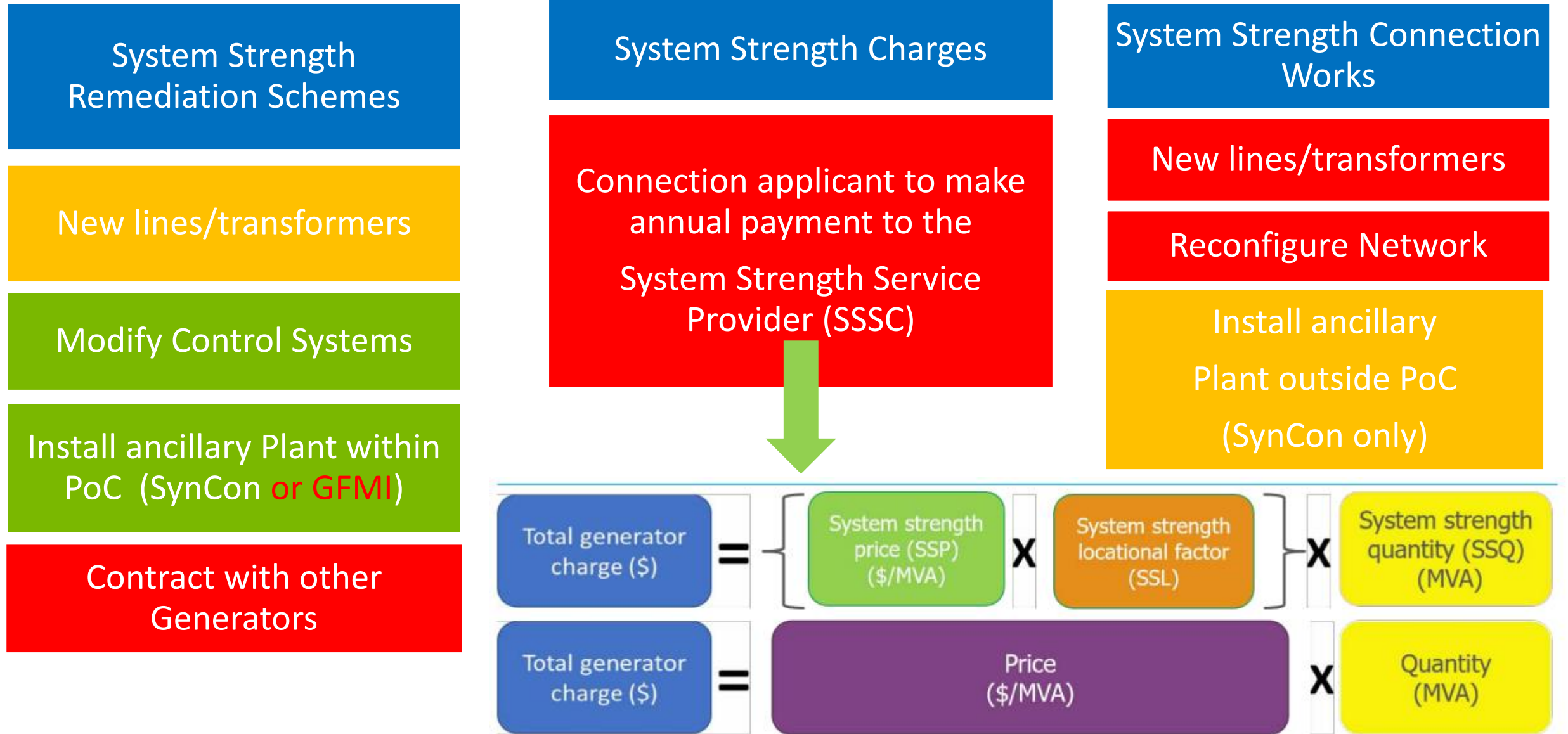
IBR under low system strength conditions (in particular for Wind Farms)

