Retrofitting Wind Farms with Virtual Synchronous Machine Control

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Motivation

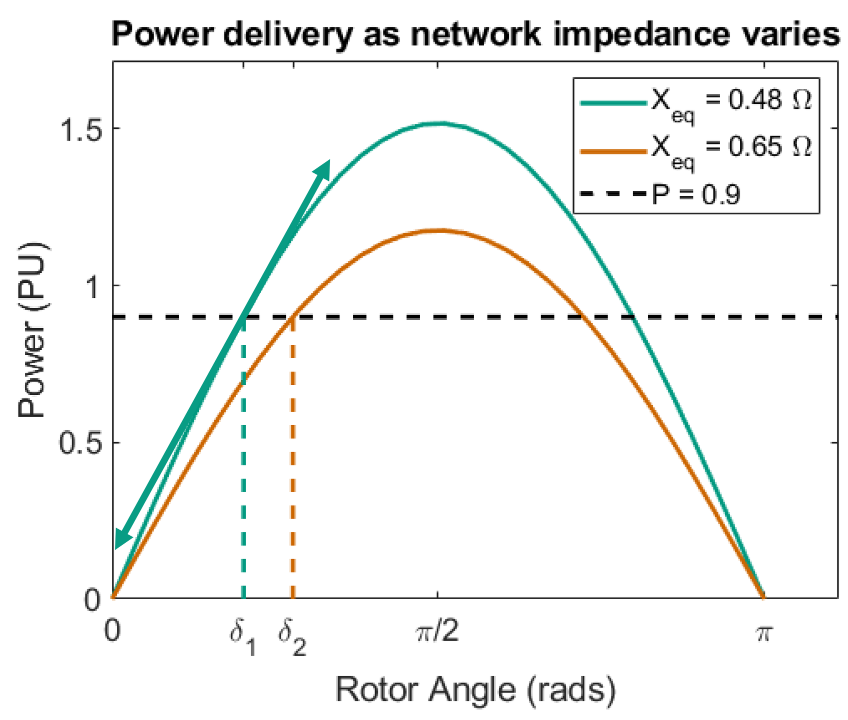
The fraction of **power electronic interfaced generation** (**PEiG**) connected to the grid is increasing. The increase is driven as more energy, delivered by distributed renewable sources, must be transformed before being injected to the system.

High penetration of distributed generation alters grid properties. Issues are associated with the redirection of power flows from remote locations and the behaviour of power converter controllers.

Renewables are being constrained because converter control is reducing the stability of grids. System operators have identified the decrease of inertia as the most pressing power electronics issue to be dealt with to support the grid in the near future [1].

Weak Power Systems

Increasingly non-linear operation

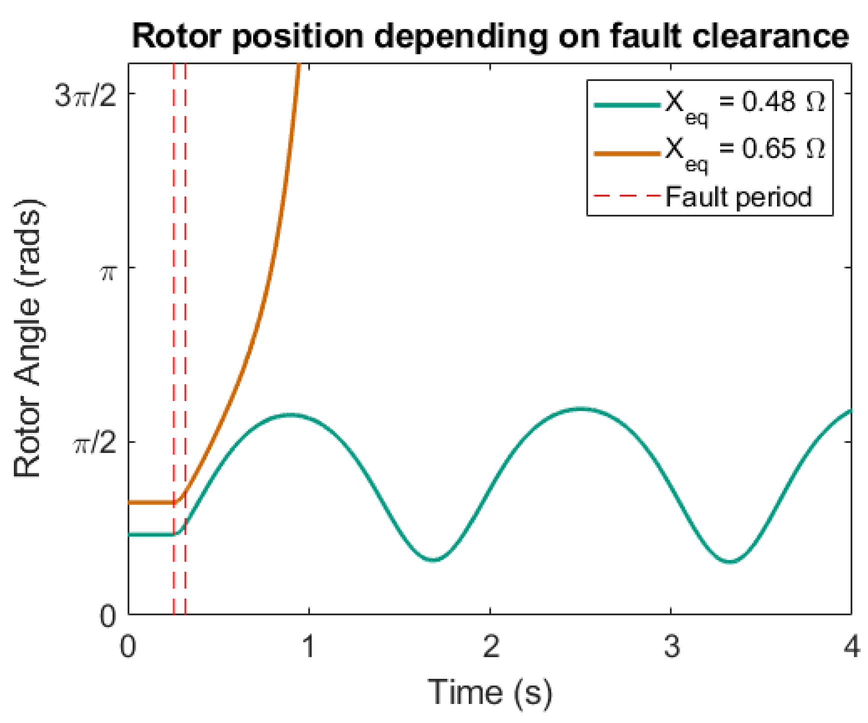


Power delivery to an infinite bus is expressed:

$$P = \frac{E'E_b}{(X_d + X_{eq})}\sin(\delta)$$

Producing the same amount of power on weaker (higher reactance/ impedance) networks requires the system to operate in non-linear regions of the curve.

