Comparison of Islanding and Synchronization for a Microgrid with Different Converter Controls

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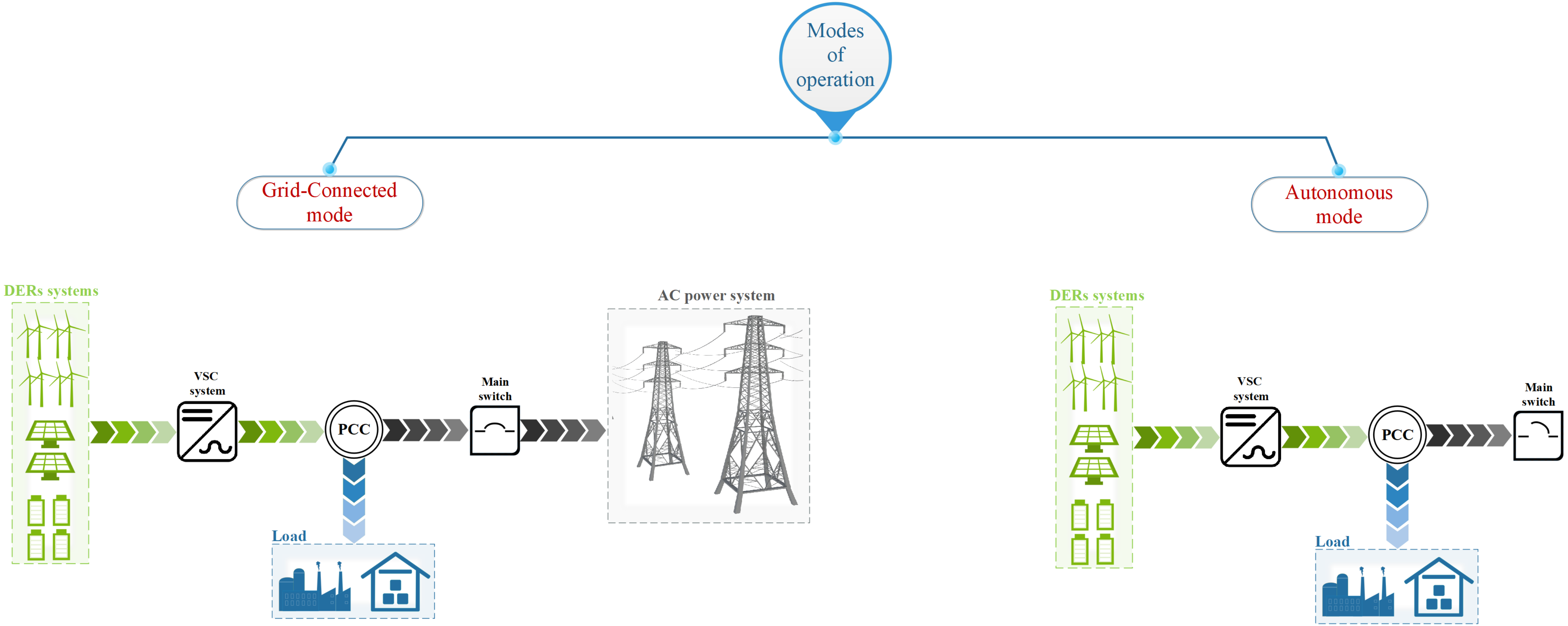
Introduction

➢ **Operation modes of microgrids.**



Work Description

Main scope:

A comparison of microgrid performance during islanding and synchronization when different voltage source converter (VSC) controls are adopted.

1. An overview of VSC controls, namely: 1) **grid-following**, 2) **grid-forming**, and 3) **grid-supporting.**
2. A Comparison of microgrid performance is conducted in two testbeds built in MATLAB/SimPowerSystem environment. The two testbeds are compared side by side for their dynamic performance.

Overview of VSC controls

1. Grid-Following VSC:

- *Active* & *reactive* power at the PCC are controlled by tuning the <u>*converter AC current*</u>.
- Also, *DC voltage* & the *PCC voltage* could be regulated.
- It is operated as a <u>current source</u> [7].
- A synchronization mechanism "PLL" is required in order to be ***synchronized*** with the grid by <u>*extracting*</u> the grid frequency and PCC voltage angle θ_{PLL}.