System strength remediations for connecting IBR: 2018

*Bringing ideas
to life*

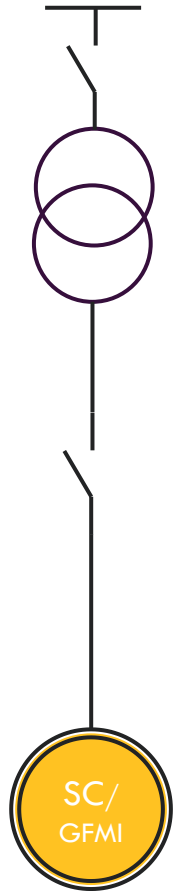


System strength remediations for connecting IBR: 2023

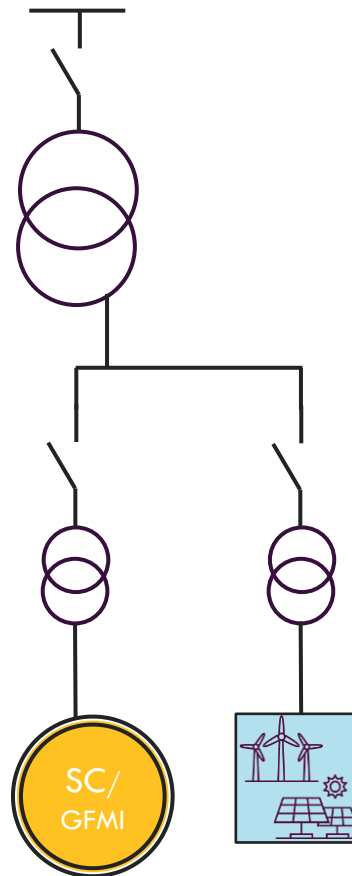


The impact of regulatory and commercial constraints

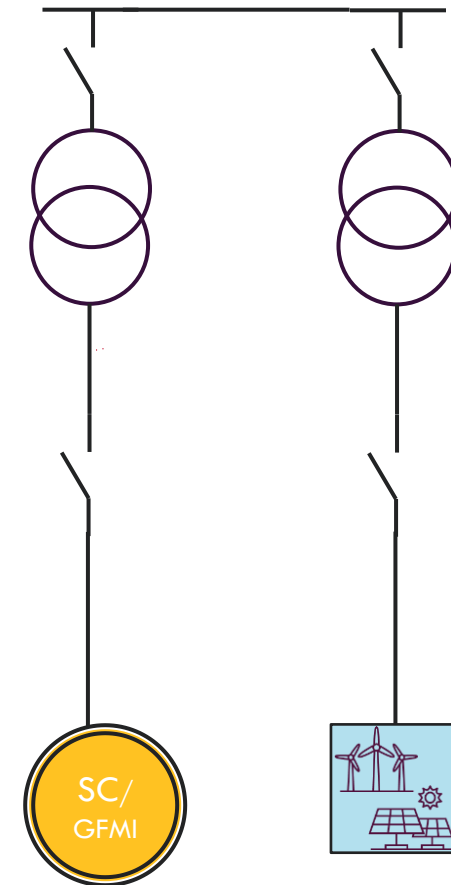
SynCon/GFMI in the wider transmission network



SynCon/GFMI co-located with the GFLI



SynCon/GFMI nearby the GFLI, but with a separate connection point



How is the need for/size of remediation is determined?

Previous approach

- Preliminary impact assessment (PIA) determines the need for the second stage model detailed assessment referred to as full impact assessment (FIA).
- Wide-area EMT studies will determine if an instability exists and the solution addressing the problem.
- No actions is required by the connecting party if no instability is identified.

Current approach

- A reduction in the network fault level based on $\Delta AFL (MVA) = (1.2 - SCR_{Withstand}) \times P_{rated}$ will determine the need for remediation.
- $SSQ = SCR_{Withstand} \times P_{rated}$
- $SCR_{withstand}$ is determined by EMT SMIB studies.
- Most GFLI cannot withstand a SCR of 1.2.
- The connecting party will need to either propose a remediation or opt in for system strength charges.

