Indirect Current Control Grid Forming Converter Challenges and Limitations During Faults

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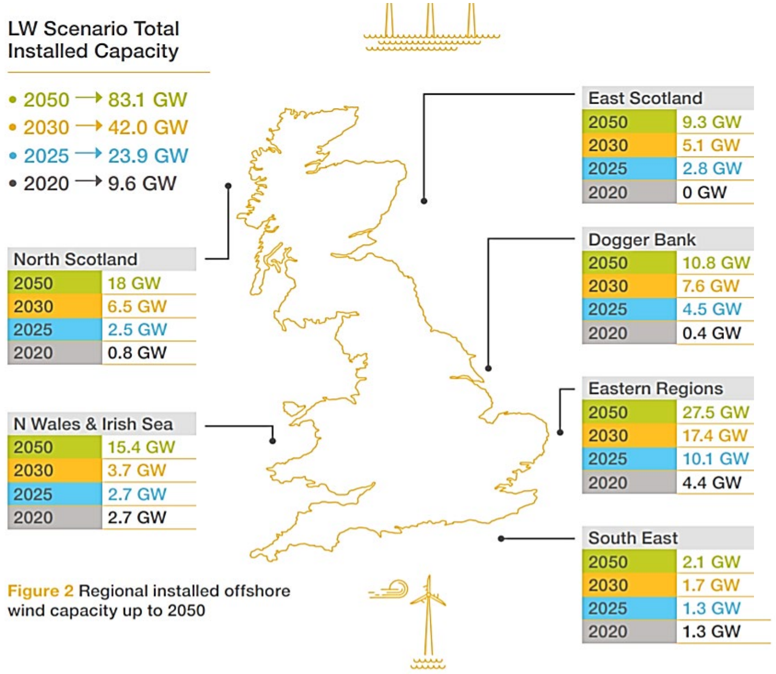
2- ORE CATAPULT

Contents

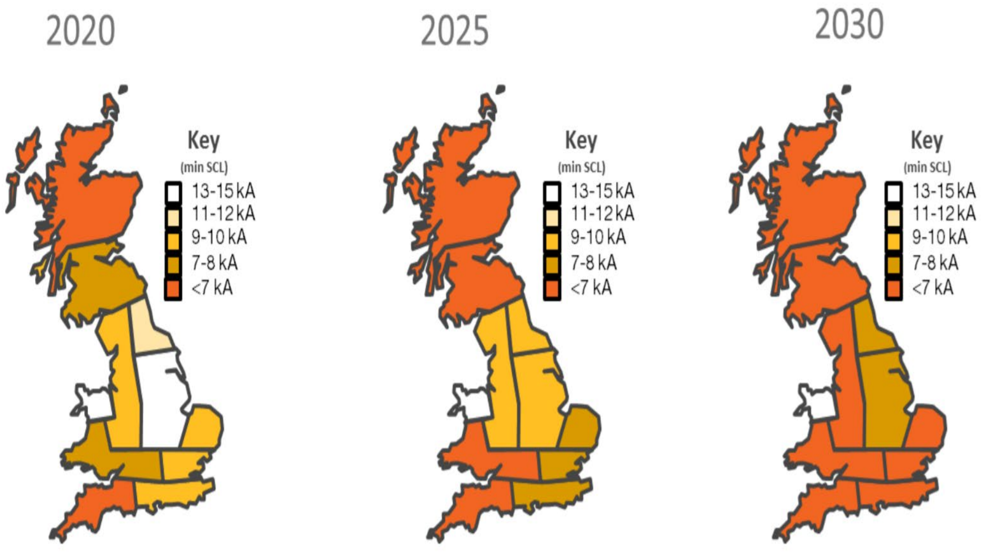
Objective of research

Renewable energy penetration



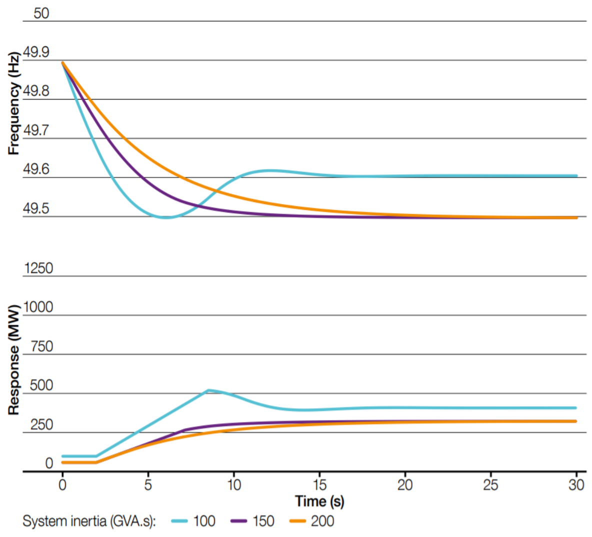
Increase of renewable energy penetration[1]

Fault current



Decrease of regional short circuit level over the next years[2]

