3DMicroGrid

DESIGN, DEVELOPMENT AND DEMONSTRATION OF A SMART MICRO GRID

Active Power Sharing in Microgrids Using Multiple Grid-Forming Inverters

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SEVENTH FRAMEWORK PROGRAMME

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Introduction and Background

The vast majority of existing microgrids still rely on synchronous generators (often Diesel-powered).

The need to achieve 100% renewable power supply in the foreseeable future also applies to island systems and microgrids.

Solar PV and wind power are the predominant renewable sources in many island systems, and use inverter-based generation technologies.

How can we run island power systems, including microgrids, without synchronous generators?

We will need island power supply systems using exclusively inverter-based generation.

Grid-Feeding and Grid-Forming Inverter Control

Grid-Feeding

Control scheme for inverters connected to a system dominated by synchronous generators

Measures voltage waveform and frequency using a PLL (phase-locked loop)

Transient behavior during disturbances in the grid similar to a current source

Frequency droop and synthetic inertia implementation possible based on frequency measurement

→ Predominant control scheme

Grid-Forming

Control scheme for inverters in systems without synchronous generators

Voltage and frequency are not measured, but follow self-determined references

Transient behavior during disturbances similar to a voltage source

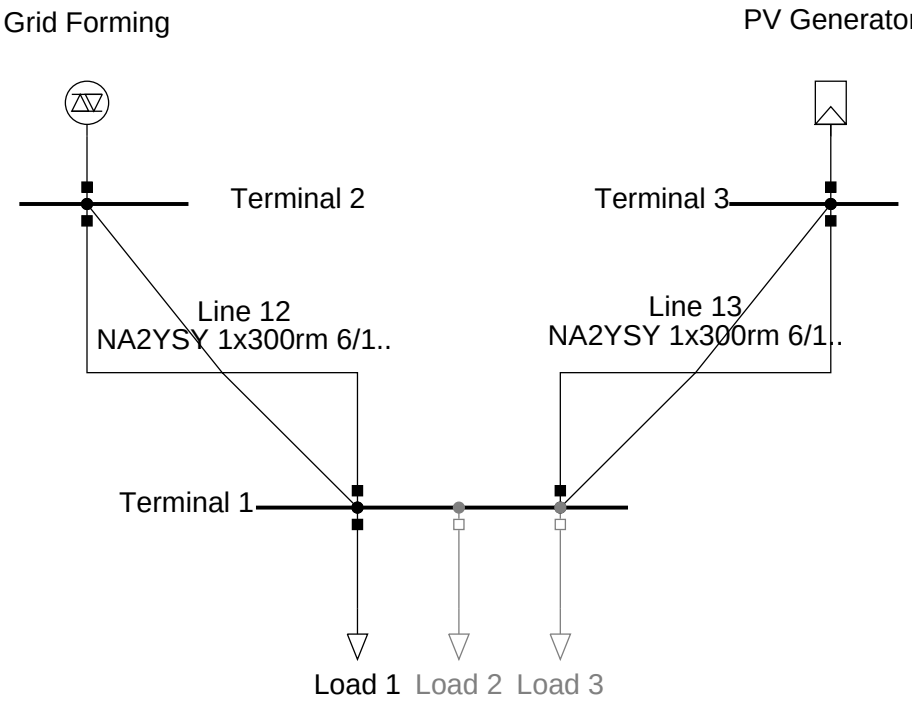
Can provide response indistinguishable from synchronous machine inertia