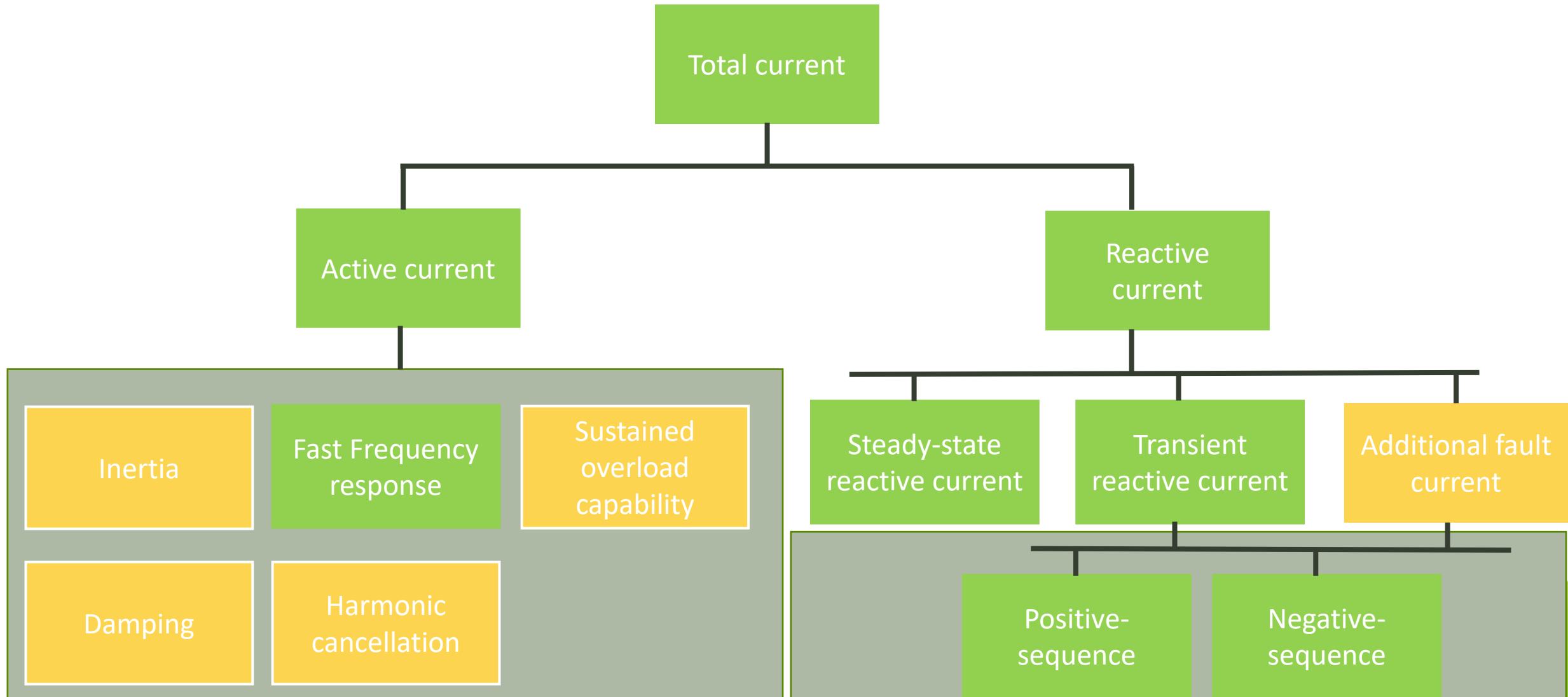
Likely future approach

- A subtle change in the above equation $SSQ = \Delta AFL = (SCR_{Withstand} - 1.2) \times P_{rated}$
- Smaller charges if the connecting party opt in for system strength charges.
- Rule change submitted in September 2023.