Inertia



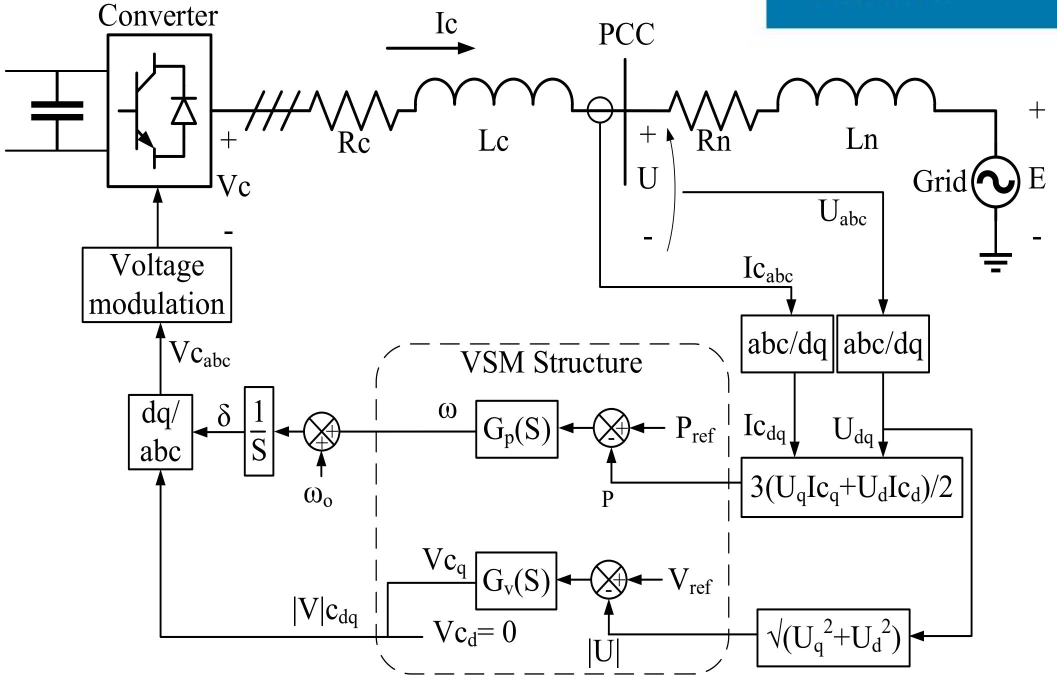
Frequency containment simulation of 500MW generation loss on a 20 MW system[3]

[1] Source: https://www.nationalgrideso.com/document/177296/download
[2] Source: https://www.nationalgrideso.com/document/135561/download
[3} Source: https://www.nationalgrid.com/sites/default/files/documents/8589937803-SOF%202016%20-%20Full%20Interactive%20Document.pdf

Objective of research

Solution	Estimated Cost	RoCoF [1] [2]	Sync Torque/Power (Voltage Stability/Ref) [2] [*] [4]	Prevent Voltage Collapse [2]	Prevent Sub-Sync Osc. / SG Compitable [2] [*]	Hi Freq Stability [2]	RMS Modelling [1] [2] [*] [4]	Fault Level [1] [2]	Post Fault Over Volts [2]	Harmonic & Imbalance [5]	System Level Maturity	Notes
Constrain Asyncronous Generation	Hgh	I	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Proven	These technologies are or have the potential to be Grid Forming / Option 1
Syncronous Compensation or More Sync. Gens at lower load	High	I	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Proven	
VSM	Medium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	P	Modelled	
VSM0H	Low	No	Yes	Yes	No	P	P	P	Yes	P	Modelled	Has the potential to contribute but relies on the above Solutions
Synthetic Inertia	Medium	Yes	No	No	P	No	No	No	No	No	Modelled	
Other NG Projects	Low	Yes	P	Yes	No	No	No	P	P	No	Theoretical	

Ierna, Richard, Johnson, Anthony, Marshall, Ben, Urdal, Helge, Li, Can, Sumner, Mark and Egea-Àlvarez, Agustí, **Dispatching parameters, strategies and associated algorithm for VSM (virtual synchronous machines) and HGFC (hybrid grid forming convertors)** , wind Integration Workshop 2019



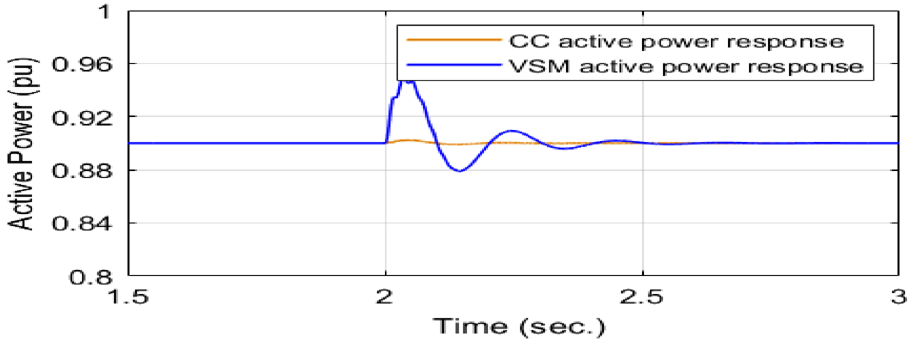
$$G_p = k_p + k_i \frac{1}{S} = \frac{D k_i}{P_{maximum}} + \left(\frac{\omega_0}{2H\ S_{rated}}\right)\left(\frac{1}{S}\right)$$

