IBR Grid Connection Studies – Lessons Learned

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

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System strength remediations for connecting IBR: 2018

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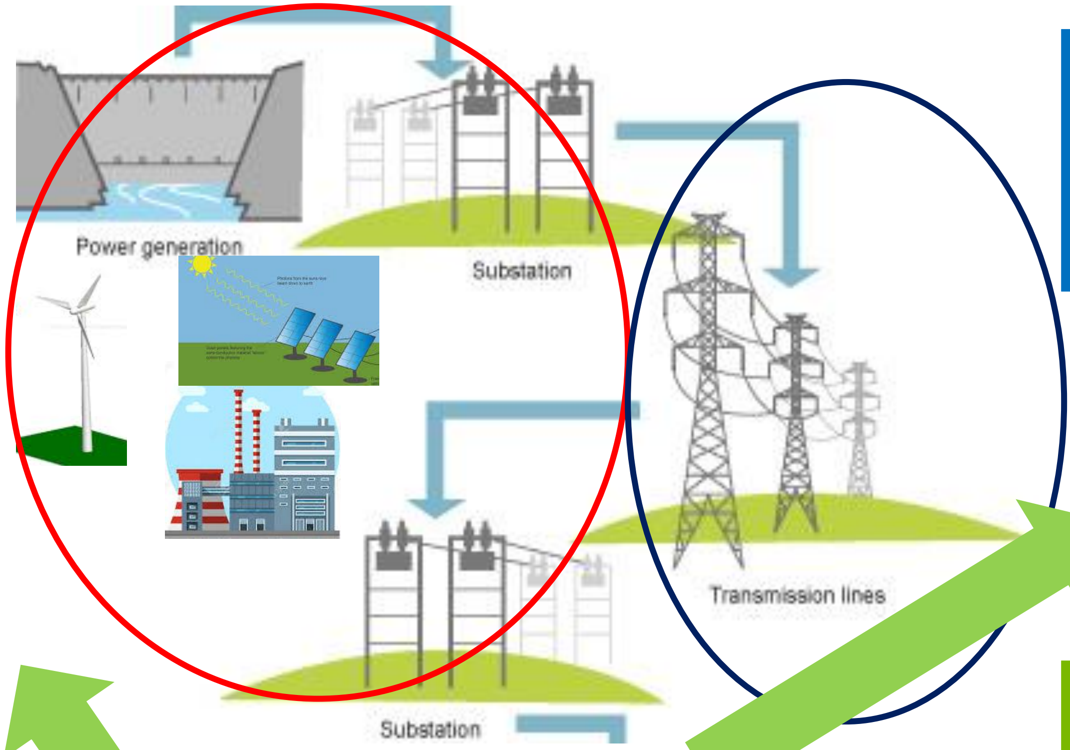
System Strength Remediation Schemes

Alternate lines/transformers

Modify Control Systems

Install ancillary Plant within PoC (SynCon only)

Contract with existing Generators



System Strength Connection Works

Alternate lines/transformers

Reconfigure Network

Install ancillary Plant outside PoC (SynCon only)

Initiated by network owner

Initiated by developer

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System strength remediations for connecting IBR: 2023

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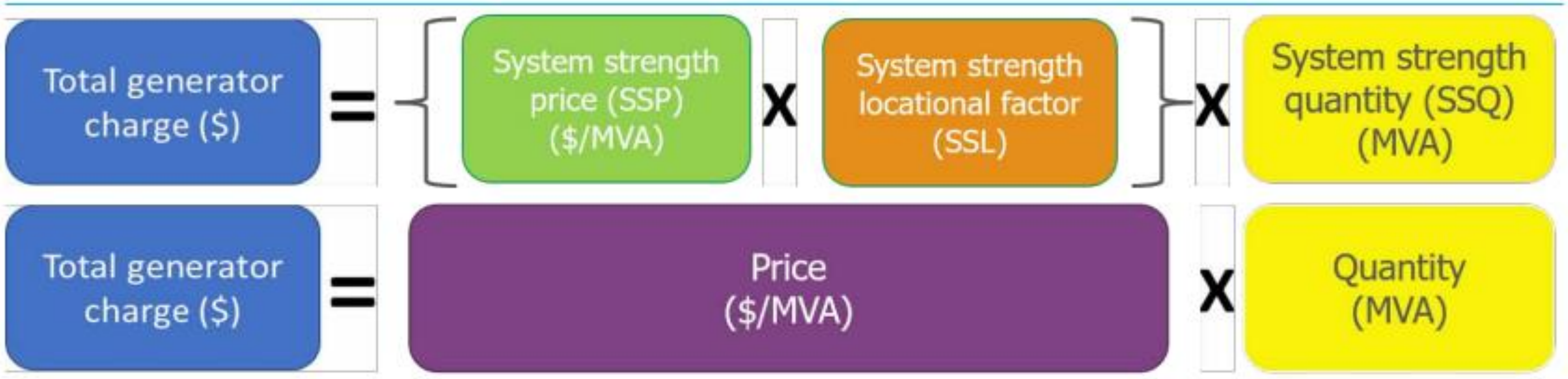
System Strength Remediation Schemes