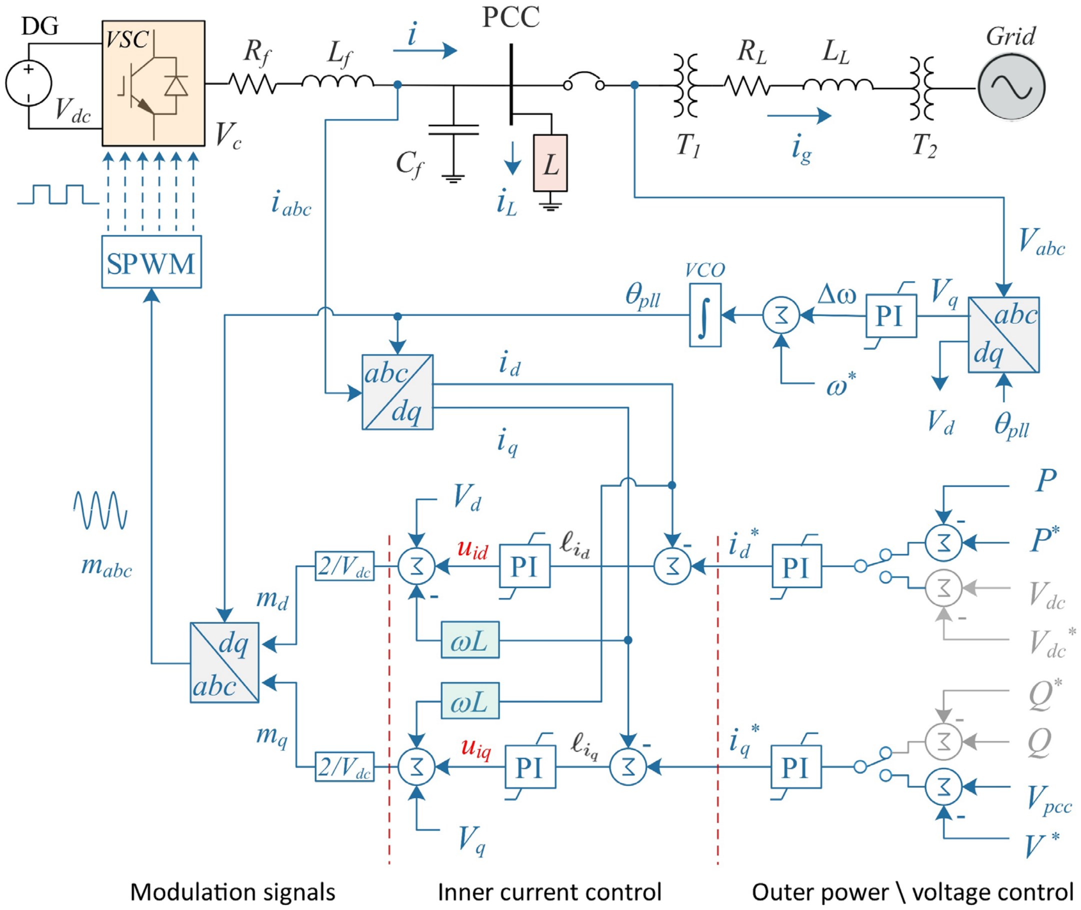


Fig. 1: Schematic control structure of grid-following VSC

Overview of VSC controls

2. Grid-Forming VSC:

- It is operated in MGs as the source of voltage & frequency control by regulating the AC current of the converter.
- It is operated as an ideal AC voltage source [2].
- It is similar to the grid-following control structure ***except*** the outer loop.

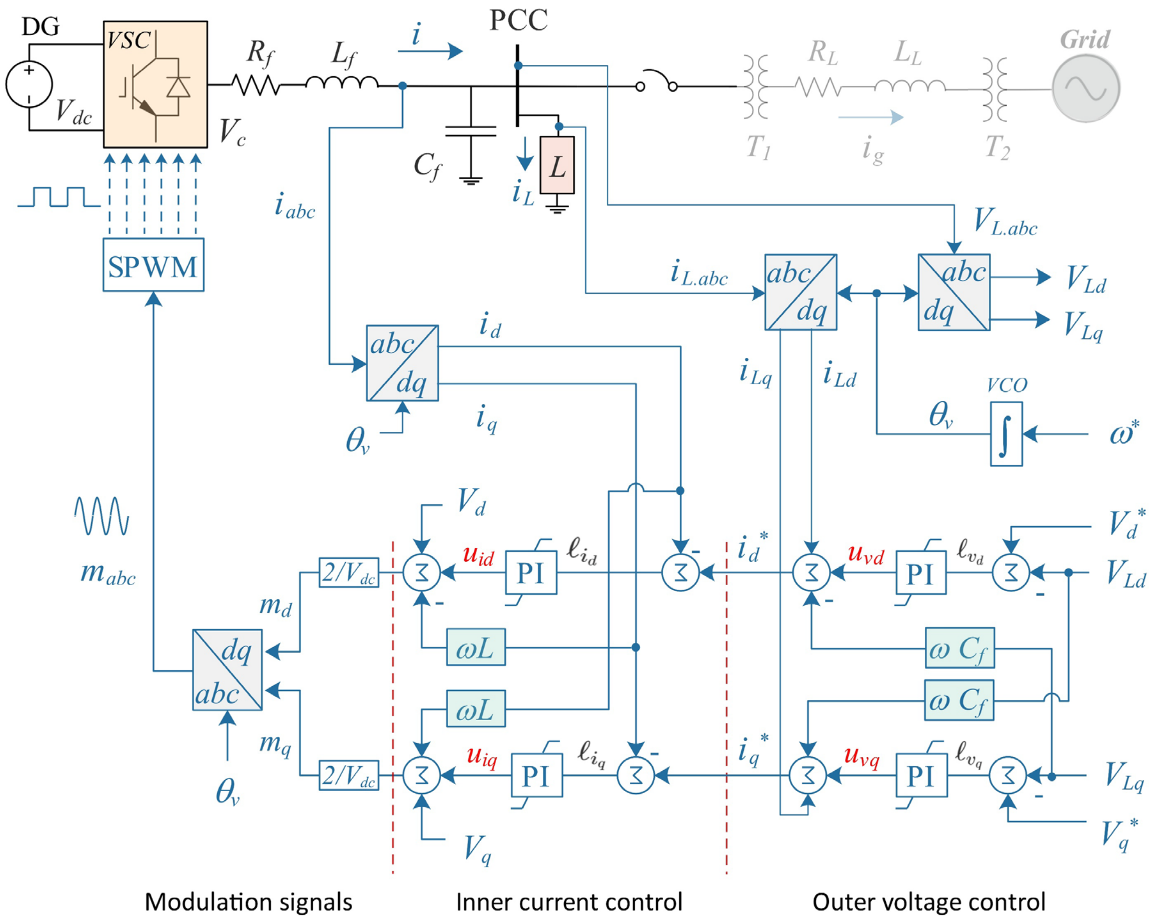


Fig. 2: Schematic control structure of grid-forming VSC.

