Simulation and Implementation of a PV Inverter with Improved THD

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1. Introduction

Recently, there is an intense integration of photovoltaic (PV) energy into the grid mainly due to decreased PV module prices and mature PV technology

- ✓ This causes challenges related to the power quality of the PV system and the grid
- ✓ PV single-phase inverters produce harmonics during operation causing:
  - ❑ additional power losses,
  - ❑ different malfunctions,
  - ❑ instabilities of the grid.

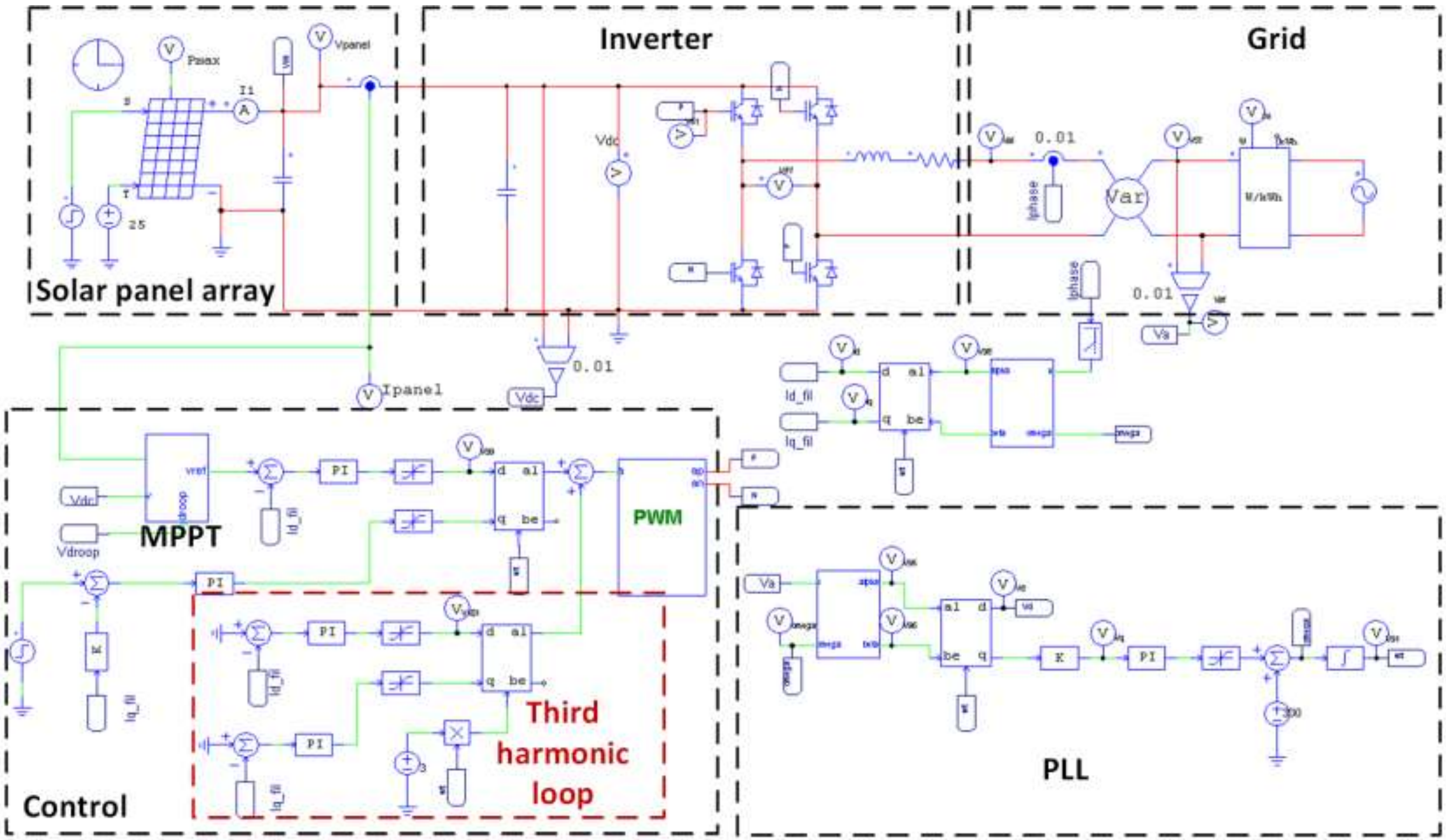
→ **Standards impose THD < 5%**

- ✓ Methods for the inverter control to address the issue:
  - ❑ PI controllers,
  - ❑ proportional resonant (PR) controllers,
  - ❑ multitenant controllers.