- New lines/transformers
- Modify Control Systems
- Install ancillary Plant within PoC (SynCon or GFMI)
- Contract with other Generators

System Strength Charges

Connection applicant to make annual payment to the

System Strength Service Provider (SSSC)



Source: AEMC

System Strength Connection Works

- New lines/transformers
- Reconfigure Network
- Install ancillary Plant outside PoC (SynCon only)

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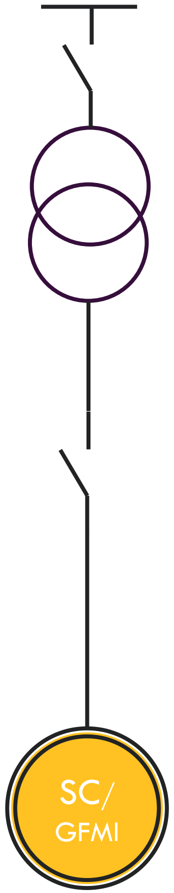
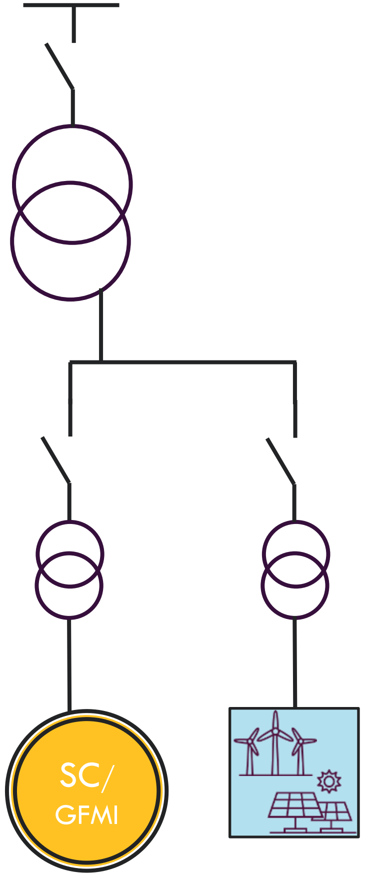
The impact of regulatory and commercial constraints

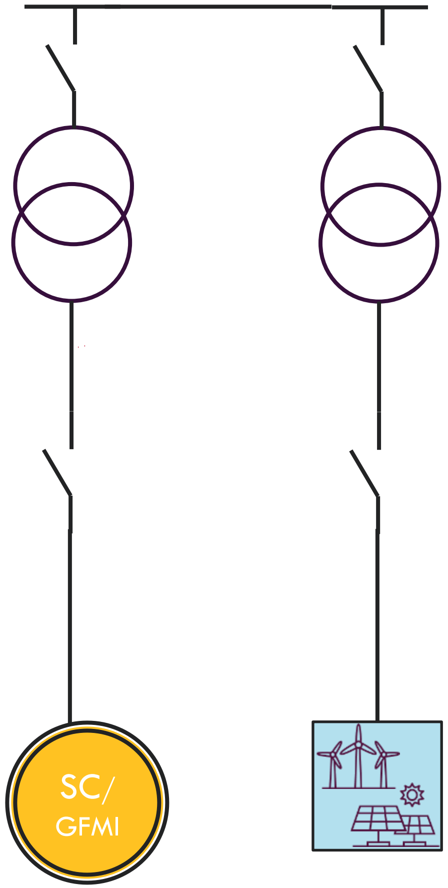
SynCon/GFMI in the wider transmission network