→ Special applications

Control Schemes for Power Sharing in Island Systems

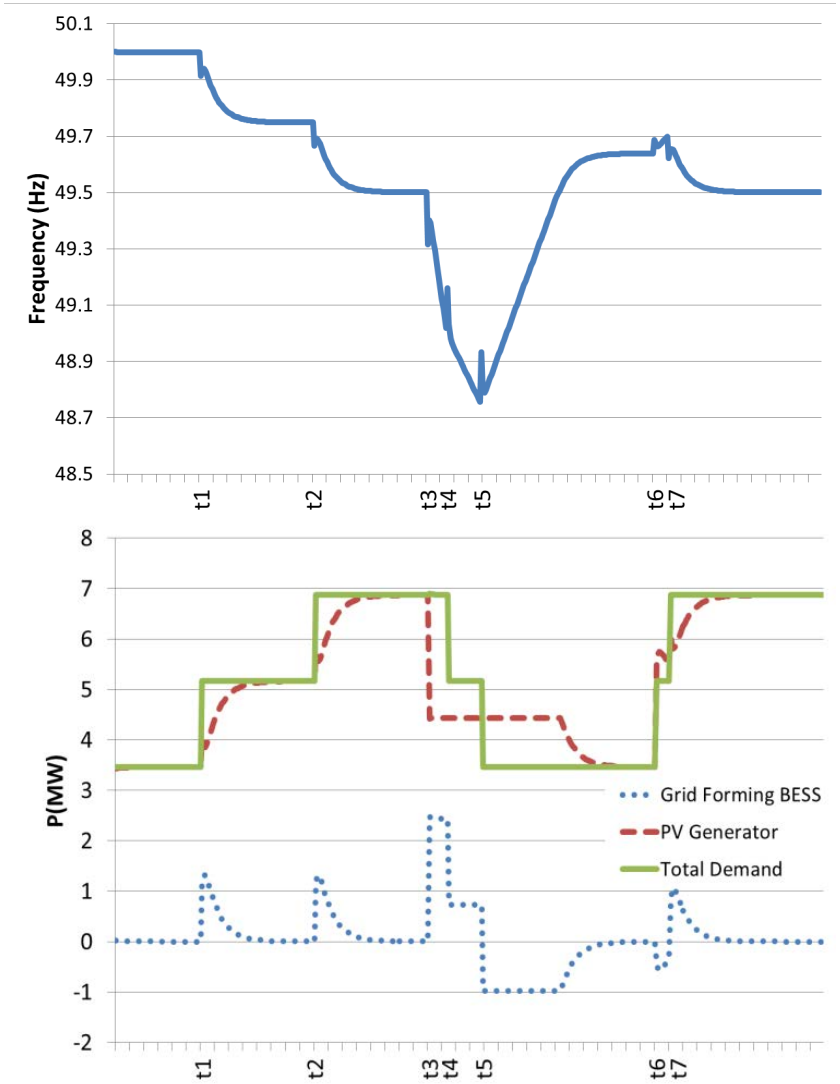
Concepts	Advantages	Disadvantages
Communication-based	Can address many different objectives and many constraints	Requires communication infrastructure
Droop-characteristic-based	Simple and robust: no communication infrastructure	Often inefficient, not well-suited for microgrid resynch.
Virtual-structure-based	Simple and efficient: no communication infrastructure	Not robust, requires good knowledge of grid impedance
Signal-injection-based	Robust and efficient: no communication infrastructure	Not simple, requires complex capabilities and control
Hybrid	Application-specific	Complexity

Simulation Setup: Single Battery plus PV and Load



ASSETS		RATINGS
Grid-forming battery inverter	Nominal active power	10 MW
Grid-following PV inverter	Nominal active power	6.9 MW
Load 1	Active power	3.45 MW
Load 2 (non-essential)	Active power	1.715 MW
	Disconnection threshold	49 Hz
	Reconnection threshold	49.65 Hz
Load 3 (non-essential)	Active Power	1.715 MW
	Disconnection threshold	48.75 Hz
	Reconnection threshold	49.7 Hz
Line 12	Type	NA2YSY 1X300 6/10kV it
	Length	2 km
Line 23	Type	NA2YSY 1X300 6/10kV it
	Length	2 km

