European Union
European Regional Development Fund

HELLENIC REPUBLIC
MINISTRY OF ECONOMY & DEVELOPMENT
SPECIAL SECRETARY FOR ERDF & CF
MANAGING AUTHORITY OF EPAnEK

EPAnEK 2014-2020
OPERATIONAL PROGRAMME
COMPETITIVENESS
ENTREPRENEURSHIP
INNOVATION

ΕΣΠΑ 2014-2020
ανάπτυξη - εργασία - αλληλεγγύη
Partnership Agreement 2014 - 2020

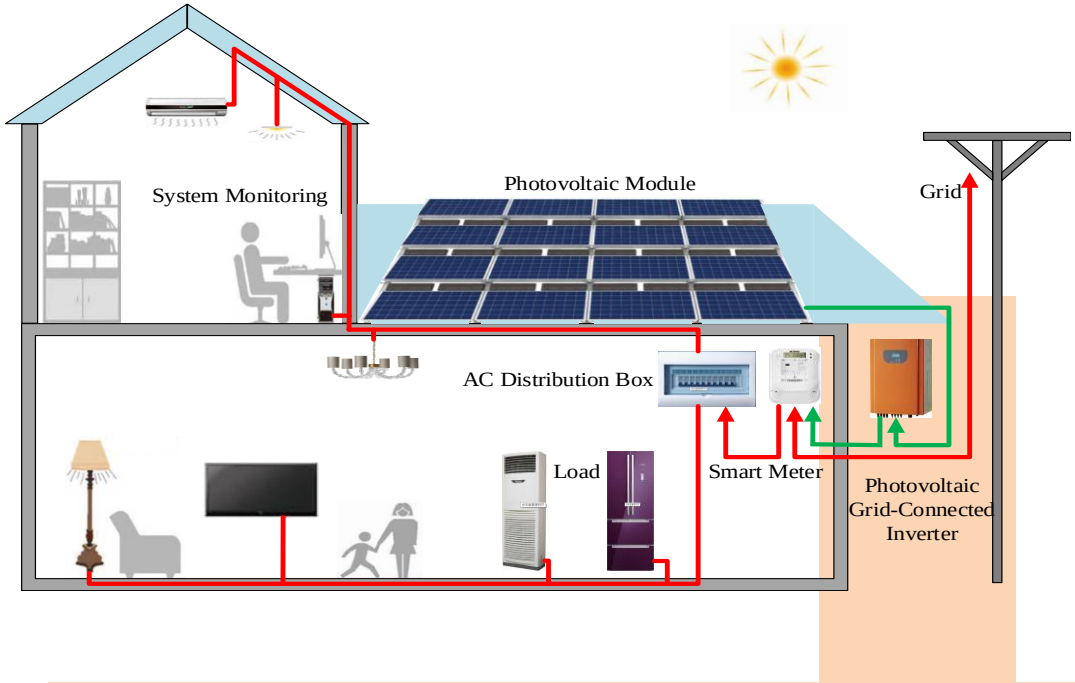
Co-financed by Greece and the European Union

eSOLAR:
Principle and control of high-efficiency Buck-Boost type Photovoltaic inverter

Funded by the Operational Program “Competitiveness, Entrepreneurship and Innovation 2014-2020” (co-funded by the European Regional Development Fund) under the program “Bilateral and Multilateral Research & Technology Co-operation between Greece and China” (project code: T7ΔΚΙ-00066)

Existing technology (I)

Typical Distributed Generation (DG) residential PV power system:



Photovoltaic (PV) DC/AC inverter → central component

Existing technology (II)

- Variability of meteorological conditions → **PV inverters operate with continuously changing input power/voltage**

- **Existing design optimization techniques of PV inverters:**
  - calculate the optimal types of passive and active components such that the efficiency of the overall PV inverter is maximized
  - **they are applied offline, i.e. during the PV inverter design stage**

Disadvantages:

- The PV inverter structure is not optimally matched to the input PV array
- Do not guarantee maximum PV energy production

The solution developed in the eSOLAR project (I)

eSOLAR:

A new **smart** low-cost, single-phase string PV inverter with:

- ✓ **high efficiency and**
- ✓ **IoT connectivity**

for use in residential applications

The solution developed in the eSOLAR project (II)

- Exploitation of the **Internet of Things (IoT)** framework for:
  - ✓ **real-time optimization of the PV inverter** &
  - ✓ status monitoring of the PV inverter

Advantages:

- improvement of PV energy production
- continuous remote monitoring of the residential PV system operation
- reduction of energy losses caused by the PV system malfunctions that may remain undetected for a long period of time

eSOLAR project goals

- Develop and experimentally test a novel PV inverter in a real residential PV system
- Conduct research on PV inverter power circuits and control techniques
- Disseminate the project results in top-tier scientific journals and conferences
- Submission of applications for national and international patents

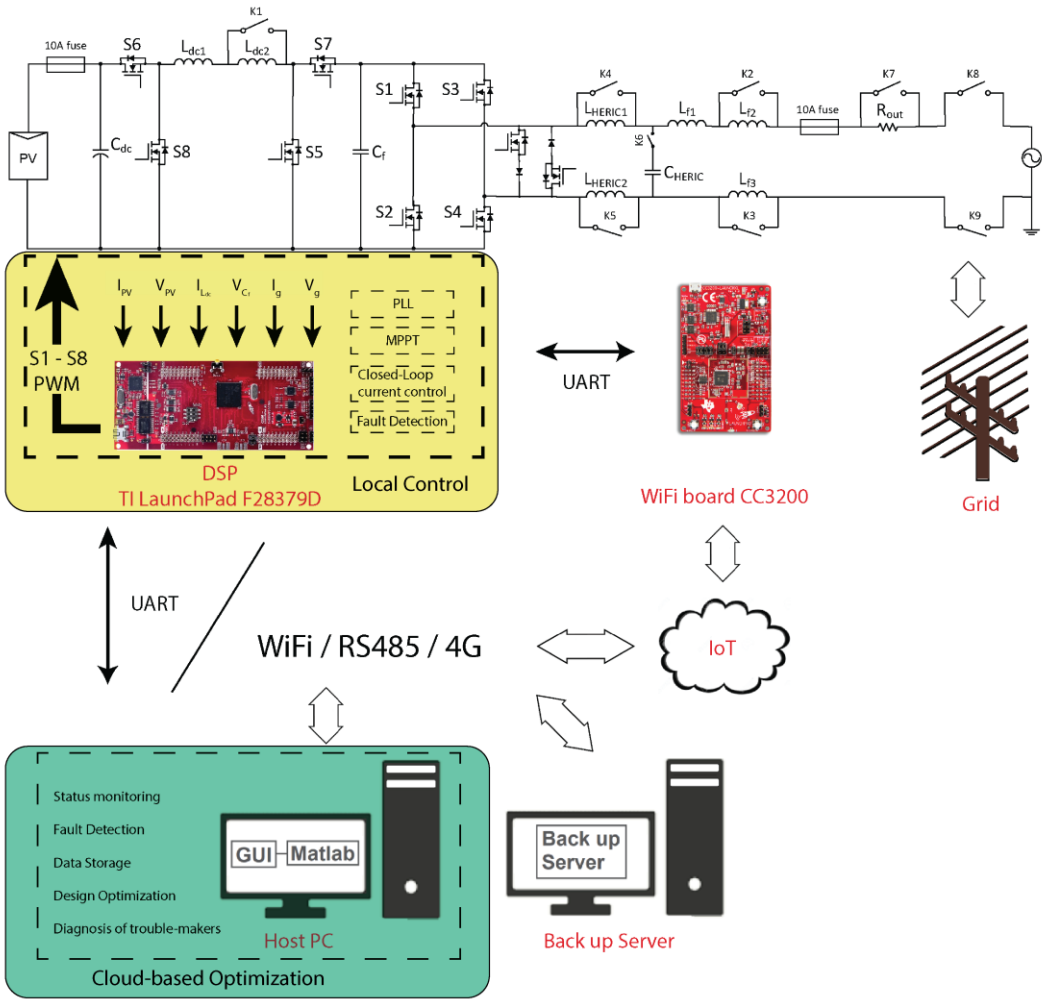
eSOLAR project implementation

- Starting date: **14-10-2019**