Where:

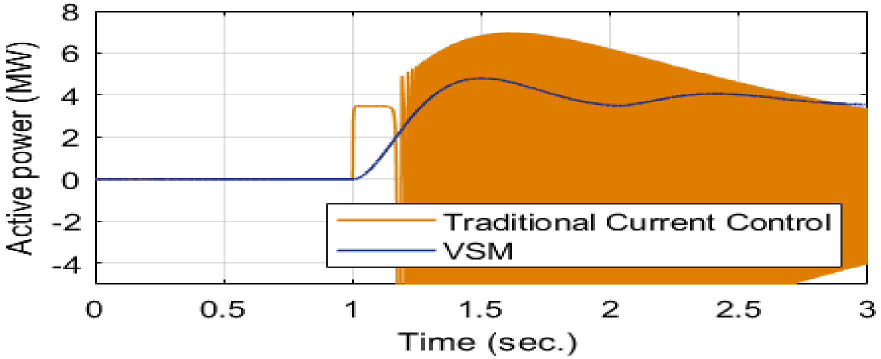
H Inertia constant

D Damping factor

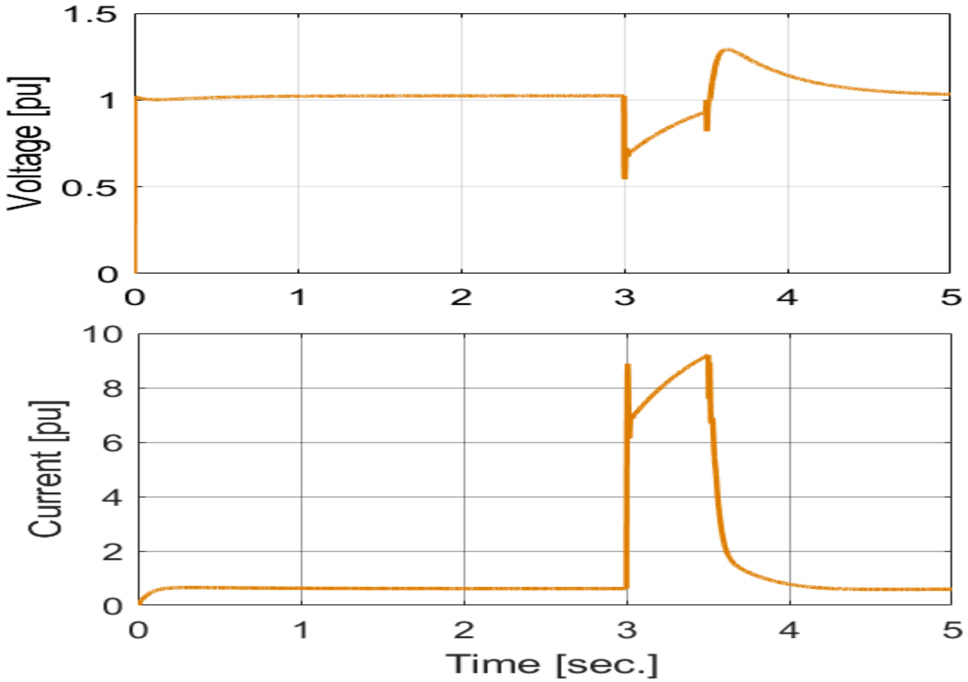
Objective of research



(a) Frequency drop comparison



(b) Low SCR comparison (SCR = 1.6)



PCC Voltage and current waveforms when the basic VSM structure is subjected to a **Three phase to ground fault (no current limitation).**

Advantages:

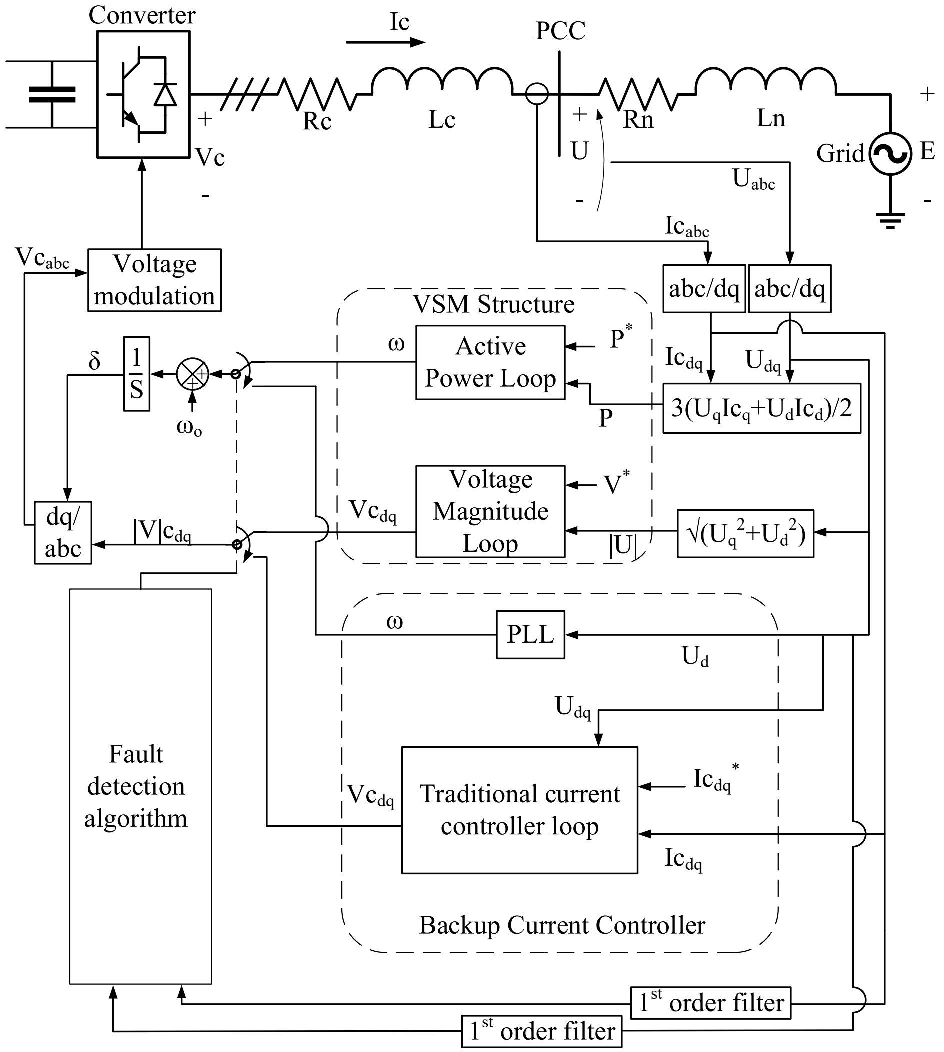
(a) VSM provides Inertial response

(b) VSM has better performance in weak grids

Disadvantages:

FRT capability (**PhD challenge**)

Control structure



Normal condition:

- Active power loop responsible for converter synchronization
- Voltage controller responsible for controlling the voltage magnitude

Fault condition:

- Current control loop responsible for controlling the current during fault
- PLL responsible for synchronization during fault

Fault detector algorithm:

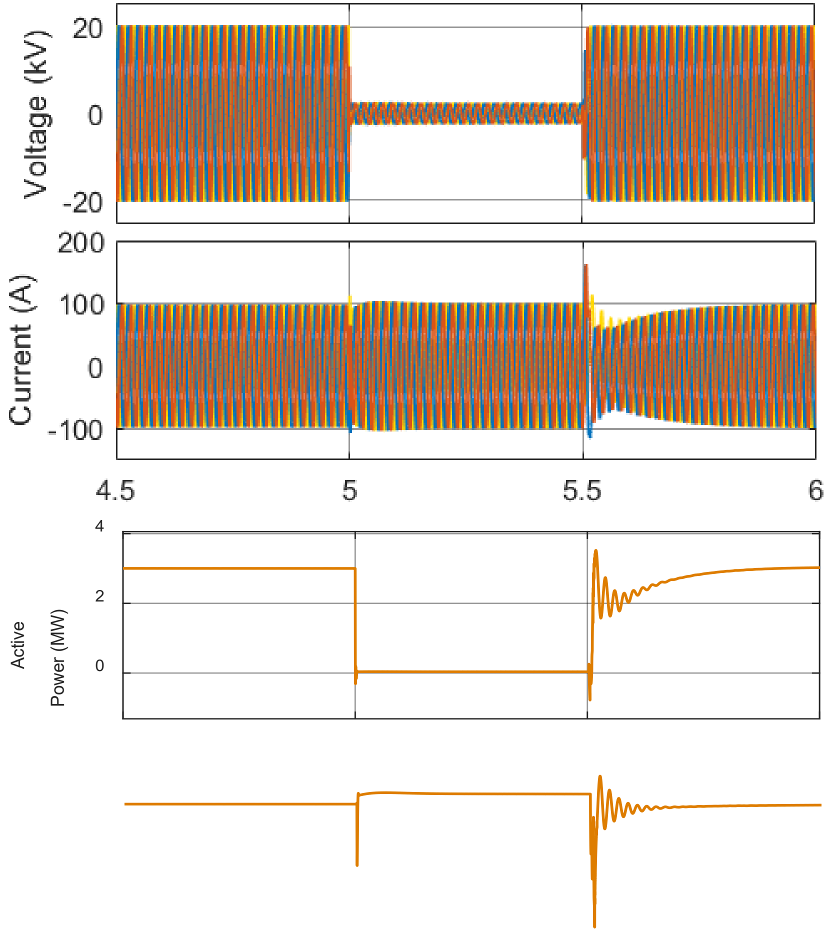
$$|U| < 0.9 \times U_{rated} \quad (1)$$

