Demystifying Grid Forming Control for Grid-Connected Power Electronics Converters

Several variations of the definition of grid forming (GFM) control exist in the literature today. GFM does not mean any one specific or well-defined control scheme. Out of all definitions, the commonality is that GFM is considered to be the control of voltage and frequency of a source, in a way that it coexists with other sources connected to the grid. There are three popular types of GF control – Droop-based control, Virtual Synchronous Machine (VSM), and Virtual Oscillator Control.

Droop-based control and VSM are designed as linear control systems based on control laws inspired by the legacy grid dominated by rotating machines. These control laws are derived from the steady-state phasor domain power flow equation, given by (1). This relationship has three fundamental underlying assumptions: small power angle δ, constant inductive reactance X_L, and no harmonics in either of the voltage sources. These assumptions may have been true for the legacy power systems comprising of rotating machines. However, they may not always be valid for power electronics-based power systems.

$$P = \frac{V_1 V_2 \sin\delta}{X_L} \approx \frac{V_1 V_2 \delta}{X_L} \quad (1)$$

Since the steady-state behavior of the old power system is already well established and understood, power converters are programmed to behave like machines in the old power system in order to make use of existing knowledge of the grid. However, by emulating rotating machines, the strength of power converters, i.e. fast control dynamics, is not fully utilized and its weakness, i.e. limited overcurrent capability, is exposed. Power converters cannot completely emulate inertia like rotating machines, even if the physical energy storage at DC link is provided (shown in Fig. 1), because of limited overcurrent capability. Therefore, even though virtual inertia may be programmed within the software controls of the inverter, the hardware limitation of the semiconductor switches causes a bottleneck in virtual inertia implementation. When the current limit of inverters is exceeded, the inverter fails to establish the voltage and frequency in this case.

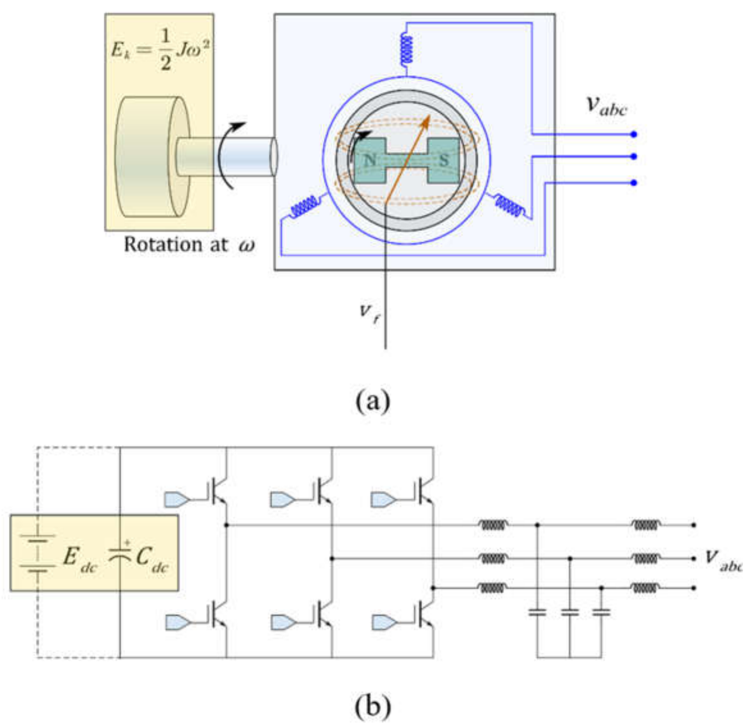

Fig. 1. Energy storage elements for inertia implementation in (a) rotating machines and (b) power electronics

Therefore, currently existing GFM schemes are based on making the "new" power electronics systems act like "old" rotating machines. Fundamental differences between power electronics and rotating machines lead to some assumptions that are not always true. This leads to unexpected behavior, especially in fault conditions.