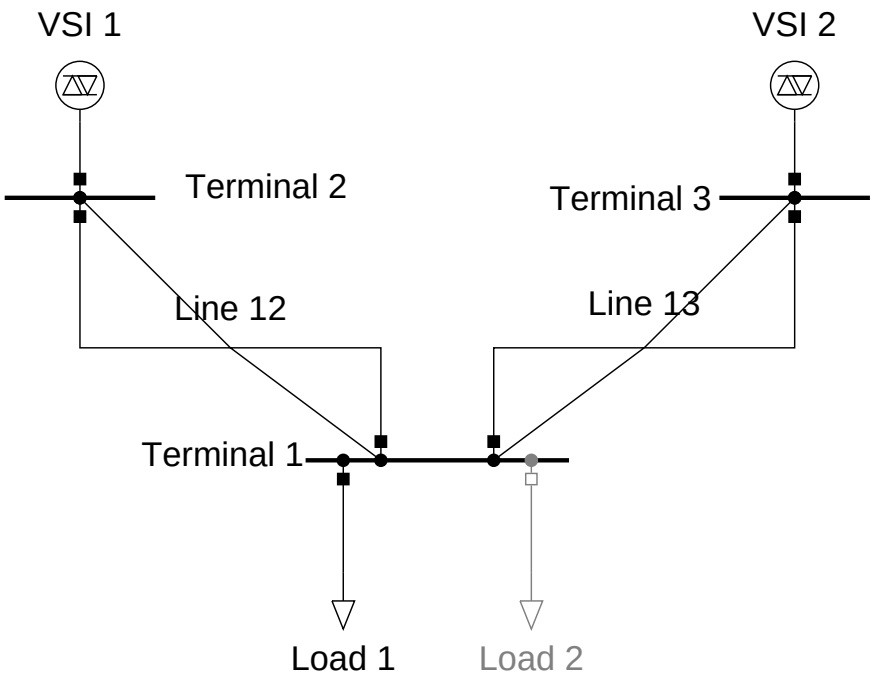
Simulation: Single Battery plus PV and Load



Sequence of events

- t1 – load 2 connection
- t2 – load 3 connection
- t3 – solar power decrease
- t4 – load 2 shed
- t5 – load 3 shed
- t6 – solar power increase
- t7 – load 2 and 3 reconnect

Simulation Setup: Two Grid-Forming Inverters in Parallel



ASSETS		RATINGS
Grid-forming inverter VSI 1	Nominal active power	10 MW
Grid-forming inverter VSI 2	Nominal active power	6.9 MW
Load 1	Active power	3.45 MW
Load 2 (non-essential)	Active power	1.715 MW
Line 12	Type	NA2YSY 1X400 6/10kV it
	Length	15 km
Line 23	Type	NA2YSY 1X400 6/10kV it
	Length	10 km

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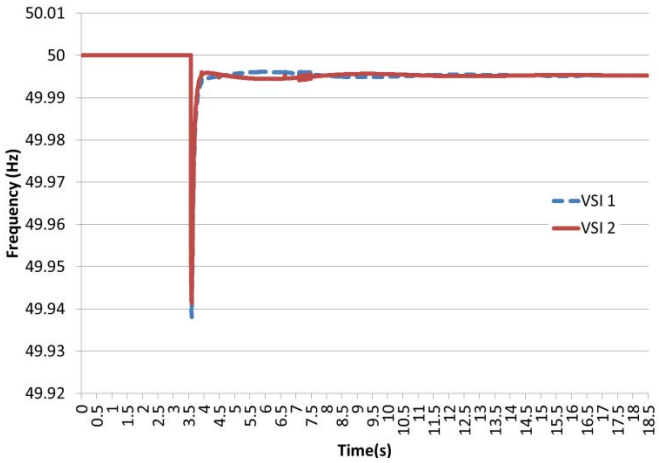
Simulation: Two Grid-Forming Inverters in Parallel