$$|I| > I_{rated} \quad (2)$$

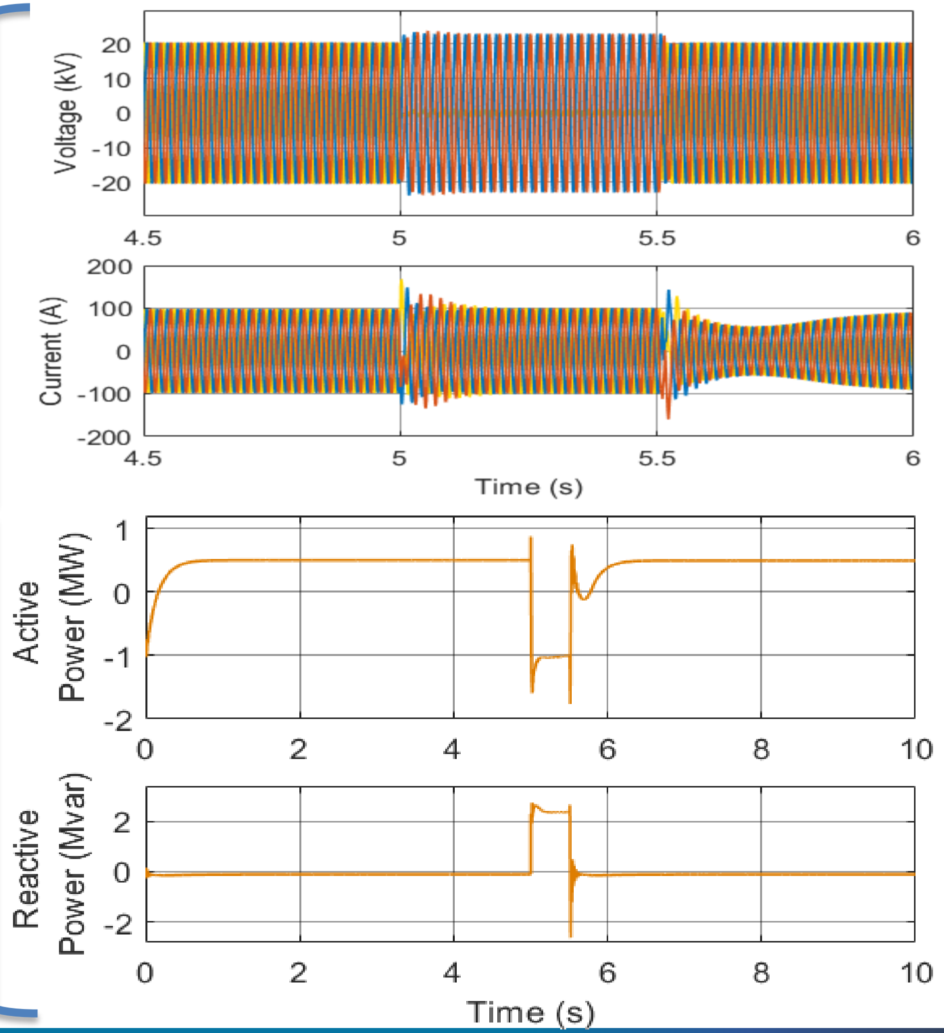
$$Algorithm = \begin{cases} eq.(1)\ or\ eq.(2)\ is\ true, & signal = 1 \\ eq.(1)\ and\ eq.(2)\ are\ false, & signal = 0 \end{cases}$$