→ **High computational burden**

MAIN OBJECTIVE - *The current paper analyzes the improvement of the power quality only when the third harmonic is eliminated in the case of a single-phase PV inverter.*

2. System description



Block diagram of the PV system with single-phase inverter.

3. Output current THD correction method

Problem

The voltage that supplies the inverter from the solar panels is:

$$u_{dc}(t) = \frac{P_M}{2 \cdot \omega_{grid} \cdot U_C \cdot C} \cdot \sin(2 \cdot \omega_{grid} \cdot t)$$

The output voltage that supplies the inverter from the solar panels is:

$$U_{out}(t) \approx d(t) \cdot u_{dc}(t) = D \sin(\omega_{grid} \cdot t + \varphi) \cdot \frac{P_M}{2 \cdot \omega_{grid} \cdot U_C \cdot C} \cdot \sin(2 \cdot \omega_{grid} \cdot t)$$

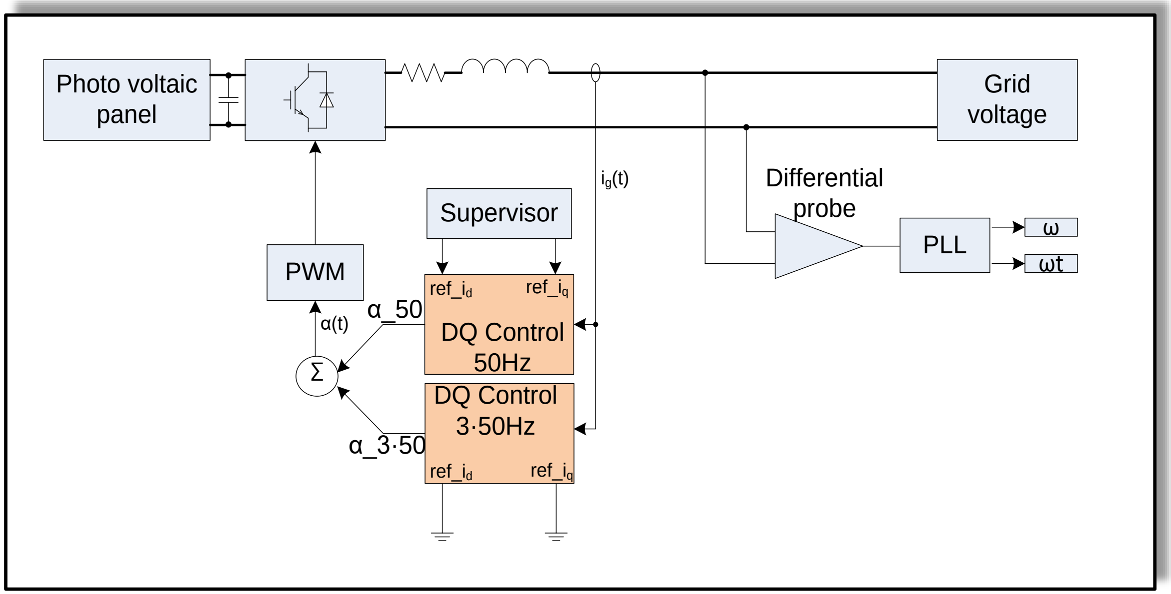
Solution

Compensation method

- ✓ In order to include third harmonic information into the feedback, a separate loop is added.
- ✓ It also uses the dq transform, but its input will be the third harmonic.
- ✓ The set point values for both d and q components will be 0, such that the third harmonic is eliminated.
- ✓ The output of the additional loop will be added to the output of the main, fundamental frequency, loop.
- ✓ Consequently, the time varying duty cycle signal will be intentionally distorted in order to reduce the distortion at the output of the inverter.

