Large-Bandwidth Triple-Loop Control of Grid-Connected Inverters

DEPARTMENT OF INFORMATION ENGINEERING

Qing Liu[1], Simone Buso[1], Tommaso Caldognetto[1,2]

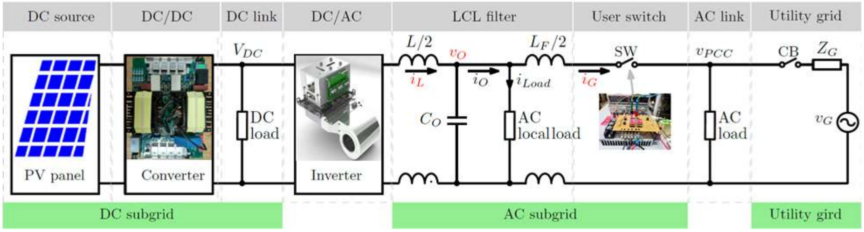
[1]Department of Information Engineering, University of Padova – Padova, Italy

[2]Interdepartmental Centre Giorgio Levi Cases, University of Padova – Padova, Italy

1. Abstract

A large-bandwidth, triple-loop controller designed for single-phase, grid-tied inverters is analyzed. This organization provides several benefits, including a regulated local ac voltage, a large-bandwidth control of the injecting power and a good robustness against different types of grid perturbations. Besides, the proposed controller is inherently able to guarantee seamless transitions between grid-tied and islanded operation, showing good potential for application to nano- and micro-grid utility interface converters.

2. System configuration

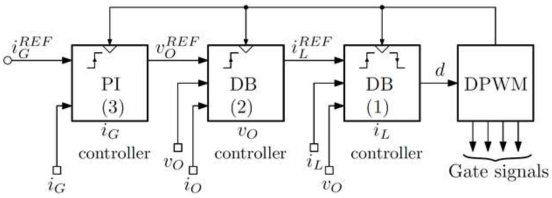


Symbol	Value	
V_{DC}	450	V
f_{sw}	20	kHz
L	1.4	mH
ESR_L	60	mΩ
C_o	30	μF
L_F	0.55	mH
ESR_{L_F}	75	mΩ
S_o	3	kVA
V_G	230	V

3. Control strategy

- **Inductor current loop** (deadbeat controller) provides satisfying system damping and rapid overcurrent protection.
- **Output voltage loop**(deadbeat controller) guarantees seamless mode transitions and high-quality local-voltage supply.
- **Grid current loop** (PI controller) can be designed with relatively large bandwidth. This is crucial to attain good harmonic attenuation and resilience to grid perturbations.

4. Large-bandwidth triple-loop controller



Structure of the proposed triple-loop controller

Control equations of each loop:

$$d = \frac{L f_{sw}}{V_{DC}} \cdot [i_L^{REF} - i_L] + \frac{v_O}{2V_{DC}} + \frac{1}{2}. \quad (1)$$

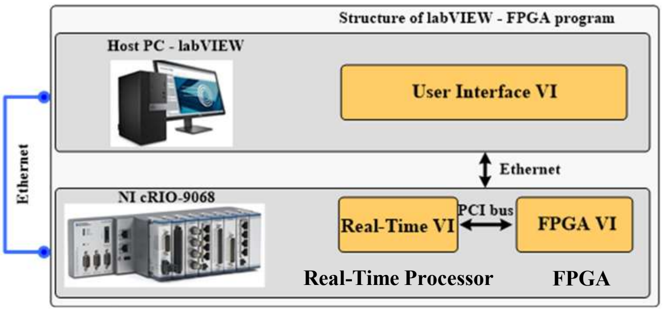
$$i_L^{REF} = C_O f_{sw} \cdot [v_O^{REF} - v_O] + i_O, \quad (2)$$

$$v_O^{REF} = H_{PI} \cdot (i_G^{REF} - i_G). \quad (3)$$

5. Achieved advantages

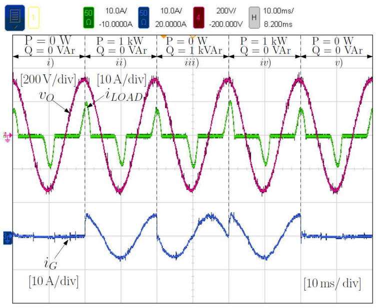
- excellent reference tracking performance.
- a strong attenuation of converter-side and grid-side harmonics.
- grid-connected and islanded operations and seamless transitions between the two.
- robust stability in the presence of grid perturbations (grid voltage harmonic pollution, amplitude and frequency fluctuations or connection impedance parameter variations).

