Dispatching Grid-Forming Inverters in Grid-Connected and Islanded Mode

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Abstract

This paper explores the dispatchability of grid-forming (GFM) inverters in grid-connected and islanded mode. An innovative concept of dispatching GFM sources (inverters and synchronous generators) is proposed to output the target power by adjusting their droop intercepts. The fundamental principle is that the GFM inverter's active and reactive power is dictated by its frequency and voltage, and thus dispatching the active and reactive power of a GFM inverter can be achieved through dispatching its frequency and voltage. The concept is validated with an example microgrid system with two GFM inverters, one diesel generator, one GFL inverter, and the load in both grid-connected and islanded mode. This pioneering work results in practical guidance for the development of energy management systems for future electric grids with GFM and GFL inverters. The key findings are summarized as follows:

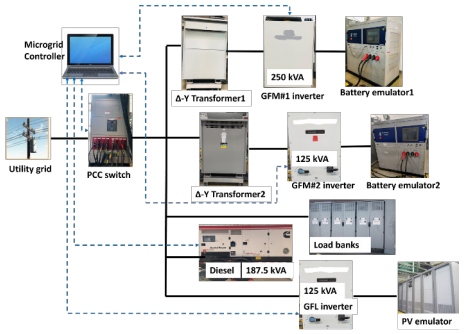
*1) The GFM inverters can be **dispatched through frequency and voltage droop intercepts** to output the target power;*

2) The dispatch rule for grid-connected and islanded mode is slightly different.

Motivation

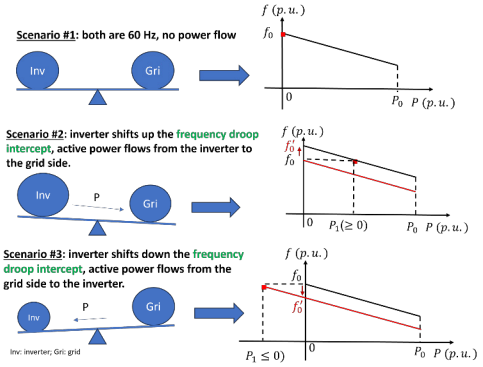
- *GFM inverters usually use droop control to automatically share power with other GFM sources (inverters and synchronous generators) and follow the change in the load demand; however, they can be dispatched like their grid-following (GFL) counterparts to output the target active and reactive power.*
- *This will help grid operators better manager their IBRs to improve operation efficiency and reliability.*

Testing Circuit



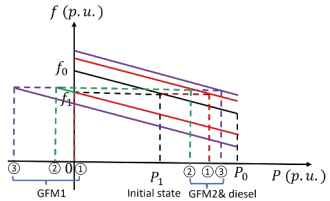
Dispatch Rule of GFM sources

Grid-connected mode



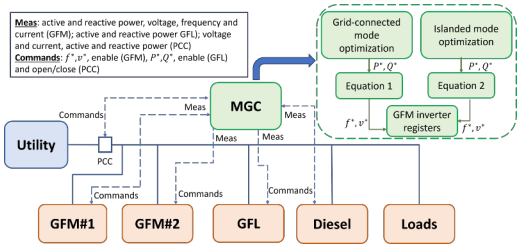
$$f^* = 60 + \Delta f = 60 + m * P * 60$$

Islanded Operation Mode



$$\Delta f = (P_{new} - P_{old}) * m * 60$$

Schematic diagram of the integrated control system



Specifications of the three GFM sources

Specification	GFM 1	GFM 2	Diesel
Capacity (kVA)	250	125	187.5 (PF 0.8 lagging)
Frequency droop settings	0.25%	0.5 Hz	Bias of −0.36 Hz
Frequency droop	0.25%	0.83%	0.6%
Voltage droop settings	5%	24 V	Bias of 0%
Voltage droop	5%	5%	3.7%
Synch check	Yes (GCB and MCB)	No	Yes (GCB)
Operation mode	GFM, GFL, and grid-supporting control	GFL and GFM control	GFL and GFM control
Communication protocol	Modbus TCP	Modbus TCP	Modbus TCP

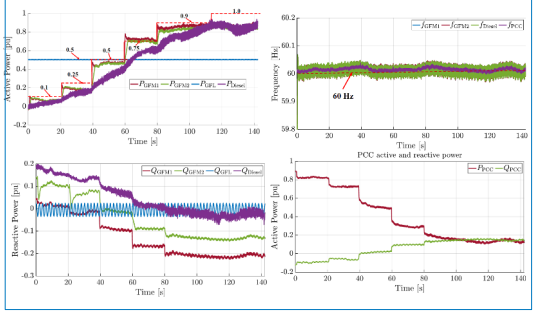
Experimental Results

Grid-connected mode

Testing condition and procedures:

- *Utility grid is used instead of grid simulator, PF1 load equal to the sum of the total of GFM capacity (250+125+150 kW) and GFL with 50% dispatch*
- *Dispatch each GFM source to target power (5%, 10%, 25%, 50%, 75%, and 100%)*

***Observation**: all the three GFM sources respond to the dispatch setpoint and output the target power with small errors.*

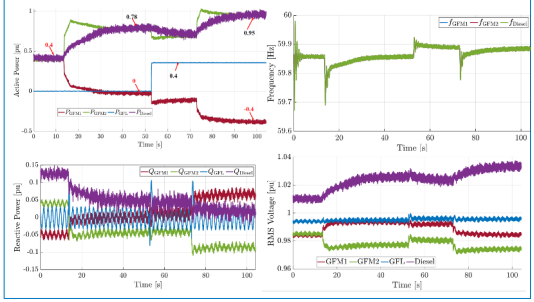


Islanded mode

Testing procedures:

- *Objective: Start from equal power sharing to charging the GFM1 with 40% power*
- *Strategy: ① Let GFM output zero active power by dispatching GFM2 and diesel; ② bring in GFL; ③ dispatch GFM2 and diesel to let GFM1 charge 40% power*

***Observation**: 1) GFM1 is dispatched step by step to charge 0.4 p.u. power; and 2) GFM 2 and diesel are dispatched accordingly and respond correctly; 3) new dispatch of GFL changes the system frequency; 4) GFM inverter can be dispatched like GFL inverters even in islanded mode.*



Conclusions

*This paper **studied the dispatchability and interoperability of GFM inverters during grid-connected and islanded mode** with the **intention of informing the GFM inverter industry** with:*

- ***GFM inverters can be dispatched like GFL inverters through voltage and frequency droop intercept (v* and f*)***
- ***GFM inverters show stability issues when dispatched to absorb reactive power from the grid. Also, when active power is dispatched, large amount of reactive power is generated.***
- ***Droop settings are critical to achieve stable dispatch of GFM inverters during grid-connected and islanded operation***

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