SynCon/GFMI co-located with the GFLI



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



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

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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 $\Delta\mathrm{AFL}\ (\mathrm{MVA}) = (1.2 - \mathrm{SCR}_{\mathrm{Withstand}}) \times \mathrm{P}_{\mathrm{rated}}$ will determine the need for remediation.
- $\mathrm{SSQ} = \mathrm{SCR}_{\mathrm{Withstand}} \times \mathrm{P}_{\mathrm{rated}}$
- $\mathrm{SCR}_{\mathrm{withstand}}$ 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 $\mathrm{SSQ} = \Delta\mathrm{AFL} = (\mathrm{SCR}_{\mathrm{Withstand}} - 1.2) \times \mathrm{P}_{\mathrm{rated}}$
- Smaller charges if the connecting party opt in for system strength charges.
- Rule change submitted in September 2023.

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Grid-forming BESS under medium system strength conditions

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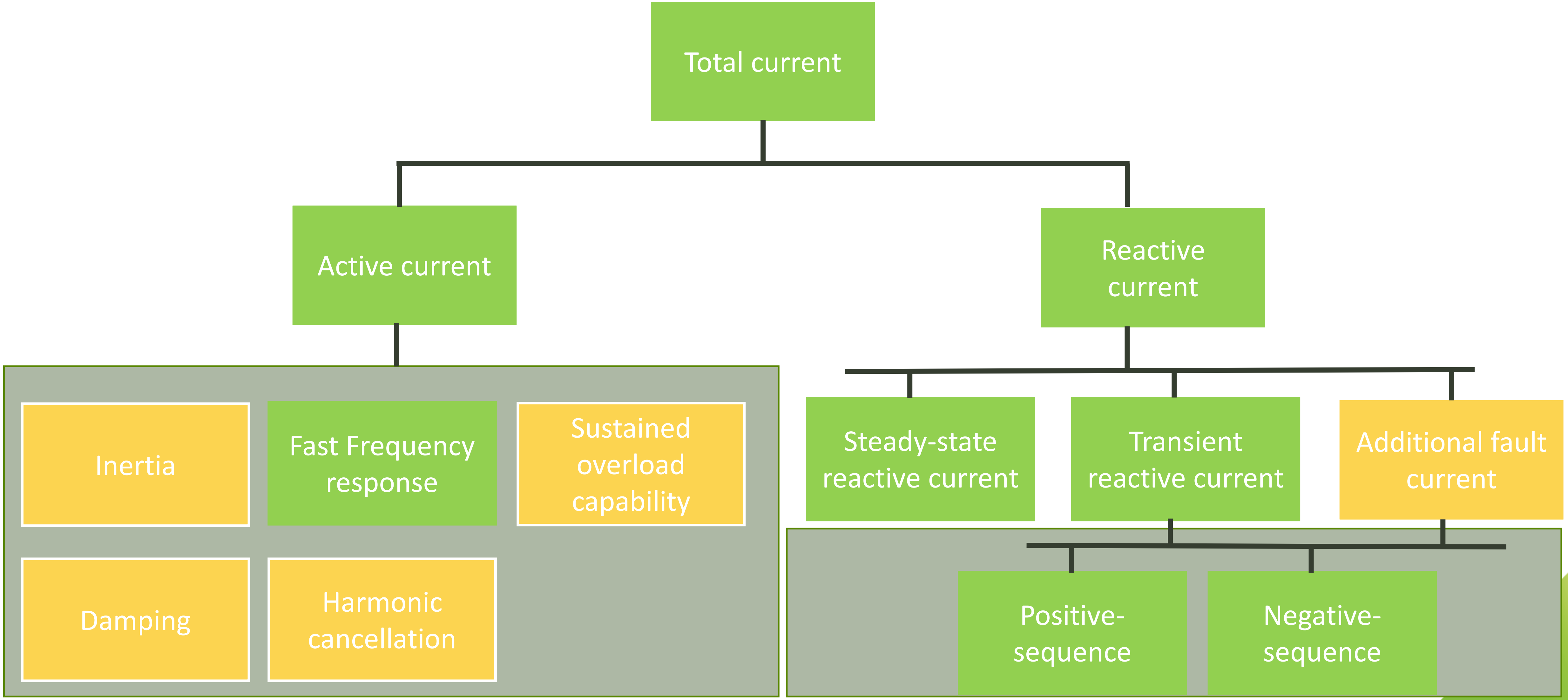
Current prioritisation in grid forming inverters (excerpt from ESIG FW 2022 presentation)



