COUNTRY : GREECE
REGISTRATION NUMBER : 6104

GROUP REF. : C4
PREF. SUBJECT : 3
QUESTION N° : 16

Grid-forming inverters in Agios Efstratios island grid

Grid-forming capability can be obtained by controlling the inverter currents, according to the desired voltage output. This can lead to significant variations in their power output in cases of system power imbalance. Wind turbines and photovoltaics cannot follow such power variations, when not facing curtailments, due to the stochastic nature of their primary source of energy. The capacitor present in the DC link of such inverters cannot serve as a significant energy buffer for this cause. On the other side, inverters in battery facilities can easily implement such a “grid-forming” operating mode, having enough storage capacity to manage effectively power variations occurring on a short timescale. In addition, PV+BESS dc-coupled inverters can also implement efficiently grid-forming capabilities. Thus, in systems operating under high inverter-based resources (IBR) share, having BESS in grid-forming, and RES in grid-supporting modes is advised. This is achievable in practical cases, since such systems have significant energy storage to be able to operate under very high, or even 100%, IBR share. Such an option is chosen for the Greek island system of Agios Efstratios as well, with the two BESS having grid-forming capability, and RES operating in grid-following mode.

When operating two (or more) BESS under grid-forming control mode, power oscillations between them can arise, especially when substantial impedance exists between the units. For this reason, the system stability should be carefully studied, and the units’ controllers tuned appropriately. Agios Efstratios is not facing such issues, having two BESS installed at the same location.

A technical requirement of grid-forming inverters is having sufficient fault current contribution, to be able to support the grid, without the presence of synchronous machines. Another issue coming from the limited current rating of inverters is the inrush current required to energize transformers. Oversizing the grid-forming inverters is a simple, yet costly, solution addressing this problem. However, this is most likely not a major issue in island systems operating under very high IBR conditions. This is because in order to achieve very high-RES penetration, RES capacity must be substantially higher than the system load. In such cases, battery inverters are over-sized to effectively manage a large portion of RES energy surplus, significantly reducing RES curtailments. In other words, a technoeconomic study of such systems, electrified mainly by RES and BESS, will most likely result in sizing the capacity of power converters to levels sufficient for fault current contribution. Agios Efstratios is such an island system, that will operate with two BESS of 500 kW each, while the existing five thermal units are of 2x80 kW and 3x200 kW. Even in the first days of August 2022 (tourist season) a single 200 kW diesel unit is committed for many hours daily[1], thus the 2x500 kW BESS will provide comparable fault current level.

Operating more than a single unit in grid-forming control requires a power sharing method amongst them. Otherwise, significant power oscillations between the grid-forming units can arise, similarly to two or more synchronous generators operating in isochronous mode. An option simulated in our work is implementing droop-type response, that is, deliberately altering frequency level ($\Delta f^* = R \cdot \Delta P$), to achieve the desired primary regulation sharing key. This operating mode can allow smooth transitioning between grid connected and islanded operation in microgrids, as well as between operating with and without any synchronous machines on-line. Simulation results of Agios Efstratios have shown that operating both BESS units in droop-controlled grid-forming mode is preferable. Indicative results are shown in Figure 1, for a generation loss event, showcasing an equal allocation of stress in both battery systems, when operating in droop-based grid-forming control mode (VS-VS).

Another issue in low-inertia systems is the increased ROCOF levels observed in contingencies, which can lead to decommitment of distributed generation or load tripping. In order to retain ROCOF to acceptable levels (e.g., 0.5 Hz/s), a maximum admissible ROCOF can be set in the control scheme of grid-forming inverters, for a smooth transition between frequency levels. Simulation results demonstrate that such a module can sustain the ROCOF to the desired level (see Figure 2).