3. Output current THD correction method

Third harmonic elimination method block diagram



Based on the previous considerations, only the ratio of I_3 and I_1 will be evaluated (as TH3)

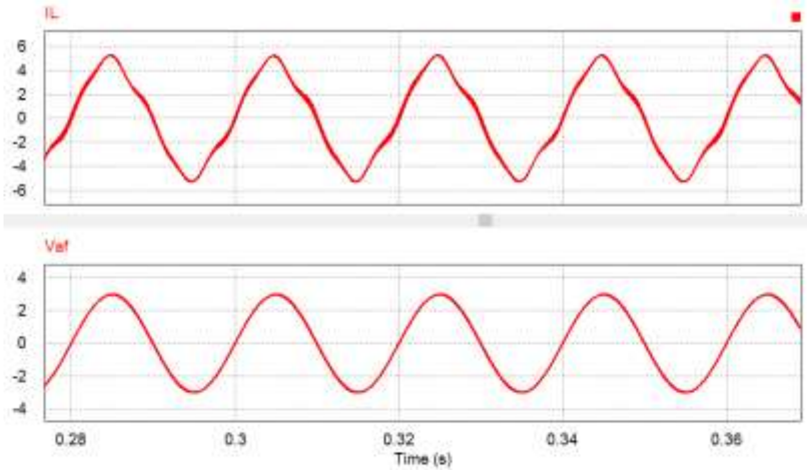
TH3 for the **uncompensated** system is:

$$TH3 = \frac{I_3}{I_1} = 8.37\%$$

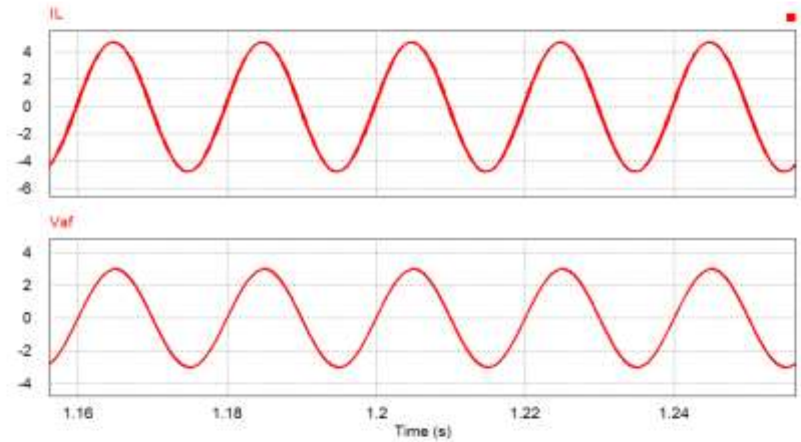
TH3 for the **compensated** system is:

$$TH3 = \frac{I_3}{I_1} = 0.282\%$$

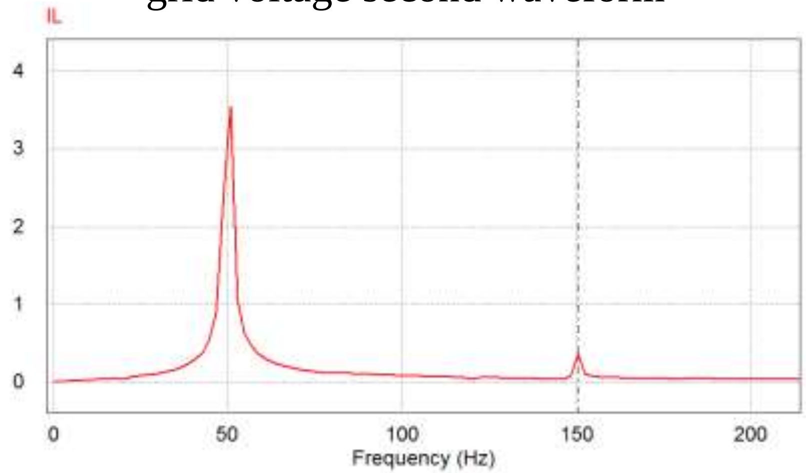
4. Simulation results



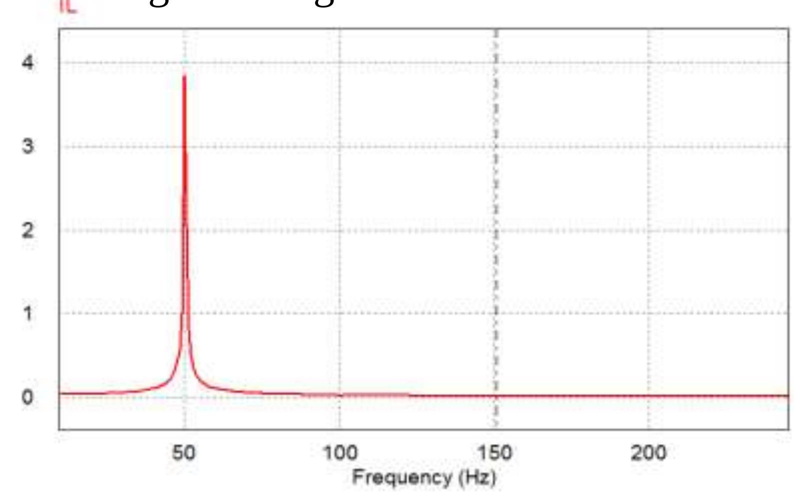
Uncompensated current first waveform and grid voltage second waveform