Smaller stability margins



Weaker networks are required to operate at higher rotor angles. The reduced stability margins require faster fault clearance to remain stable.

A fault cleared after $\Delta t = 0.065\ s$ is exhibited in a second order r-k model. The low impedance network remains stable, whereas, the high impedance network does not.

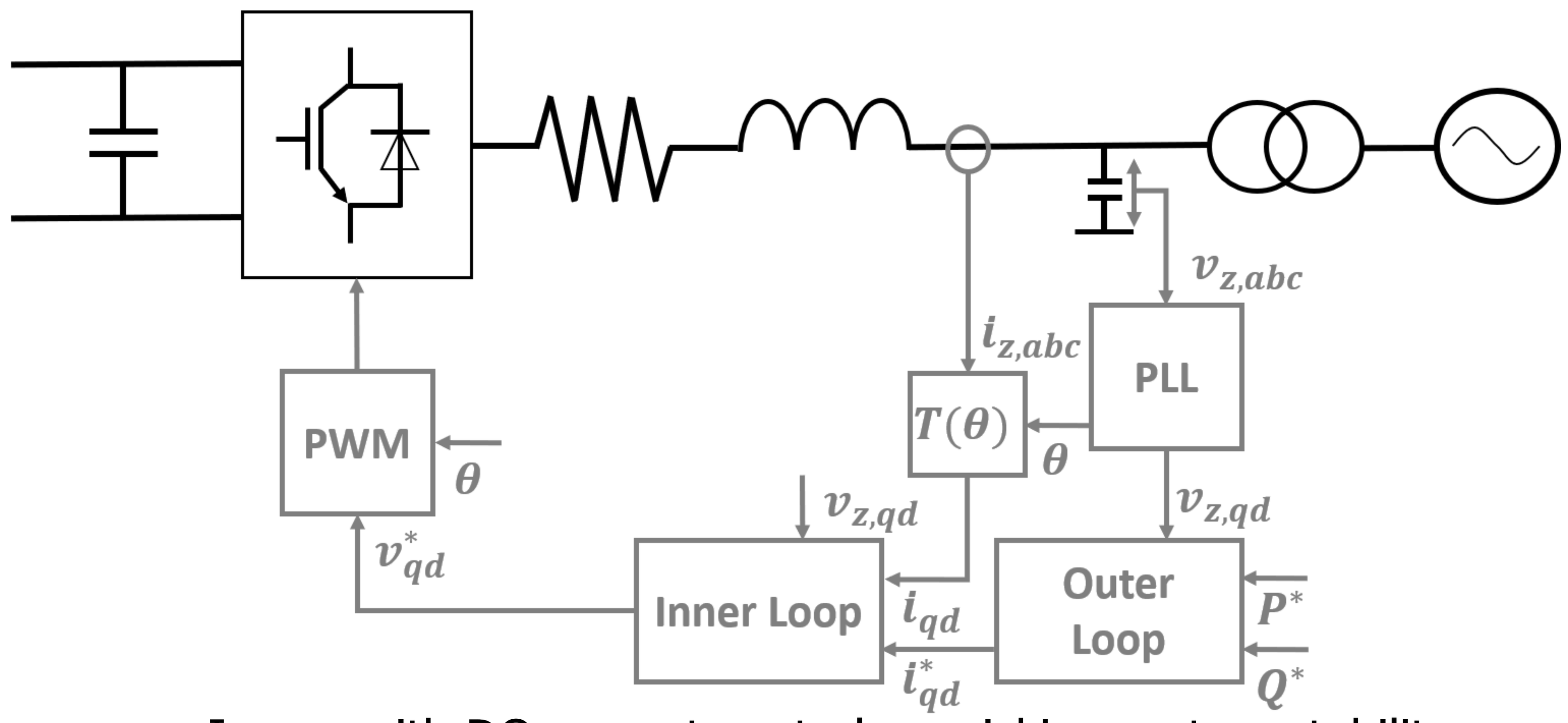
References

[1] T. Breithaupt et al., "MIGRATE D1.1 Report on systemic issues." 15.Dec.2016.