Overview of VSC controls

3. Grid-Supporting VSC:

- It can operate either in grid-connected mode or autonomous mode.
- No need to re-configuration the converter control.
- Droop controls are implemented on top of a grid-following control structure.
- It can contribute controlling the MG **voltage**, **frequency, active** & **reactive** power at the PCC through its droop design, in both modes:

$$f - f^* = -m(P - P^*)$$

$$V - V^* = -n(Q - Q^*)$$

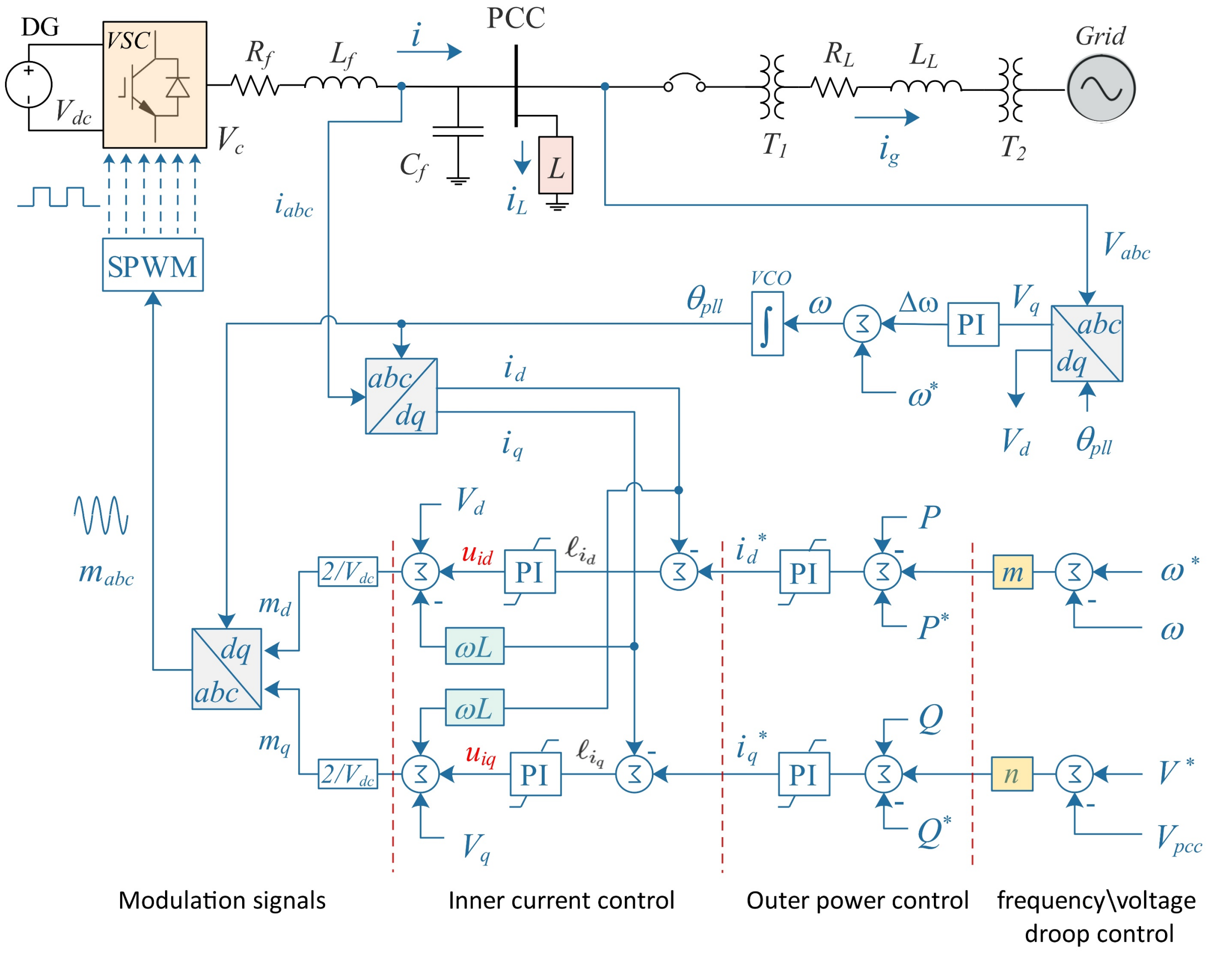


Fig. 3: Schematic control structure of a grid-supporting VSC.