Control structure

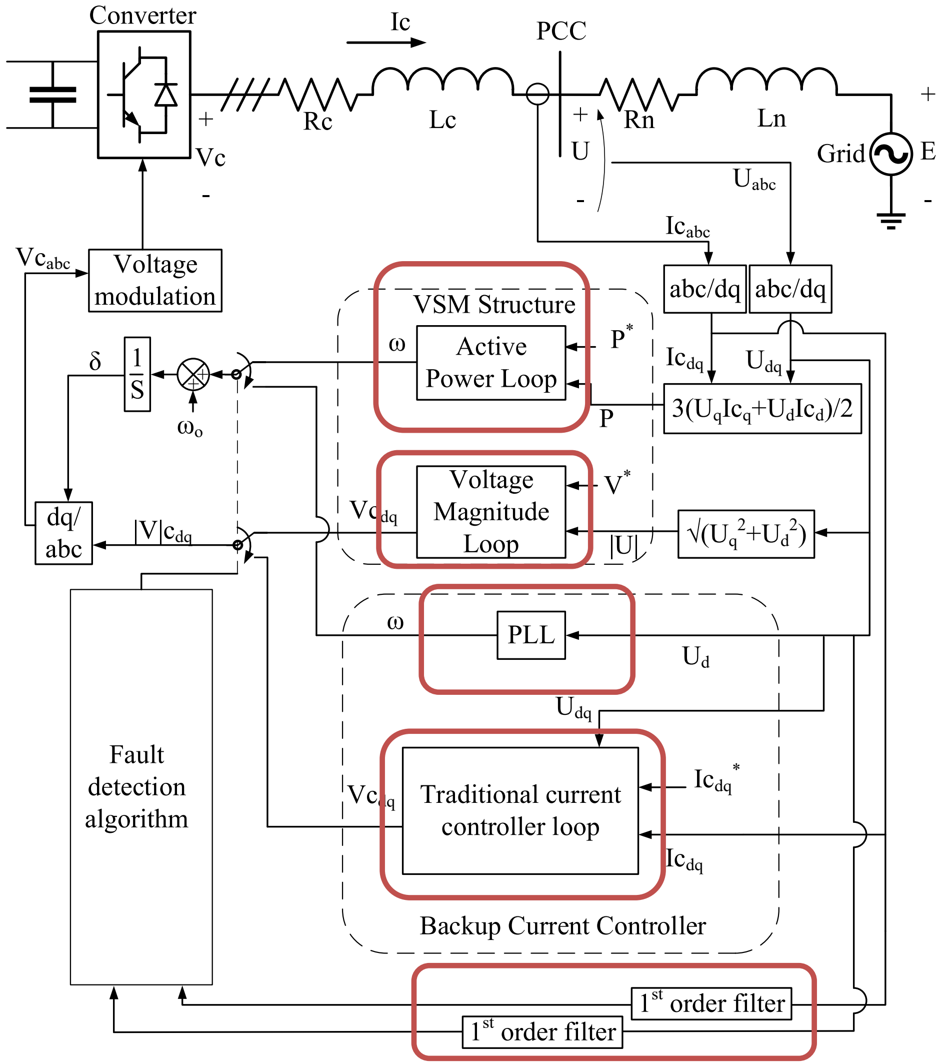
Balanced fault



Unbalanced fault



Factors affecting the response

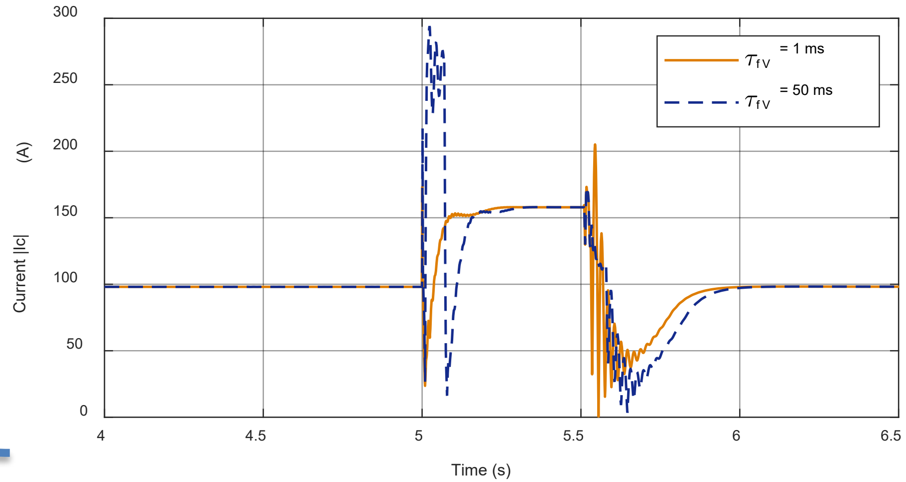


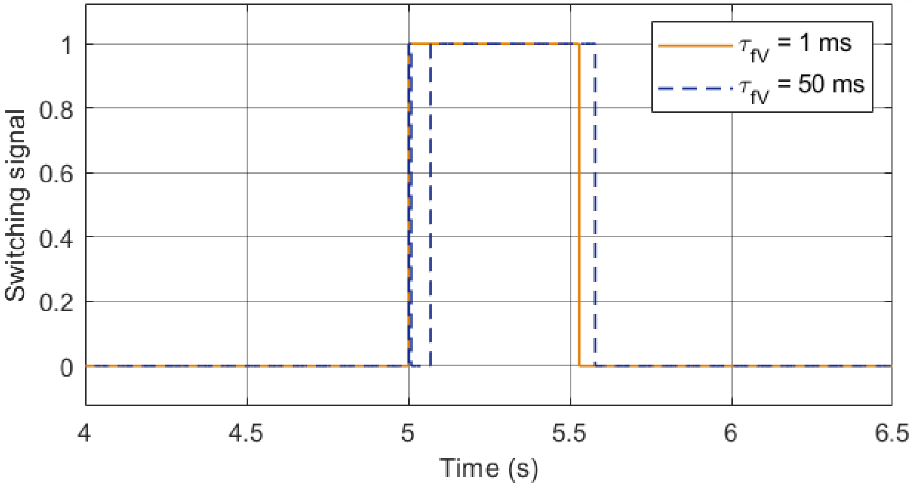
The components studied for showing the tuning recommendation of this structure are:

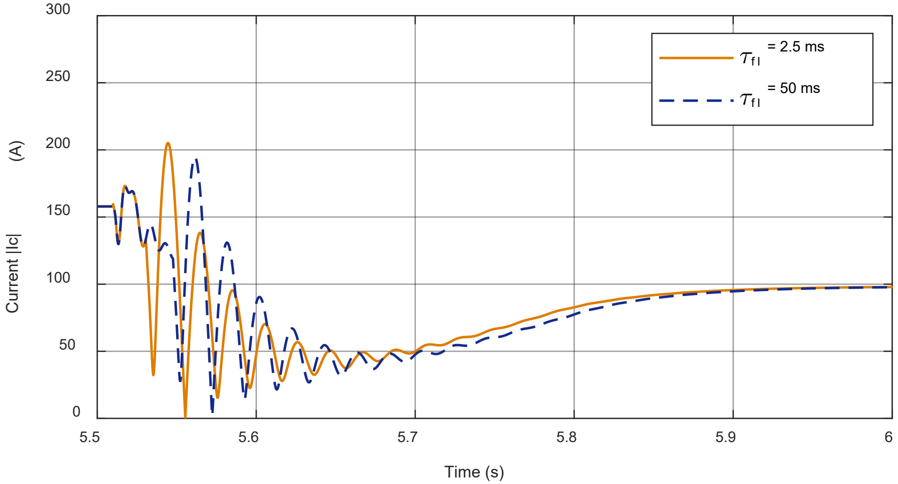
- The time constant of the voltage first order (τ_{fv})
- The time constant of the current first order (τ_{fi})
- The bandwidth of the PLL (ω_{PLL})
- The time constant of the CC (τ_{CC})
- The tuning ratio of the active power loop $\left(\frac{k_{ip}}{k_{pp}}\right)$
- The tuning ratio of the voltage loop $\left(\frac{k_{iv}}{k_{pv}}\right)$