[2] H. Urdal, D. Rostom, A. Dahresobh, C. Ivanov, J. Zhu, and R. Ierna, "System strength considerations in a converter dominated power system," IET Renewable Power Generation, vol. 9, no. 1, pp. 10–17, Jan. 2015, doi: 10.1049/iet-rpg.2014.0199.

DQ Current Control (DQCC)

Grid Side Converter: Current Control Strategy



Issues with DQ current control are risking system stability and imposing a limit on the amount of PEiG.

Pros	Cons
Fast	Increased RoCoF
Well understood	Loss of synchronising torque
Good control of current flow	High frequency instability

The table shows some of the benefits and issues associated with the widespread deployment of current control converters identified in [2].

Virtual Synchronous Machine (VSM) Control

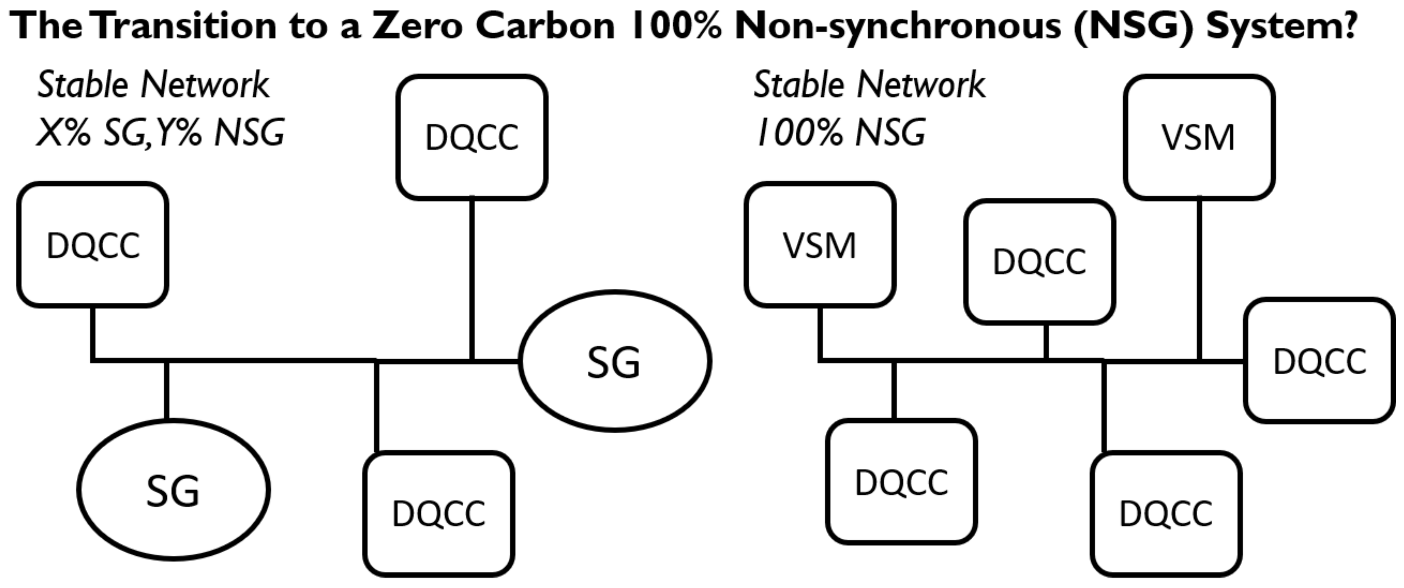
Virtual synchronous machine control strategies replicate synchronous machine dynamics using the swing equation:

$$\frac{2H}{\omega_r}\frac{d^2\delta}{dt^2} = P_m - K_s\sin(\delta) - K_d\frac{d\delta}{dt}$$

VSM converters offer a solution to many of the issues experienced with high penetration of current control. Benefits include:

- A stiff voltage source to the grid
- An inertial response
- The potential for low bandwidth control

The Transition to a Zero Carbon 100% Non-synchronous (NSG) System?



The PhD will produce a techno-economic assessment of VSM and supporting energy storage

- How much energy/ power is required from VSM to support the grid?
  - How will the balance of synchronous, non-synchronous and VSM generation affect the response requirement?
- Where should inertia come from within a wind farm?
- How can VSM and energy storage devices be retrofitted in the most cost-effective manner?