Simulation & Results

Two testbeds built in MATLAB/SimPowerSystem as follows:

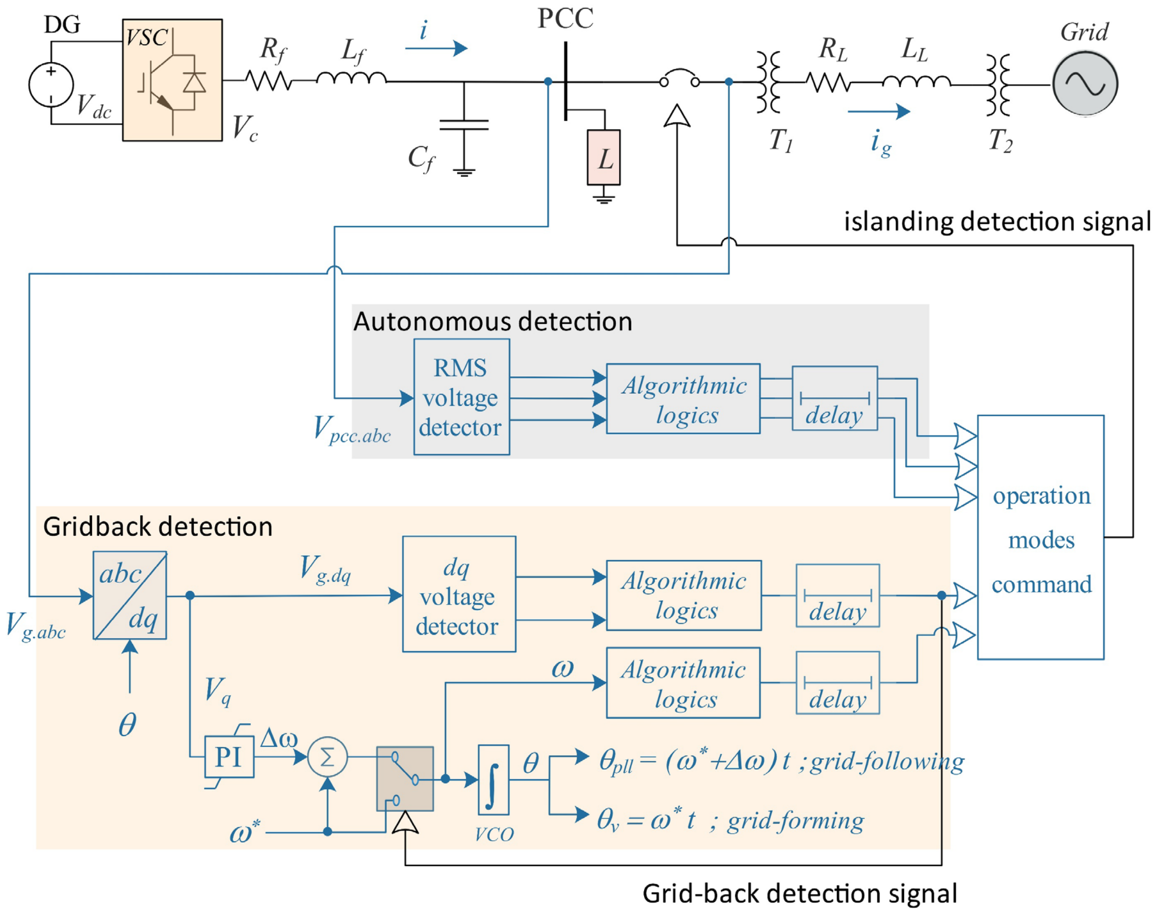
Testbed 1.

A VSC switches back and forth between *grid-following* and *grid-forming* control during islanding and synchronization "grid-connected mode".

Testbed 2.

A VSC works in *grid-supporting* mode regardless of the microgrid operation mode.

Fig.4: an **islanding scheme** and a **grid-back detection** scheme are designed to automatically switch the operation modes of the VSC.



Simulation & Results

- The testbeds parameters:

	Description	Parameters	Value
Grid side	Transformer 1	T_1	400 kVA 260 V \ 25 kV
	Transformer 2	T_2	400 kVA 25 kV \ 120 kV
	Transmission line	R_L , X_L	$0.1X_L$, 0.2 pu
DG side VSC	Rated power	S_b	**400 kVA**
	Rated voltage	***ac/dc side***	**260/500 V**
	Converter filter	R_f	0.156/50 pu
		X_f	0.156 pu
	Shunt capacitor	C_f	0.25 pu
Load	fixed load	L	**300 Kw**