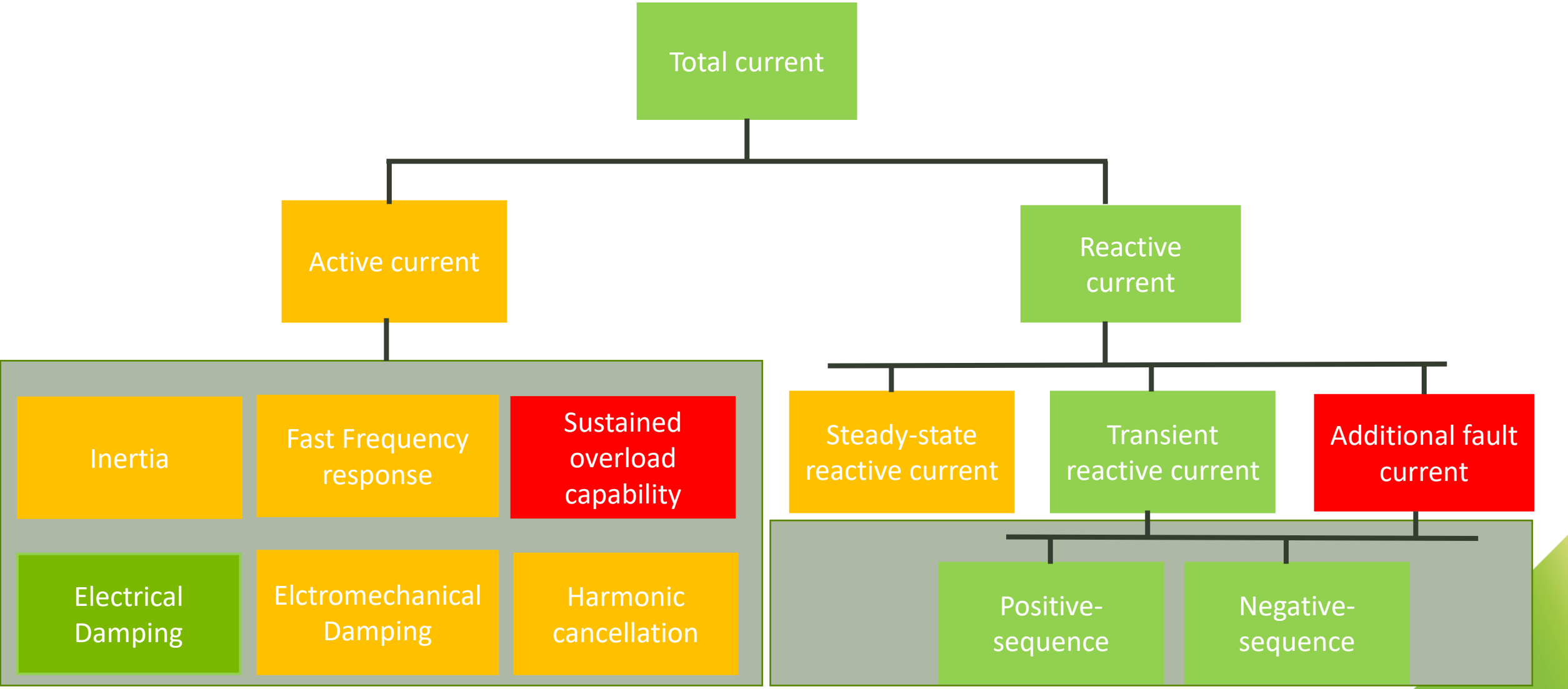
Grid-forming BESS under medium system strength conditions

Current prioritisation in grid forming inverters (excerpt from ESIG FW 2022 presentation)

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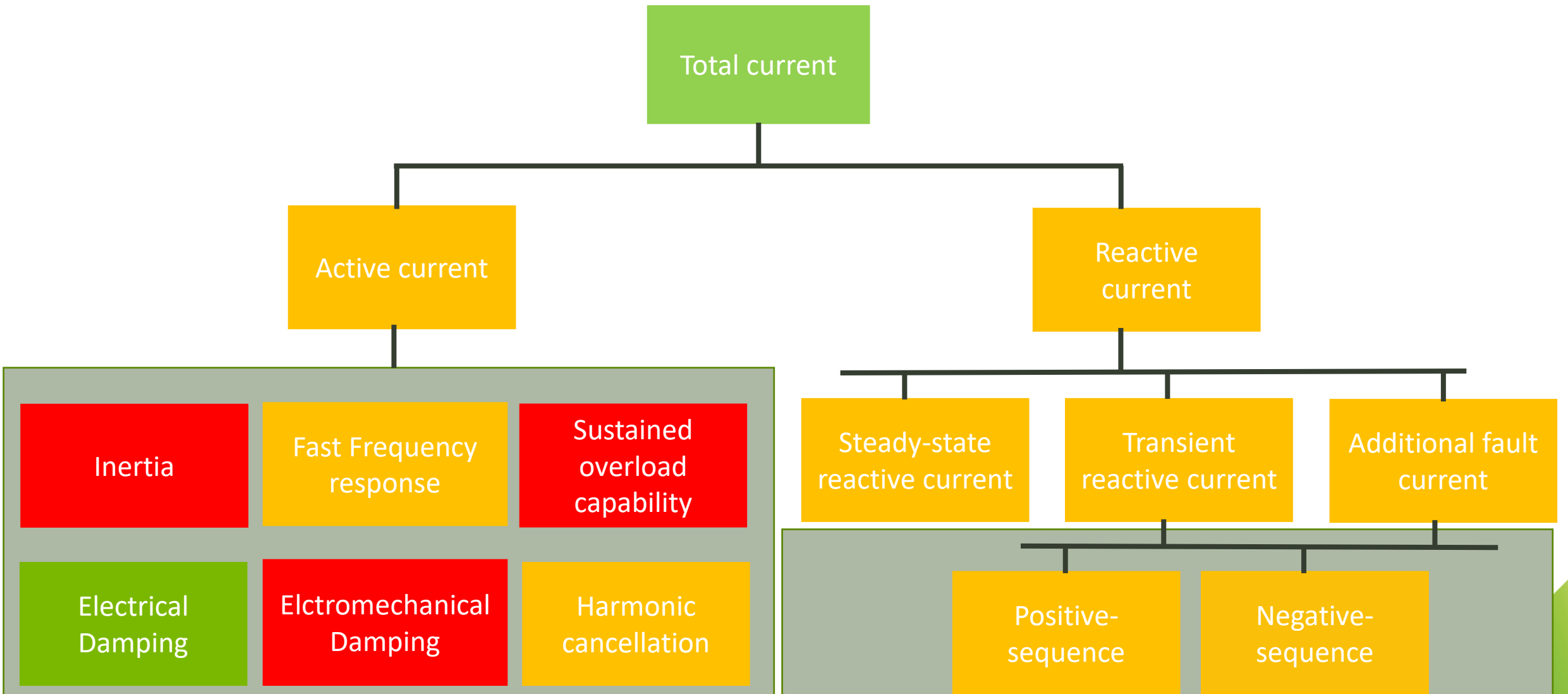
Capabilities most required