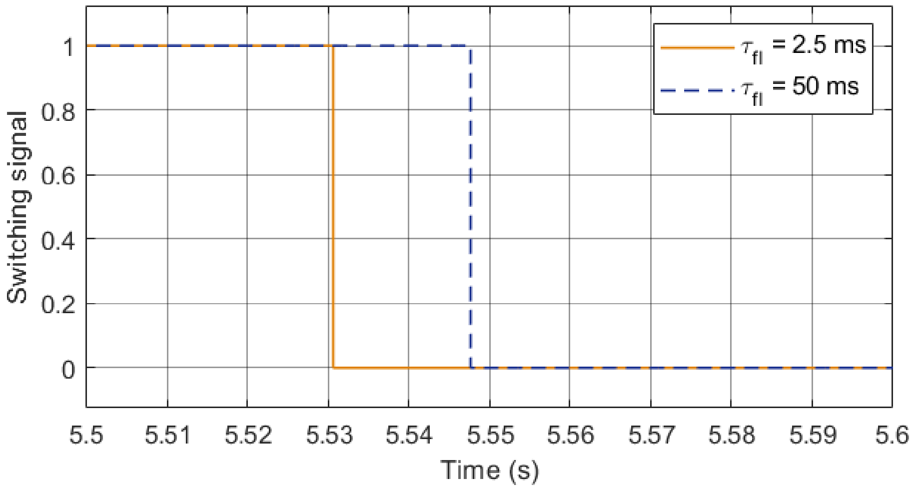
Filters time constant

Voltage filter time constant



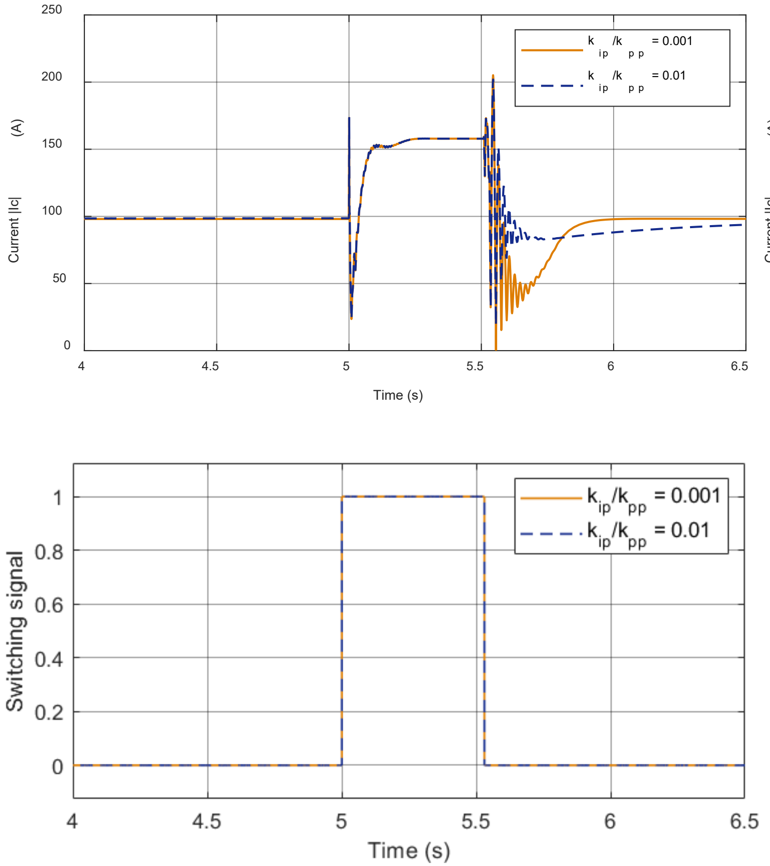




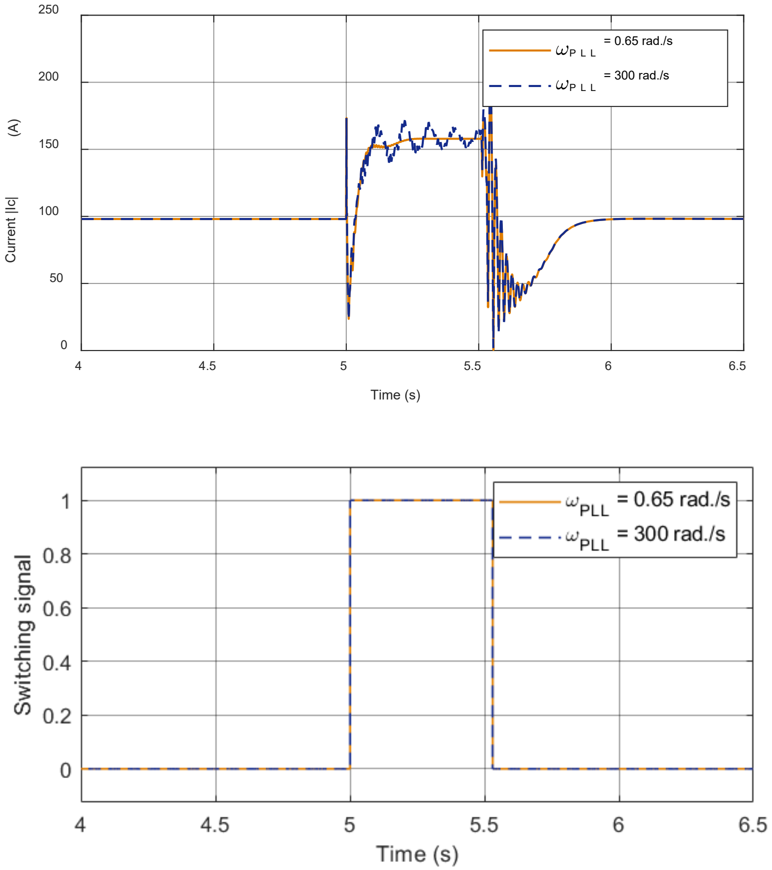


Current filter time constant

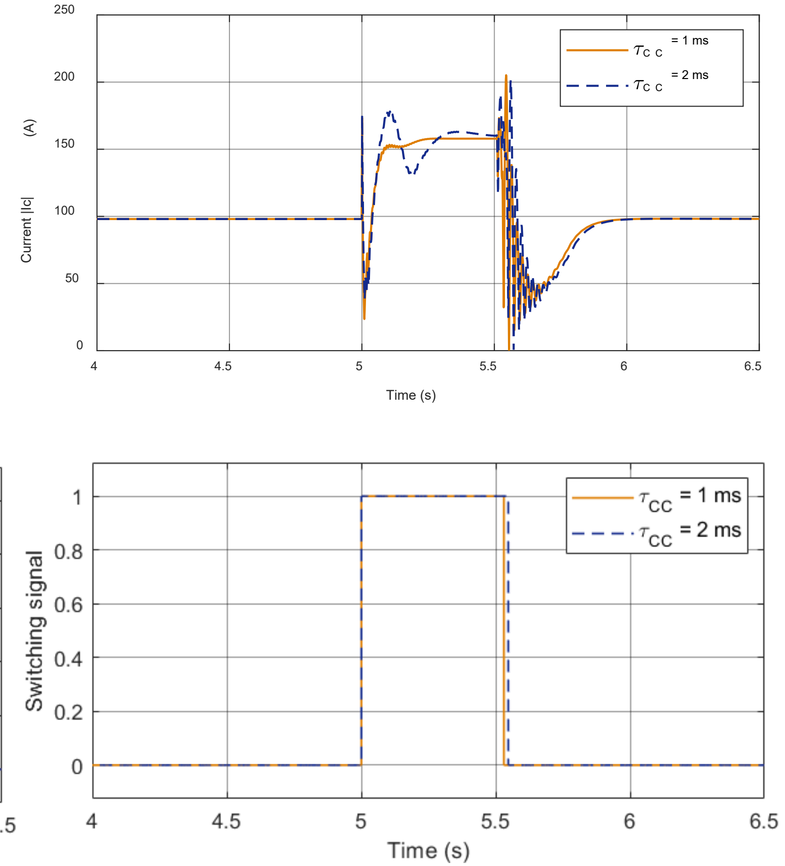
Controllers parameters tuning



Power loop tuning



PLL bandwidth tuning



CC bandwidth tuning

Summary for the comparisons

Factors	Fault response performance		
	Fault signal trigger	Steady state response	Fault recovery
Voltage filter time constant τ_{fv}	Low	No change	Low
Current filter time constant τ_{fi}	No change	No change	High
PLL bandwidth ω_{PLL}	No change	Low	No change
CC time constant τ_{CC}	Low	No change	Low
Active power loop parameters ratio k_{ip}/k_{pp}	No change	No change	High
Voltage control loop parameters ratio k_{iv}/k_{pv}	No change	No change	No change

Conclusion & Future work

Conclusion

- VSM structure requires a backup current control loop during faults
- A study on the effect of the controller tunings and filter time constants change on proposed structure was introduced
- The summary table introduced can be used a reference, while designing such a control structure

Future work

- Investigate the control structure performance in weak grids
- Propose an enhanced fault detection algorithm for strong and weak grids

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