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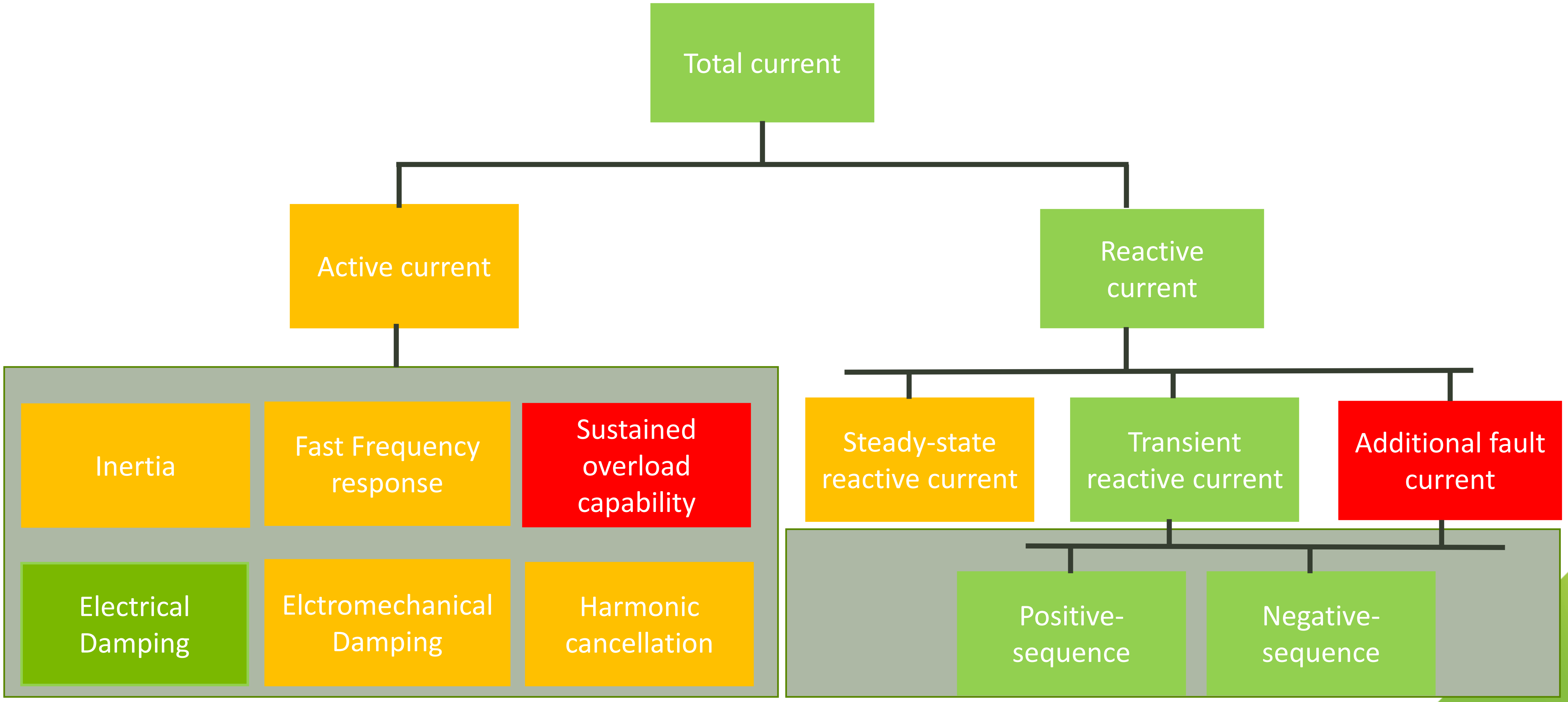
Capabilities most required