Grid-forming BESS under low system strength conditions

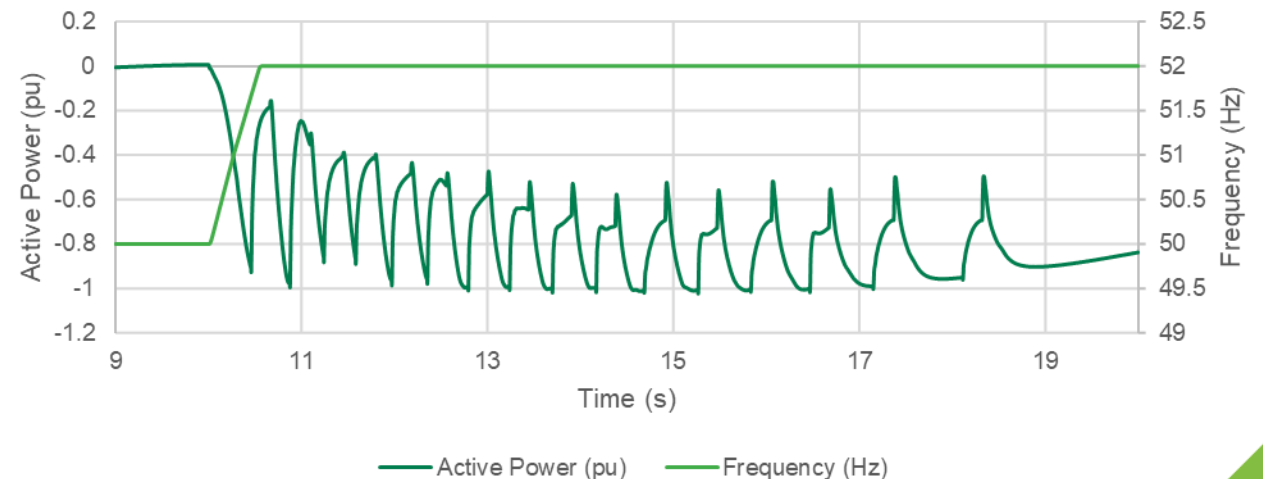
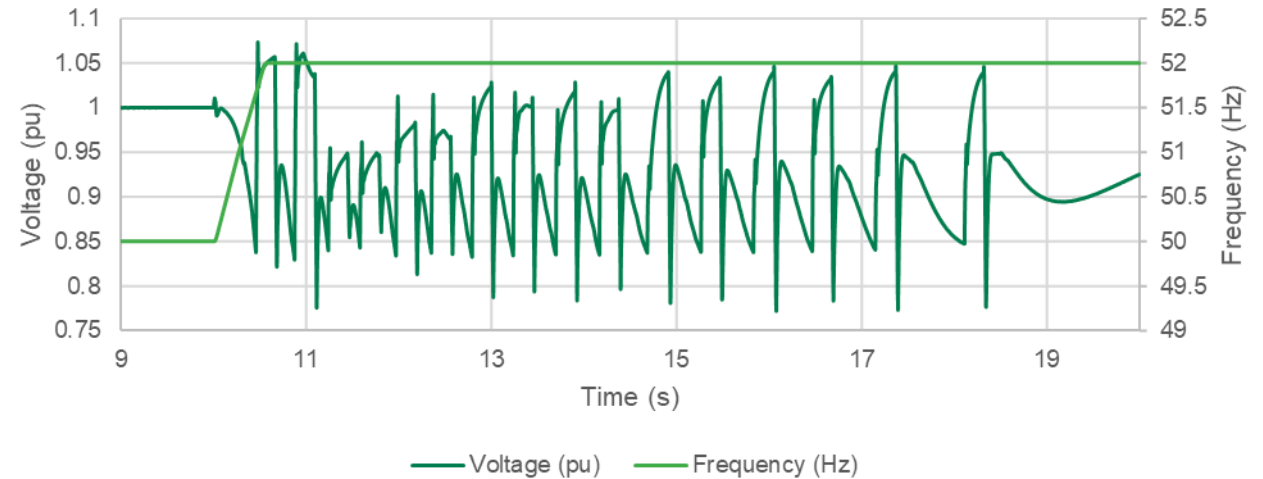
Capabilities most required