Compensated current first waveform and grid voltage second waveform

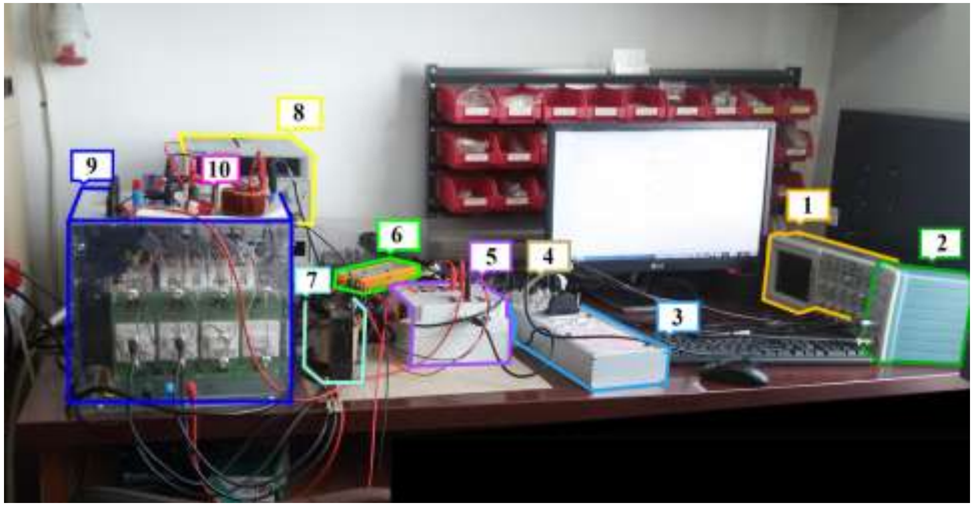


FFT of the uncompensated output current



FFT of the compensated output current

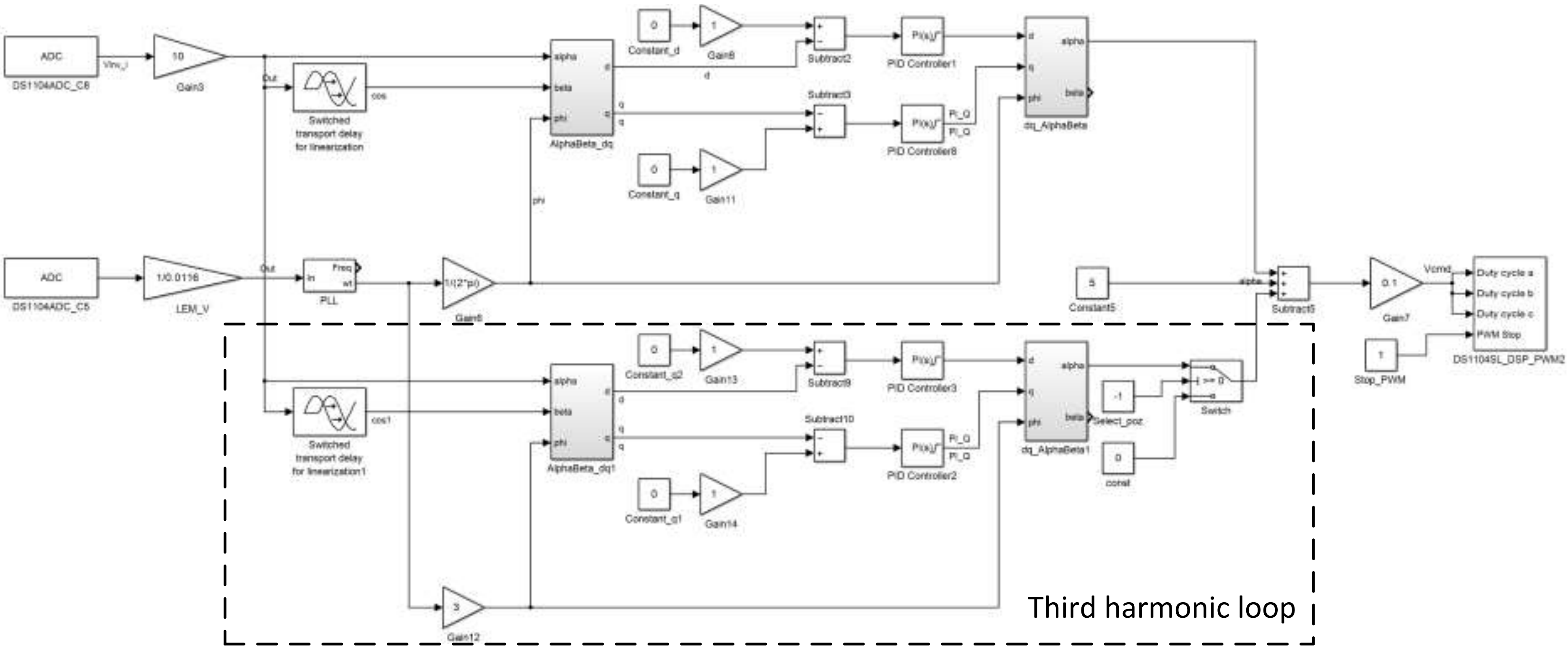
5. Experimental results



Experimental setup

1. Oscilloscope,
2. Current sensors,
3. DS1104 control board,
4. Driver circuits for the inverter,
5. Voltage and current sensors,
6. Voltage probe,
7. Grid coupling impedance,
8. Power supply,
9. H-bridge inverter,
10. LC filter.