Grid-forming BESS under low system strength conditions

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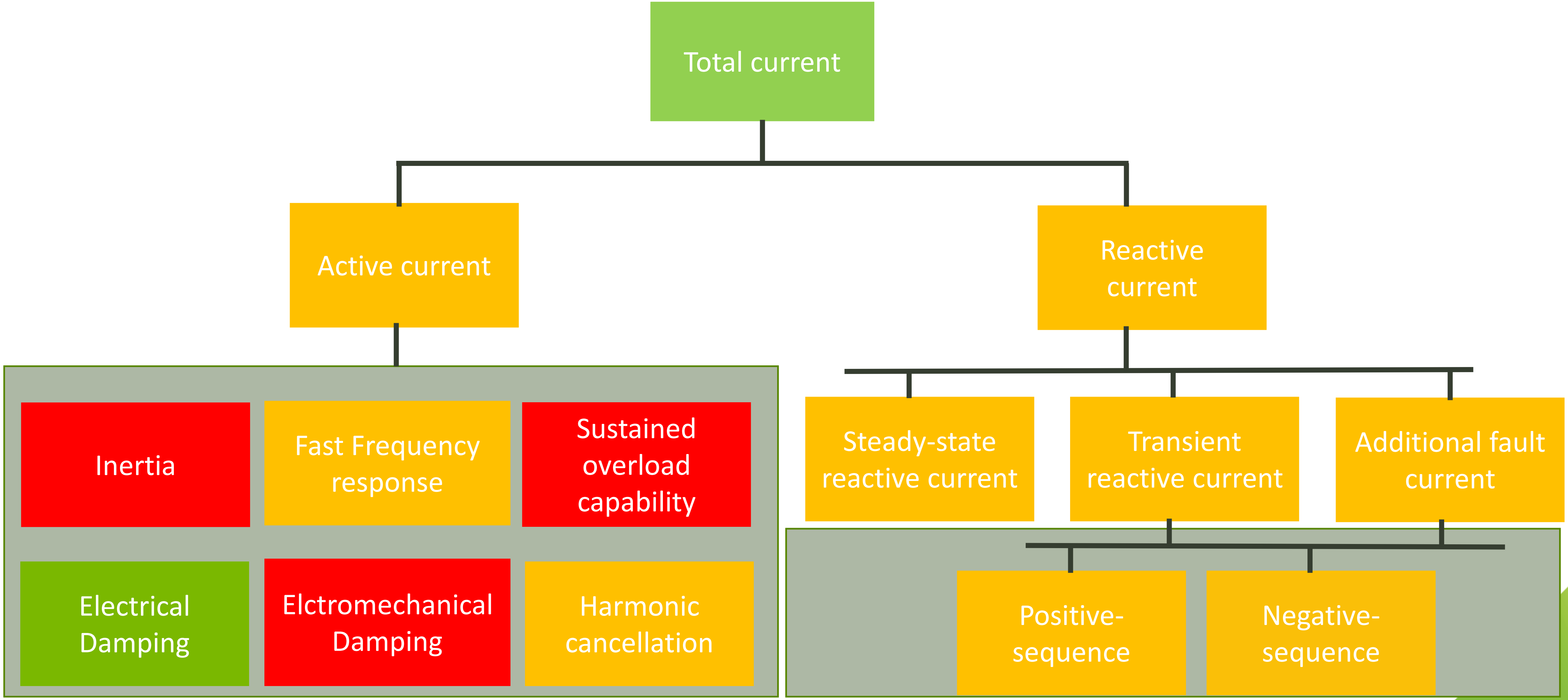