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Voltage collapse

- Virtual inertia/frequency response
- Low SCR conditions
- Active power flow change drives change in voltage
- Voltage rise/collapse ensues
- Voltage FRT re-striking occurs



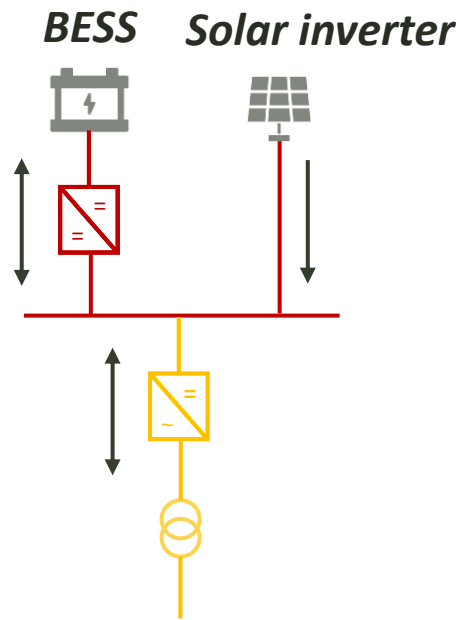
Variable speed doubly-fed induction machine (DFIM) pumped hydro

Technology comparison from a system stability perspective

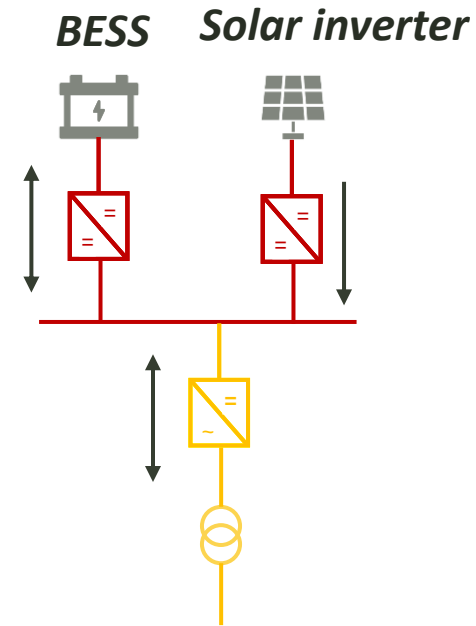
Characteristic	Fixed-speed pumped hydro	Doubly-fed pumped hydro	BESS	Type 3 Wind Farm
Bidirectional operation	✓	✓	✓	✗
SynCon operation	✓	✓	✗	✗
Operating conditions need to be studied				
Ease of mode switchover				N/A
Frequency control when operating as a load				N/A
Quality and quantity of response to frequency disturbances				
The need for dynamic reactive support plant				
Dynamic model maturity				
Impact on system strength				
Ability to ride through multiple voltage disturbances in quick succession				