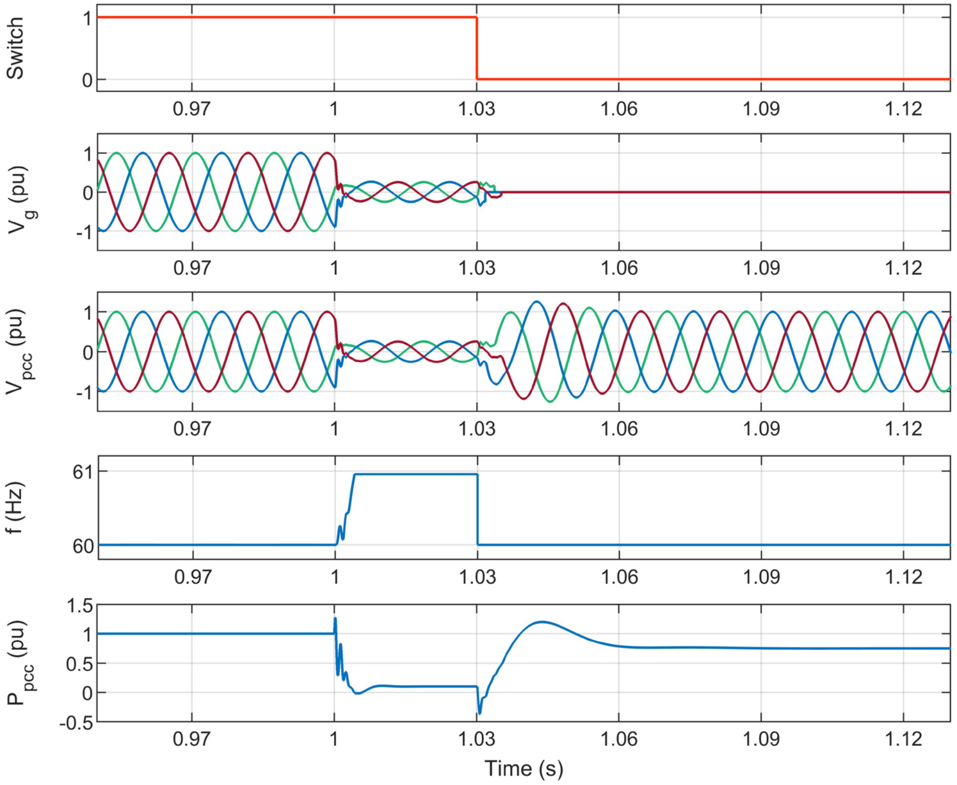
** Reference control settings: $P^*_{pcc} = 1\ pu$ $V^*_{pcc} = 1\ pu$ $\omega^* = 60\ Hz$

Simulation & Results

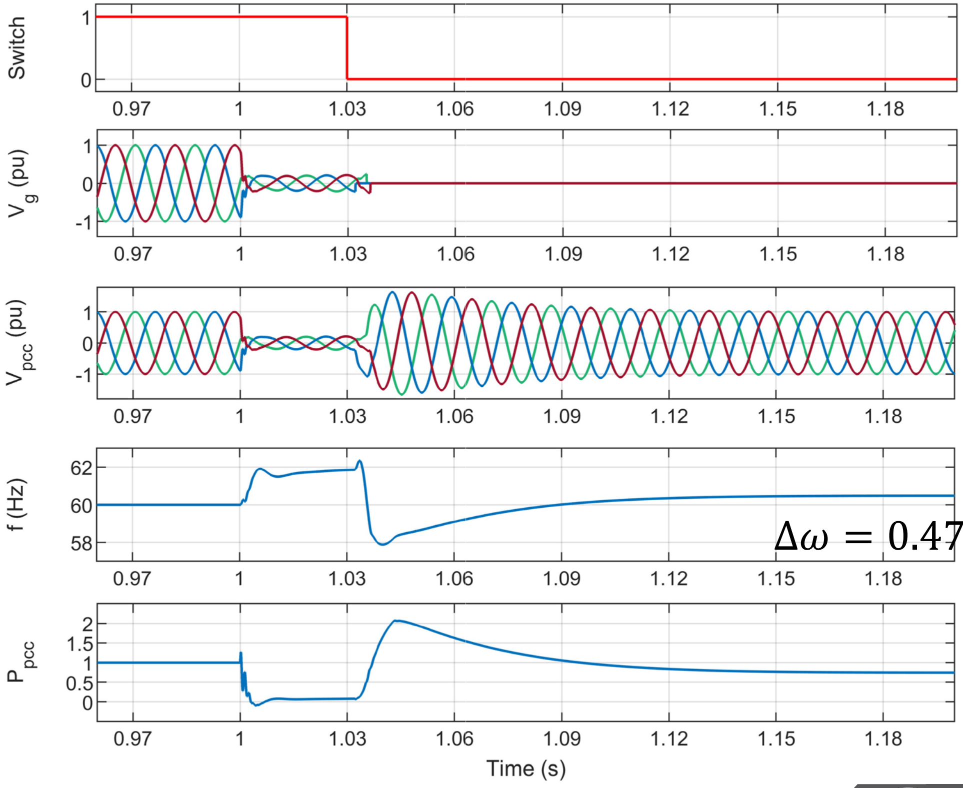
➢ **Comparison #1:** ***Grid-connected* mode to *Autonomous* mode:**

- Three phase fault occurs in the transmission line at ***1 s***.
- Islanding mode is detected after ***3 ms.***

Testbed # 1: **grid-following** / **grid-forming**



Testbed # 2: **grid-supporting**

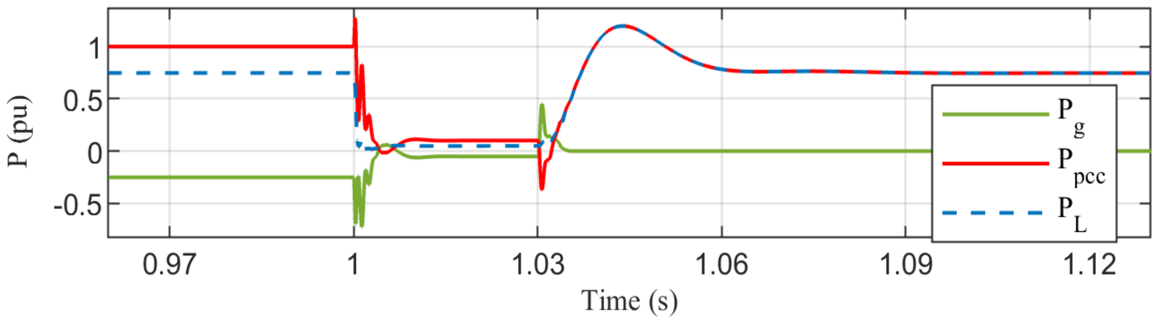


Simulation & Results

➢ **Comparison #1: *Grid-connected* mode to *Autonomous* mode:**

- Active power responses: converter output, load, and grid.
- The VSC injects a fixed active power (400 Kw) to the load (300 Kw) and the grid (100 Kw).