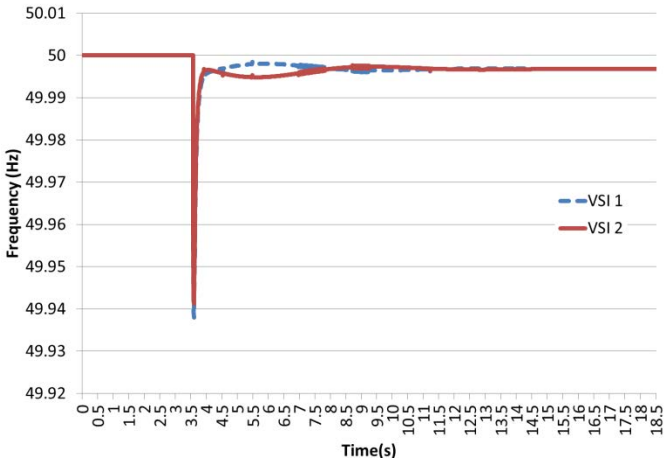
Simulation event: Connection of load 2 at t=3.5s

Variant 1: Same droop

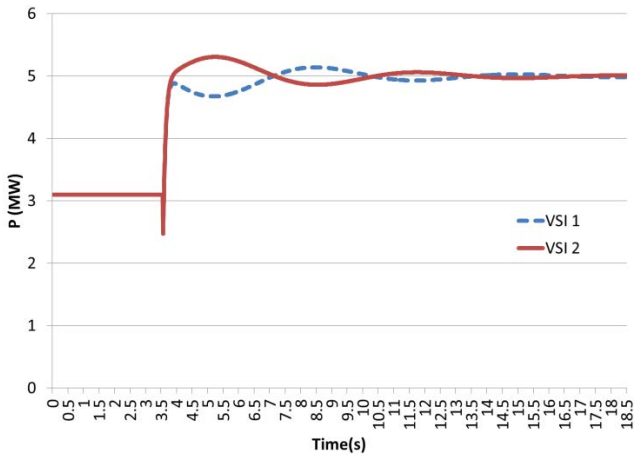
Variant 2: Different droop

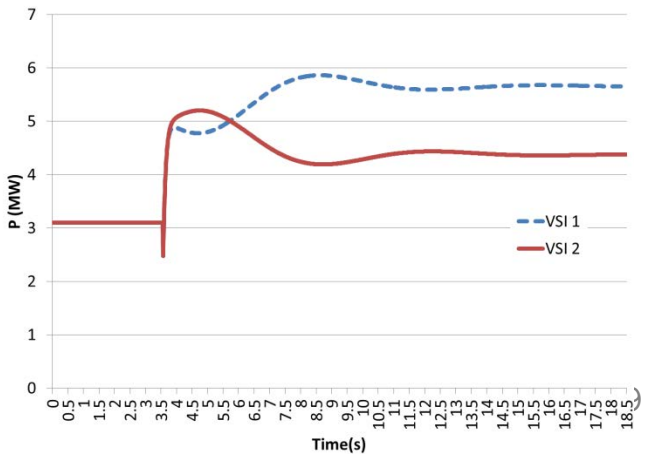
Frequency in Hz





Active Power in MW





Summary and Conclusions

Grid-forming inverter control systems allow electricity supply for islands and microgrids using purely inverter-based renewable electricity generation and storage.

Grid-forming and conventional grid-following inverter systems can interoperate within the same systems. It is also possible to use multiple grid-forming inverters in the same system.

The power sharing scheme is an important design decision for system operation. Droop-based sharing is a simple concept for small islands and microgrids. Larger systems can achieve higher efficiency with more complex concepts.

Some inverter manufacturers have grid-forming controls in their portfolio. Others, however, did not cover this (so far) niche application yet. There is an ongoing debate on if they need to (or how).

We expect that for 100%-VRE-based power systems, battery storage inverters are the best candidates to implement grid-forming control.

Acknowledgments

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Thank you!

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Questions ?