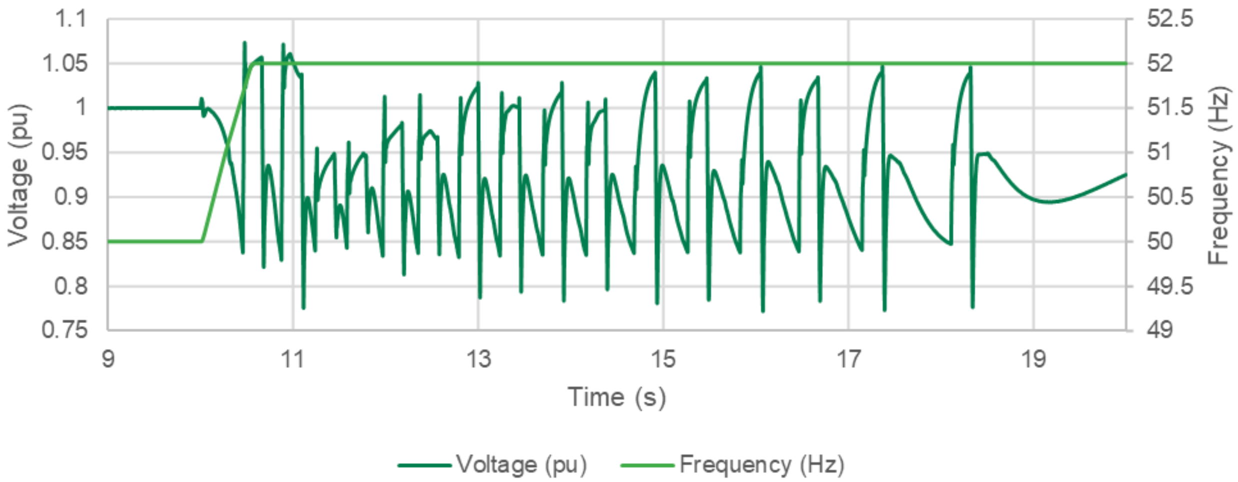
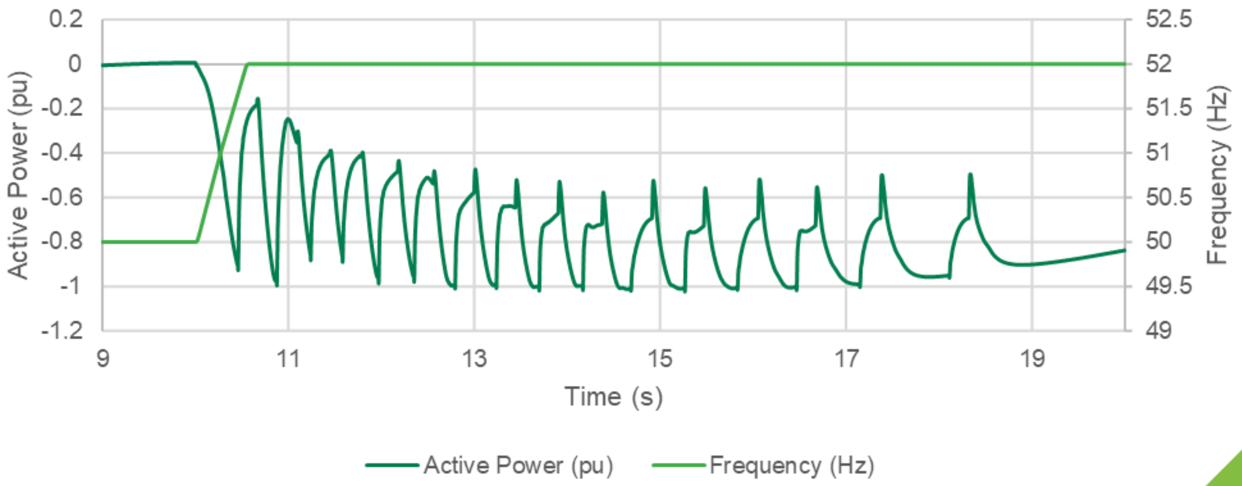
Capabilities most required