Testbed # 1: **grid-following / grid-forming**



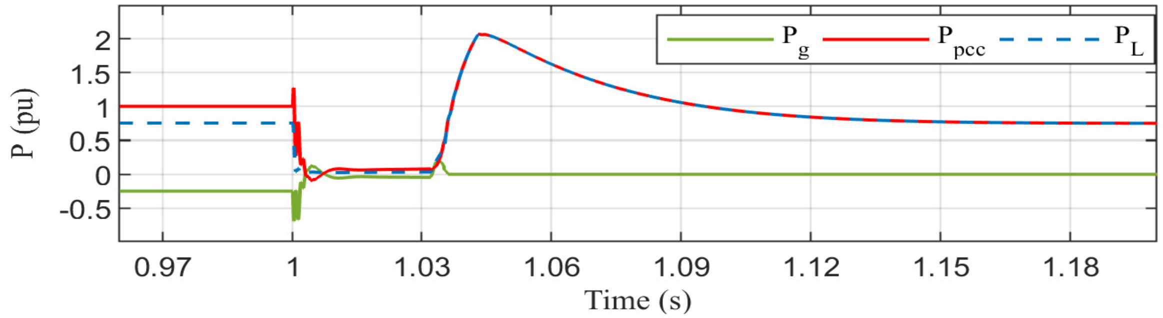
$P^*_{pcc} = 1\,pu$
$P_{Load} = 0.75\,pu$
$P_{grid} = 0.25\,pu$

Grid-connected mode

$P^*_{pcc} = 1\,pu$
$P_{Load} = 0.75\,pu$
$P_{grid} = 0$

Autonomous mode

Testbed # 2: **grid-supporting**



$P^*_{pcc} = 1\,pu$
$P_{Load} = 0.75\,pu$
$P_{grid} = 0.25\,pu$

Grid-connected mode

$P^*_{pcc} = 1\,pu$
$P_{Load} = 0.75\,pu$ } generates $\Delta\omega$
$P_{grid} = 0$