[1] https://deddie.gr/media/22707/%CF%80%CF%81%CE%BF%CF%84%CE%B5%CE%B9%CE%BD%CF%8C%CE%BC%CE%B5%CE%BD%CE%BF%CF%82-%CE%B7%CE%B5%CF%80-%CE%B1%CE%B3-%CE%B5%CF%85%CF%83%CF%84%CF%81%CE%B1%CF%84%CE%AF%CE%BF%CF%85-29-07-2022-%CE%AD%CF%89%CF%82-04-08-2022.pdf

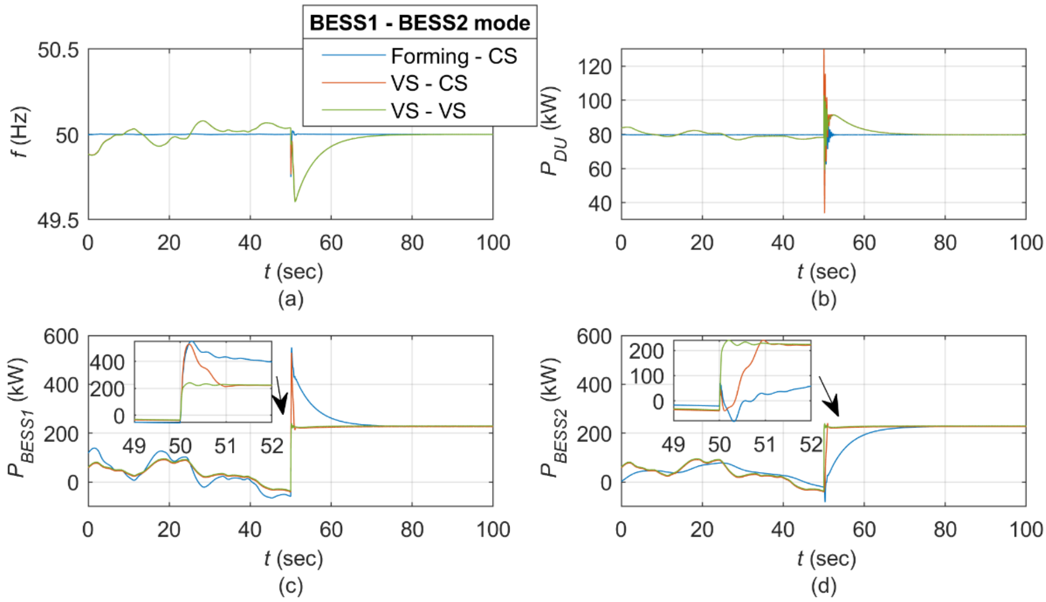

Figure 1 : System response for different BESS converter control modes. (a) Frequency, (b) DU active power, (c) BESS1 active power, (d) BESS2 active power. Forming : isochronous grid-forming, VS : grid-supporting operating as voltage-source (droop-based grid-forming), CS : grid-supporting operating as current-source (droop-based grid-following).

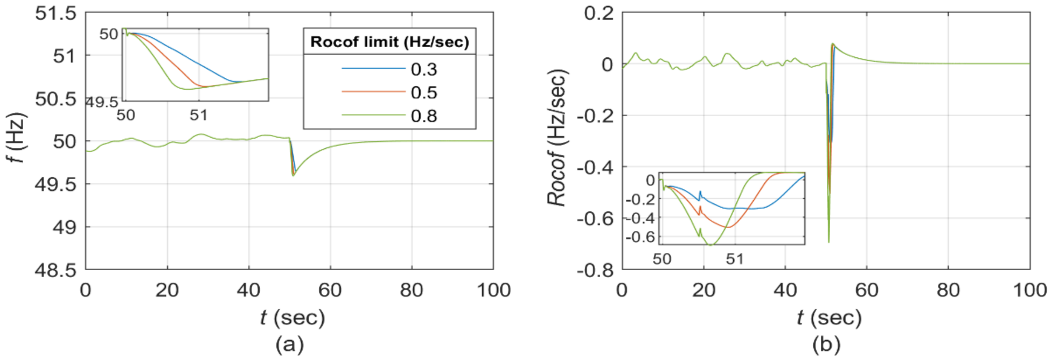

Figure 2 : System response for different ROCOF limits in BESS converter controller. (a) Frequency, (b) ROCOF.