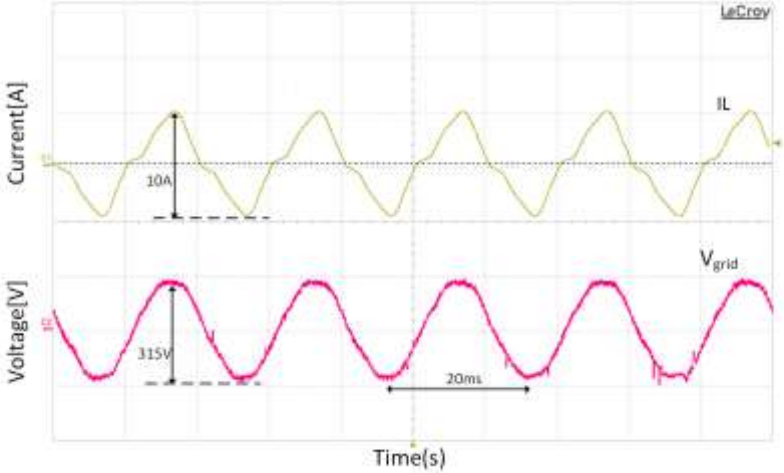
5. Experimental results



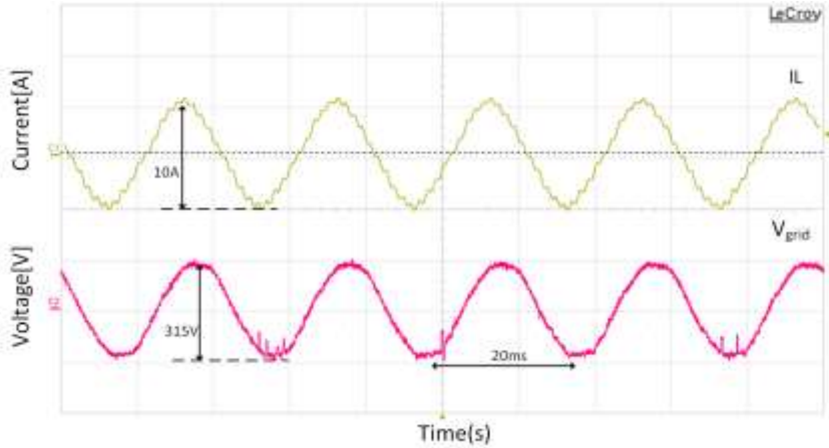
Implementation of the algorithm in Simulink

- The algorithm was implemented in **Simulink** and then loaded into a **DSpace** 1104 board

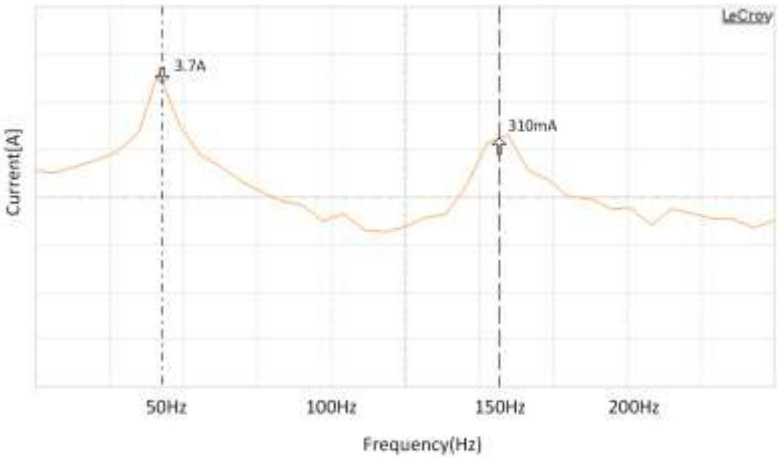
5. Experimental results



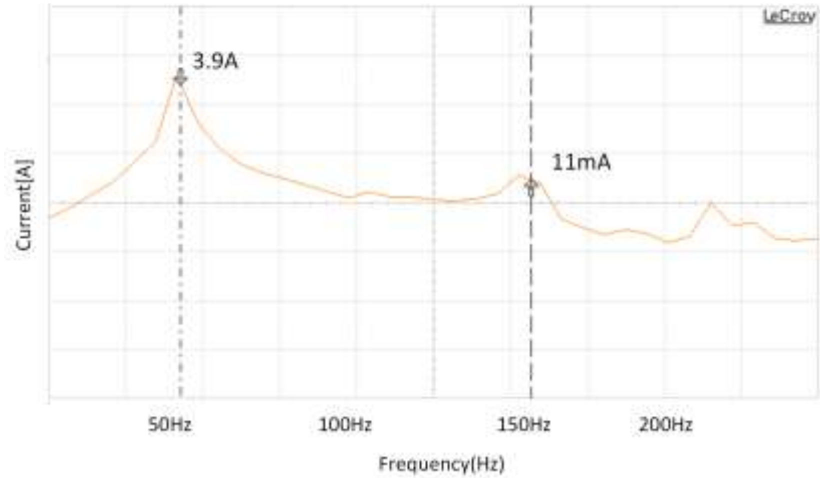
Uncompensated current first waveform and grid voltage second waveform



Compensated current first waveform and grid voltage second waveform



FFT of the uncompensated output current



FFT of the compensated output current

6. Conclusions

- ✓ The paper analyzed the influence of the input capacitor ripple voltage on the third harmonic injected into the grid.
- ✓ It proposed a method that allows for more relaxed requirements for the DC link capacitor.
- ✓ Compared to other control methods, the proposed method has low computational burden, requiring the addition of only one extra third harmonic loop to a classic DQ control scheme.
- ✓ It was shown that in the case of single-phase PV inverters using this method can fulfill the requirements of the standards regarding the THD of the currents injected into the grid.
- ✓ The experimental results are well correlated with the simulated results and support the claims made by the theoretical analysis.

Thank you !