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





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

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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

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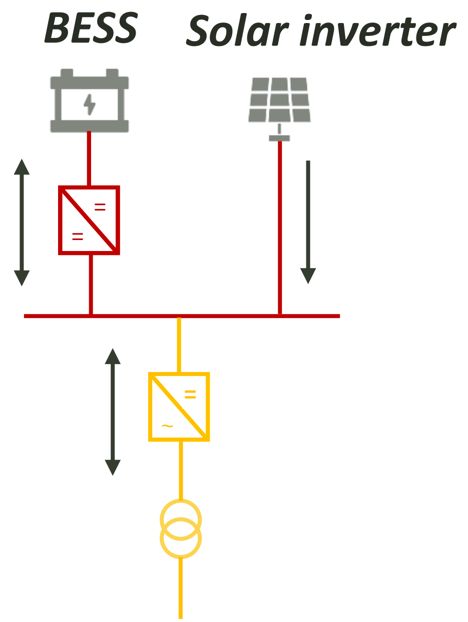
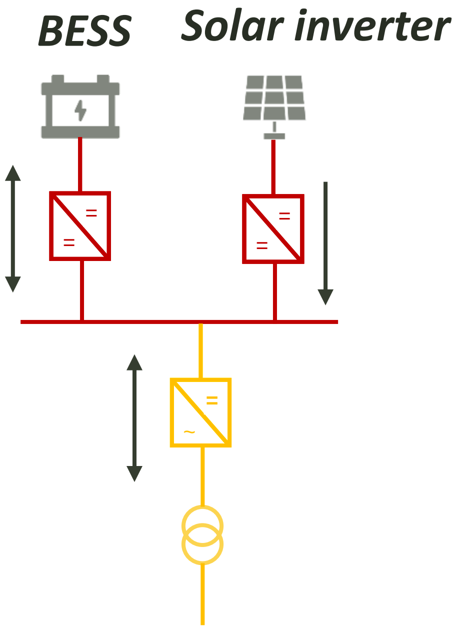
DC coupled BESS and PV



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

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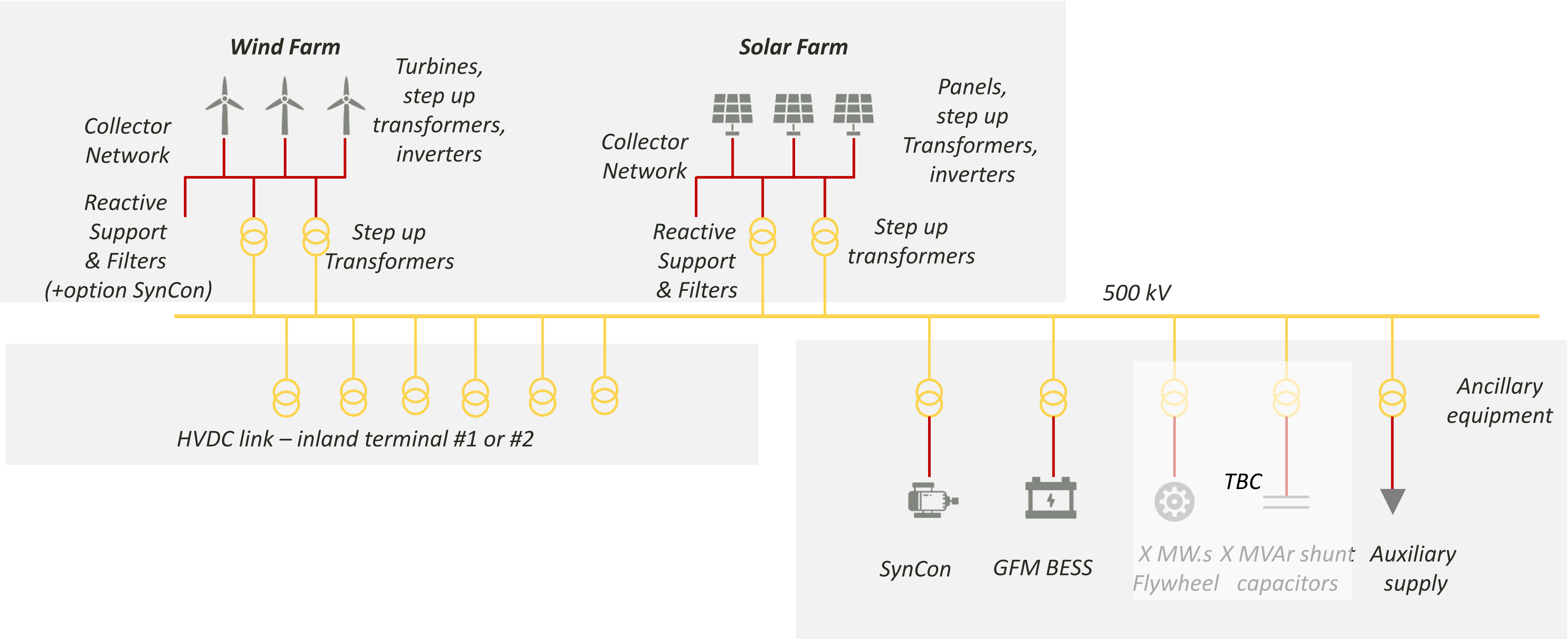
Energy island system configurations

