Rapid prototyping in renewable energy research and application

Milutin P. Petronijević[1], Marko Dimitrijević[1], Ivana Radonjić[2], Boban Veselić[1], Lana Pantić[2]
[1]Faculty of Electronic Engineering, University of Niš, Serbia,
[2]Faculty of Sciences and Mathematics, University of Niš, Serbia

eNergetics 2022

1. Introduction

Comprehensive functionality tests before wide application of innovative solutions can be provided with Rapid Control Prototyping (RCP) and emulation of field measurements in laboratory.
Development of control algorithms and embedded software for inverters powered by renewable energy sources can be a challenging task in the context of safety and emerging operation.
Detailed simulation tests are very convenient before experimental testing. This paper presents an approach with simulations used as a basic step in the development of applications with grid inverters.
This approach accelerates development and improves software quality by helping to early detect errors and design flaws. This workflow, among other things, enables rapid execution of experimental iterations to identify and resolve potential problems.

2. Single-stage Grid inverters Topology and Control

Basic control schemes include:
Grid feeding (GFe) inverter: active and reactive power flow control (PLL with PoC voltages)
Grid forming (GFo) inverter: voltage and frequency control (internal generated PLL)

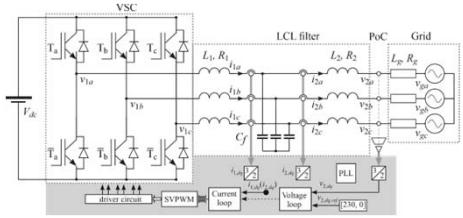

Fig. 1. General structure of SS grid inverter with GFe or GFo

3. Hardware and Software Implementation

Hardware components
Grid inverters: *three phase two-level VSI converter* ; output filters: *LCL topology with active and passive damping;*
Signal measurement and conditioning: *AC currents and voltage transducers;*
Programmable DC sources for PV or Battery emulation: 0 – 800 VDC, 6kW;
Line emulation and local loads.

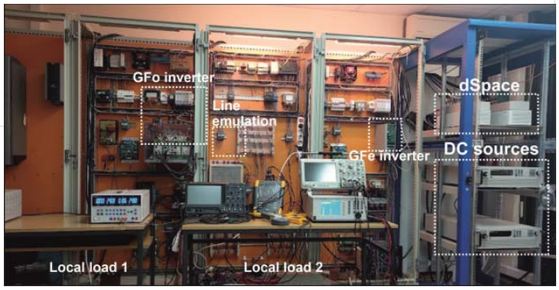

Fig. 2. Photo of the laboratory microgrid with the main hardware components used in the experiments

Software building blocks
synchronous reference frame *(dq)*
Phase-Locked Loops (PLLs): SRF, ESRF, DDSRF, MAF,
Current Controllers:
- PI, PI+RES, Sliding mode controllers,
- anti-windup function,

Coordinate transformations: abc→ dq, dq →abc
two-phase stationary reference frame (αβ)
Current controllers: PR, PR+RES

4. Case Studies

GFe three-phase inverter with DT sliding mode control
The IEEE 1547 standard defines limits regarding the content of harmonics - even and odd, as well as the total harmonic distortion of the current that distributed generators (DG) emit into the public distribution network.

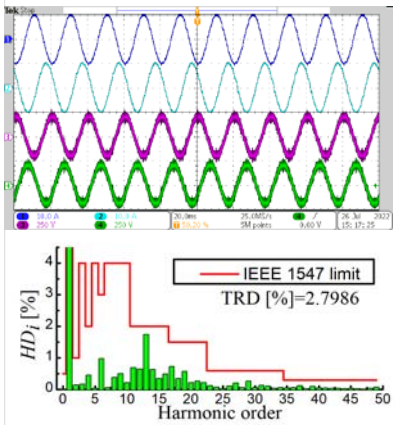

Fig. 3. Steady state performances and grid currents harmonic spectrum under the full load: trace 1 – current i_{2a}, trace 2 – current i_{2b}, trace 3 – voltage v_{2a}, trace 4 - voltage v_{2b}

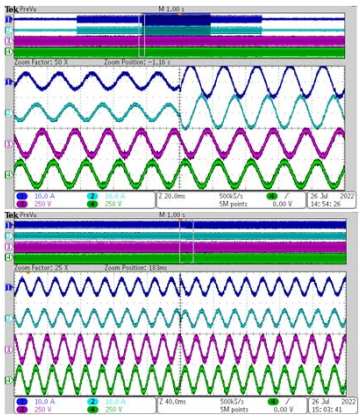

Fig. 4. Transients under abrupt change of the *d*-axis reference current (top) and power flow reversal (bottom)

Microgrid with PV panel and battery emulation
Soiling experiment conducted at the Faculty of Sciences and Mathematics in Niš showed that in the case of optimally inclined monocrystalline silicon PV panel, I-V curves of the soiled PV panel had a step in the area of the maximum power. Accordingly, it means that soiling hasn't been uniformly distributed and induced partial shading of the PV panel

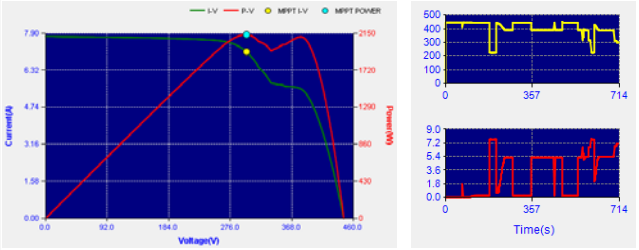

Fig. 5. Emulation of real I-V curve (left) and DC side PV panel voltage and current under variable load with GFo control (right).

5. Conclusion

The paper presents in details validation steps and experiments important for real exploitation with reference to practical problems related to RES power quality and verification in accordance with modern grid codes.
The value of the presented solutions is mostly reflected in the practical usability of the described approaches, which can be easily modified and applied in advanced topics that are at the top of today's scientific research