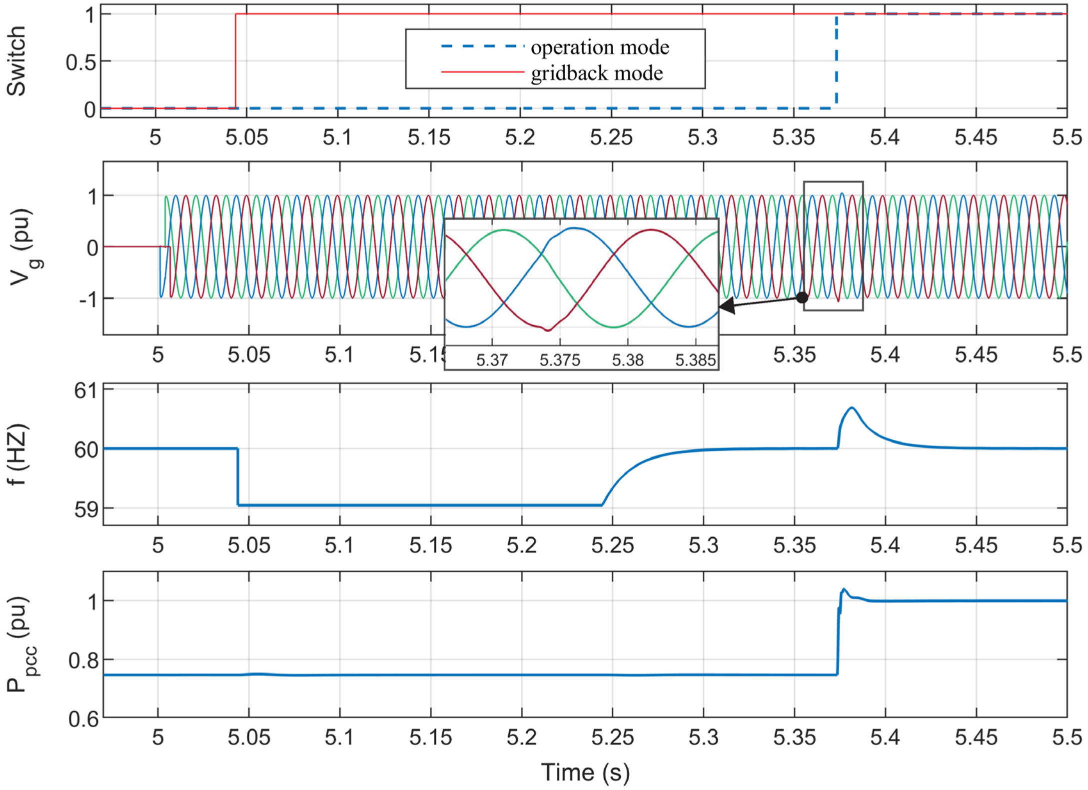
Autonomous mode

Simulation & Results

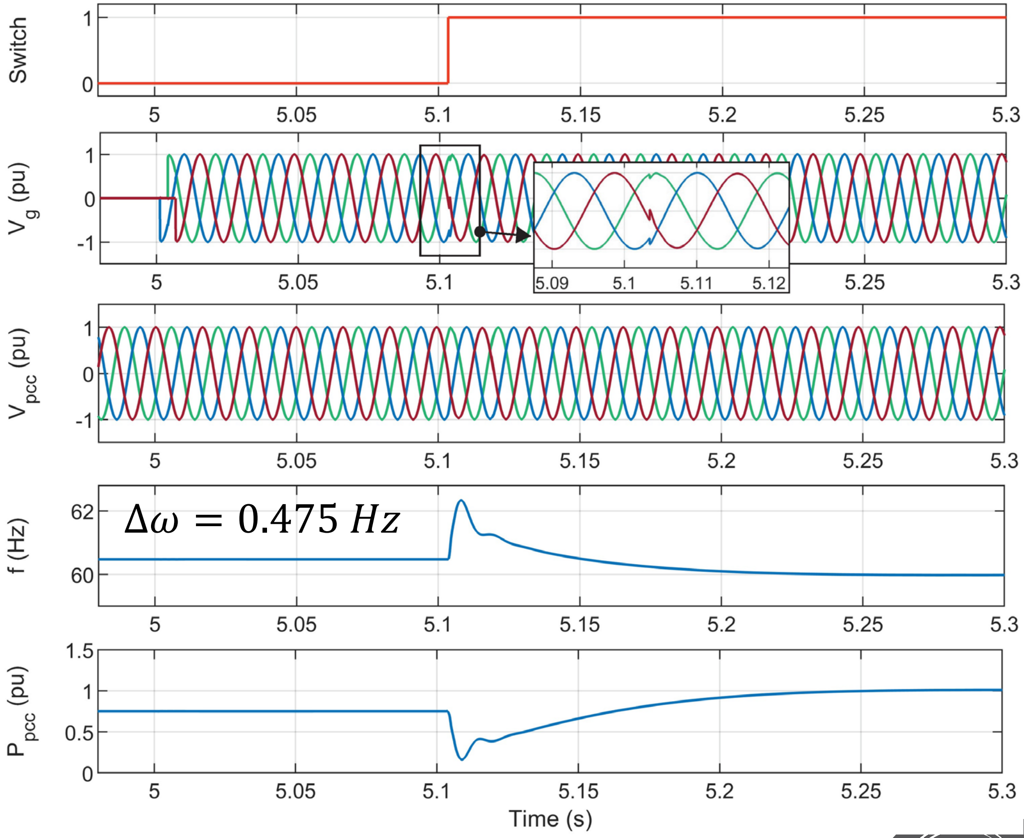
➢ Comparison #2: *Autonomous* mode to *Grid-connected* mode :

- Three phase fault is cleared at ***5 s***.
- The operation mode is switched back to grid-connected mode at ***5.37 s*** in testbed 1 and ***5.11 s*** in testbed 2.