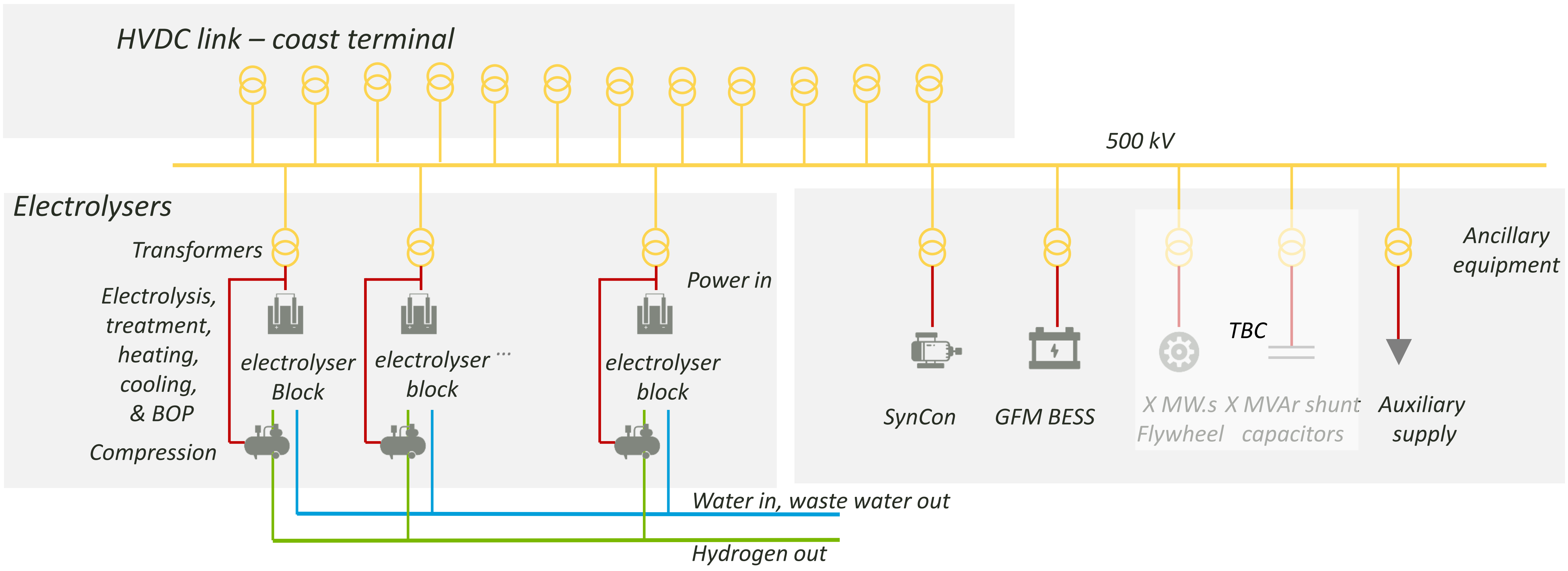
Generation and ancillary equipment arrangement



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		
	Generation			25-50		
2	Load	20-40				
	Generation	25-50				
3	Load	20-40				
	Generation			25-50		
4	Load			20-40		
	Generation	25-50				
5	Load	10-20		10-20		
	Generation	12-25		12-25		
6	Load		20-40	20-40		
	Generation		20-40	25-50		
7	Load				100	
	Generation					

Option	Side	Grid-forming BESS (%)	Grid-following BESS (%)	Synchronous condensers (%)	Grid-forming VSC HVDC (%)	Overall score
8	Load		20-40		100	
	Generation		20-40			
9	Load				100	
	Generation	25-50				
10	Load				100	
	Generation			25-50		
11	Load				100	
	Generation		20-40	25-50		
12	Load	20-40			100	
	Generation					
13	Load		20-40	20-40	100	
	Generation					

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