AC and DC hybrid BESS and Solar PV

DC coupled BESS and PV



Option 1: DC/DC converter for BESS only



Option 2: DC/DC converter for BESS and PV

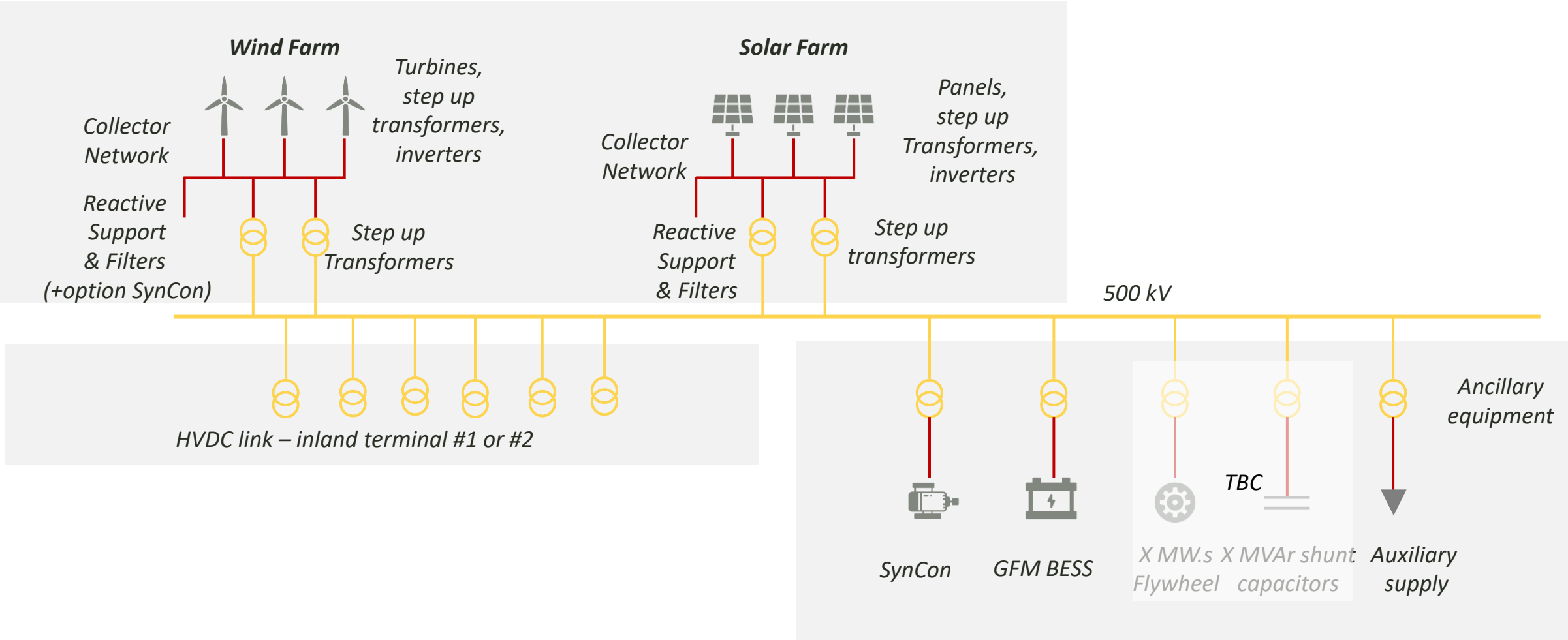
Technology comparison

Characteristic	Standalone BESS	Standalone PV	AC hybrid	DC hybrid
DC/DC converter	Optional	Optional	Not common	Essential
Efficiency				
Number of scenarios for grid connection studies				
Attractiveness for large scale development				
Dynamic model maturity				
Ease of modelling in phasor-domain simulation tools				
Grid-forming capability				
Speed of frequency response				
Risk of unit transformer saturation				