6. Implementation of the proposed controller

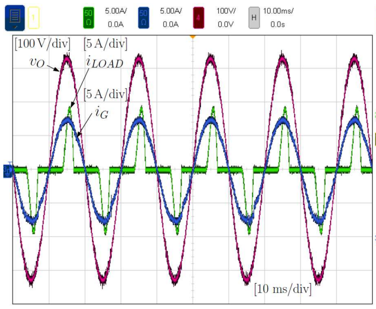


- **labVIEW:** access and integrate all the components of the cRIO; provides the operator with graphical human machine interface(HMI).
- **Real-Time processor:** provides reliable, predictable behaviour and excels at floating-point math and analysis.
- **FPGA:** excels at high-speed logic and precise timing.

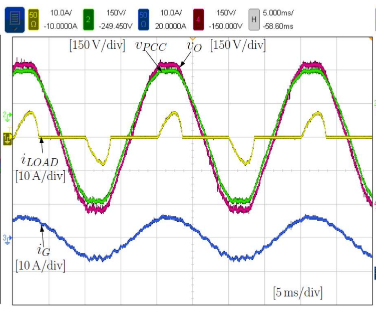
7. Experimental verification



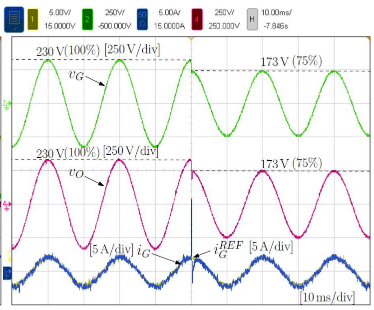
(a) Dynamic performance of the grid current loop.



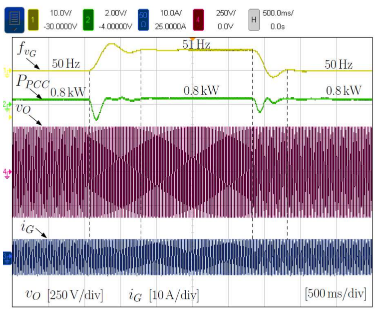
(b) Supression of converter-side harmonics.



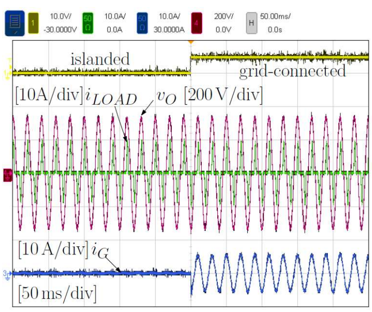
(c) Supression of gird-side harmonics.



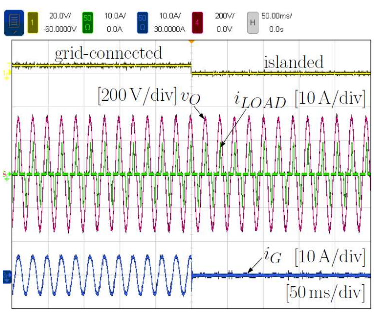
(d) Response to grid voltage amplitude step.



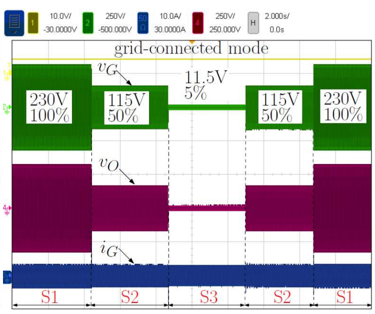
(e) Response to grid frequency step variation.



(f) Transition from islanded to grid-tied mode.



(g) Transition from grid-tied to islanded mode.



(h) Low voltage ride-through performance.

8. Future work

- Auto-tuning of the grid current loop.
- Top level control scheme of the hybrid AC/DC micro grid.

9. Acknowledgments

Qing Liu is sponsored by China Scholarship Council, 201606290045.