Testbed # 1: **grid-following / grid-forming**



Testbed # 2: **grid-supporting**

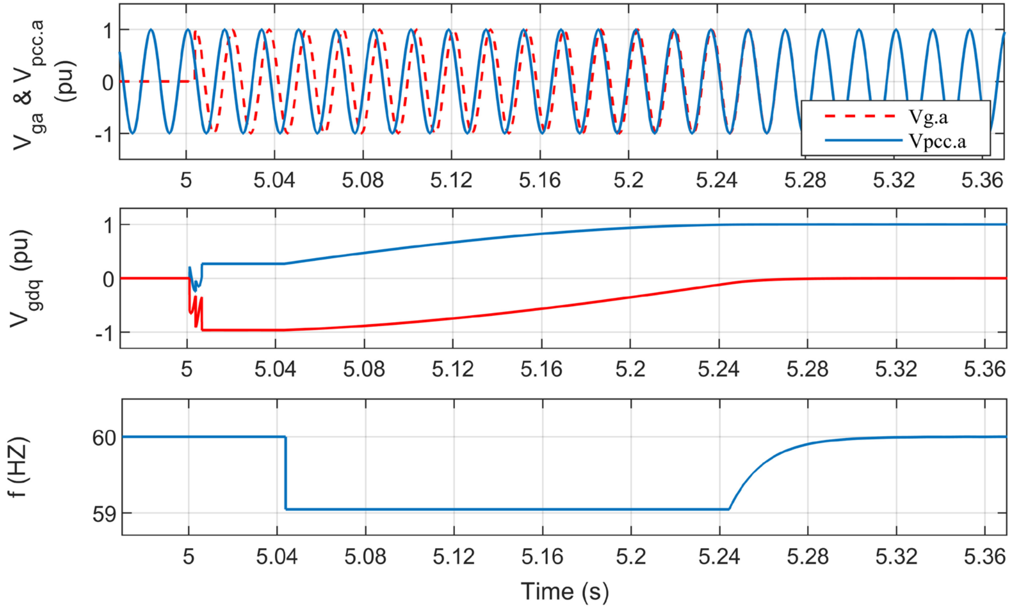


Simulation & Results

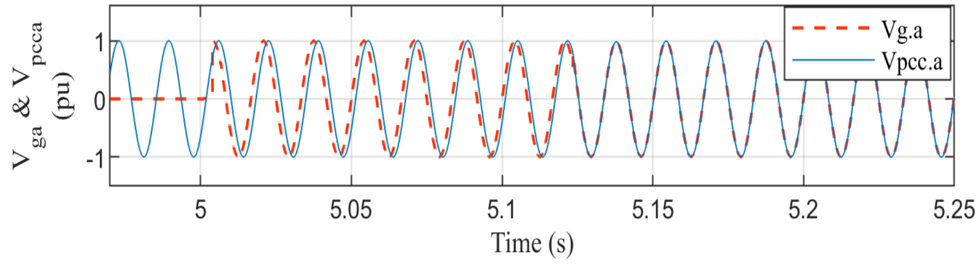
➢ **Comparison #2:** ***Autonomous*** **mode to** ***Grid-connected*** **mode :**

- **Synchronization process** between the VSC system and the grid in both testbeds:

Testbed # 1: **grid-forming / grid-following**



Testbed # 2: **grid-supporting**



- Frequency is extracted by the PLL in both modes of operation.

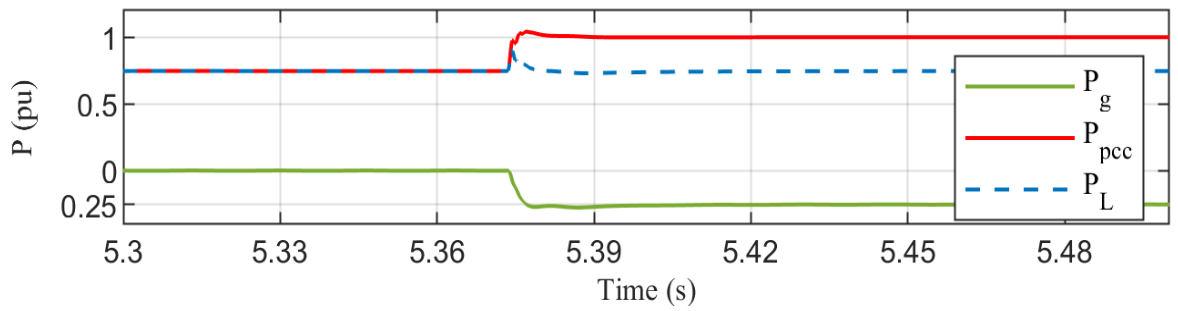
- The Gridback detection signal switches the frequency mode from free-running frequency by VCO to the PLL frequency (*imposed by the grid*).

Simulation & Results

➢ **Comparison #2:** ***Autonomous*** **mode** ***Grid-connected*** **mode :**

- Active power responses: converter output, load, and grid.
- The VSC injects a fixed active power (400 Kw) to the load (300 Kw) and the grid (100 Kw).

Testbed # 1: **grid-forming \ grid-following**



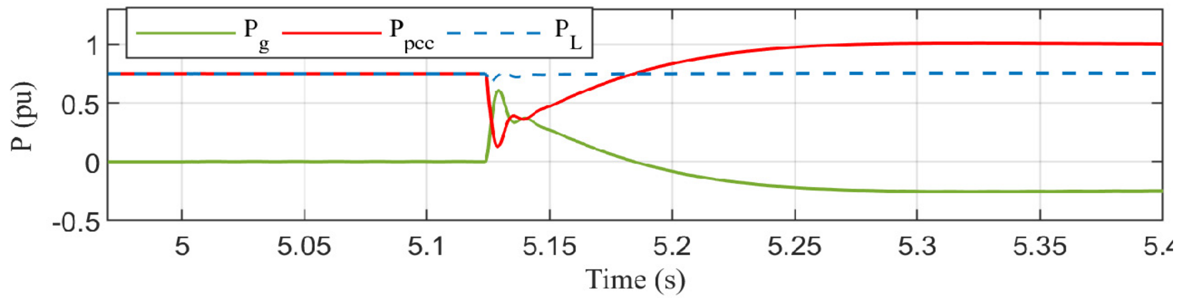
Autonomous mode

$$P_{pcc}^{*} = 1\,pu$$
$$P_{Load} = 0.75\,pu$$
$$P_{grid} = 0$$

Grid-connected mode

$$P_{pcc}^{*} = 1\,pu$$
$$P_{Load} = 0.75\,pu$$
$$P_{grid} = 0.25\,pu$$

Testbed # 2: **grid-supporting**



Autonomous mode

$$P_{pcc}^{*} = 1\,pu$$
$$P_{Load} = 0.75\,pu$$
$$P_{grid} = 0\,pu$$

Grid-connected mode

$$P_{pcc}^{*} = 1\,pu$$
$$P_{Load} = 0.75\,pu$$
$$P_{grid} = 0.25$$

Conclusion

- The simulation results of switching from one operation to another operation, namely, islanding and re-synchronization, are examined.
- Compared to either the grid-following or grid-forming VSCs, grid-supporting VSC has the advantage of operating in the both operation modes without changing control configuration.
- The droop control has been identified as an effective tool to participate in regulating the frequency , voltage, and power of the microgrid.

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Thank You
For Your Attention

Questions ?