Stand-alone energy islands, a taste of the future

Energy island system configurations

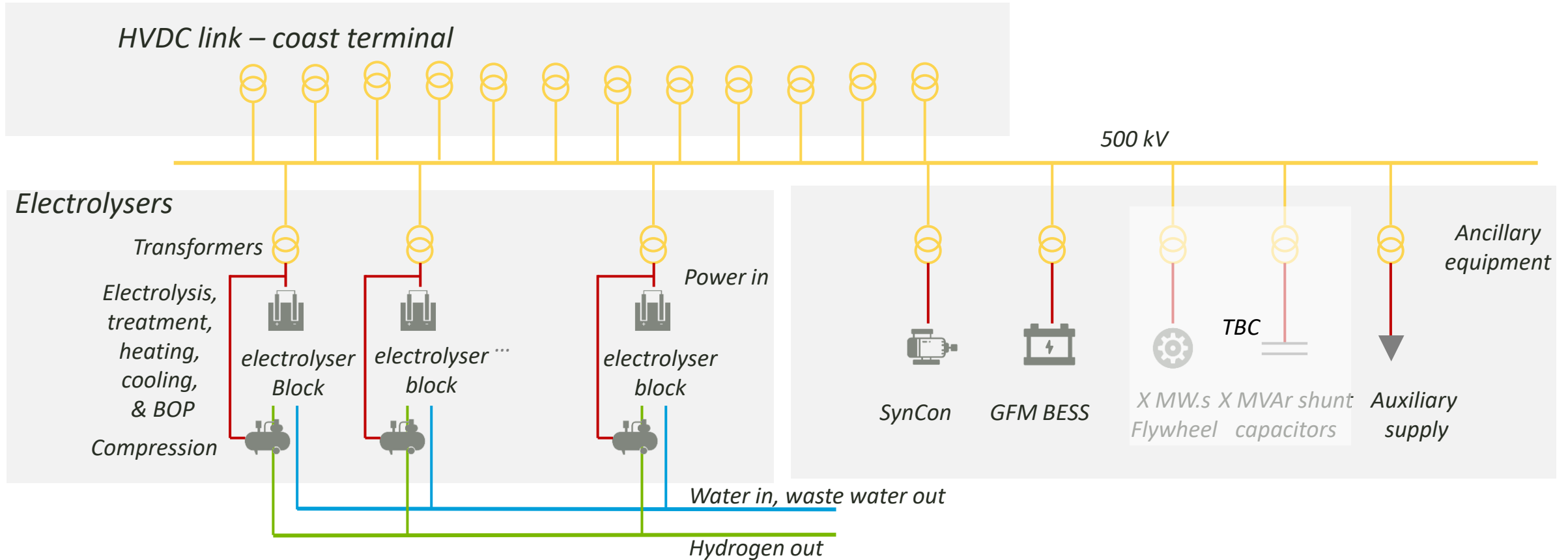
Generation and ancillary equipment arrangement



BESS and synchronous condensers can be alternatively located in the wind farm and solar farm systems.

Advice on renewable hub system configurations

H2 load and ancillary equipment arrangement



Electrolysers might require harmonic filters

Quantification of grid support assets

- Preferred approach is a combination of GFM BESS and synchronous condensers at the both ends of the HVDC link.
- With GFM HVDC maturing, solutions avoiding installation of equipment offshore will be preferred.

Option	Side	Grid-forming BESS (%)	Grid-following BESS (%)	Synchronous condensers (%)	Grid-forming VSC HVDC (%)	Overall score
1	Load			20-40		Unstable
	Generation			25-50		
2	Load	20-40				Potentially stable but the technology is not demonstrated for this application or scale.
	Generation	25-50				
3	Load	20-40				Potentially stable but the technology is not demonstrated for this application or scale.
	Generation			25-50		
4	Load			20-40		Potentially stable but the technology is not demonstrated for this application or scale.
	Generation	25-50				
5	Load	10-20		10-20		Stable with proven technology
	Generation	12-25		12-25		
6	Load		20-40	20-40		Stable with proven technology
	Generation		20-40	25-50		
7	Load				100	Unstable
	Generation					

Option	Side	Grid-forming BESS (%)	Grid-following BESS (%)	Synchronous condensers (%)	Grid-forming VSC HVDC (%)	Overall score
8	Load		20-40		100	Unstable
	Generation		20-40			
9	Load				100	Potentially stable but the technology is not demonstrated for this application or scale.
	Generation	25-50				
10	Load				100	Potentially stable but the technology is not demonstrated for this application or scale.
	Generation			25-50		
11	Load				100	Potentially stable but the technology is not demonstrated for this application or scale.
	Generation		20-40	25-50		
12	Load	20-40			100	Potentially stable but the technology is not demonstrated for this application or scale.
	Generation					
13	Load		20-40	20-40	100	Unstable
	Generation					

Unstable	Unstable
Potentially stable but the technology is not demonstrated for this application or scale.	Potentially stable but the technology is not demonstrated for this application or scale.
Stable with proven technology	Stable with proven technology