- Duration: **48 months** **(after extension due to COVID-19 protection measures)**
- Total budget: **231.817,57 €**
- Project Consortium:
  - **Technical University of Crete / Circuits, Sensors & Renewable Energy Sources Lab (Greece, coordinator)**
  - **SUN ENERGY SOLUTION S.A. (Greece)**
  - **Shanghai Maritime University (China, coordinator)**
  - **Dept. of Energy Technology, Aalborg University (Denmark) / Affiliated third-party partner**

The Buck-Boost PV inverter developed in the eSOLAR project (I)

Operations supported through IoT:

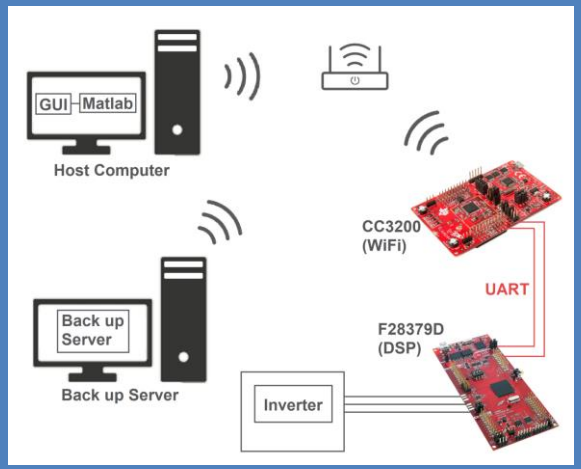
- Remote monitoring → **PV system fault detection**
- Real-time reconfiguration of the PV inverter power circuit → **increase of efficiency**
- Internal parameters estimation → **THD reduction**
- Optimizations executed on a **remote cloud server**
- Alternative ways of communication: **Wi-Fi**, **RS485**, **4G**



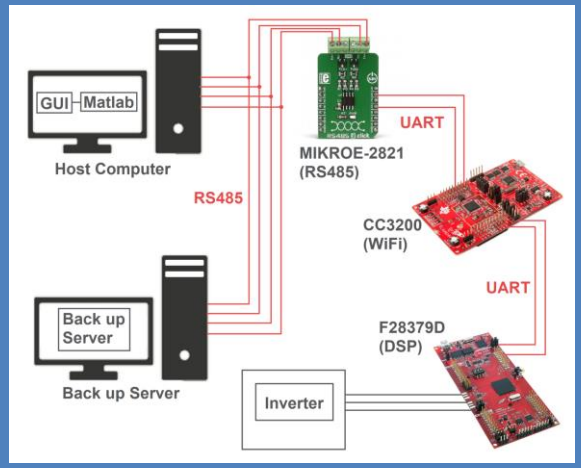
The Buck-Boost PV inverter developed in the eSOLAR project (II)

Alternative communication interfaces:

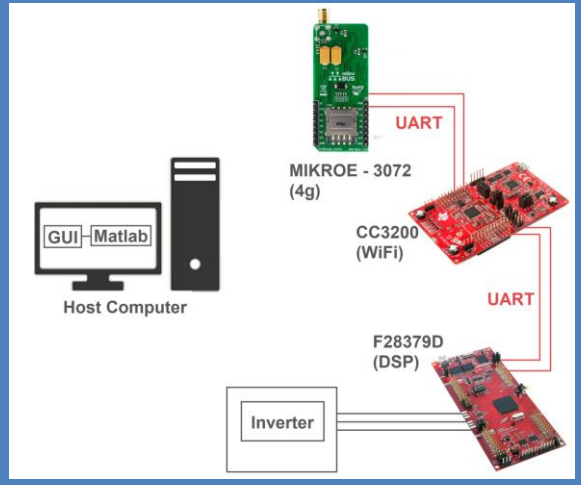
Wi-Fi



RS485



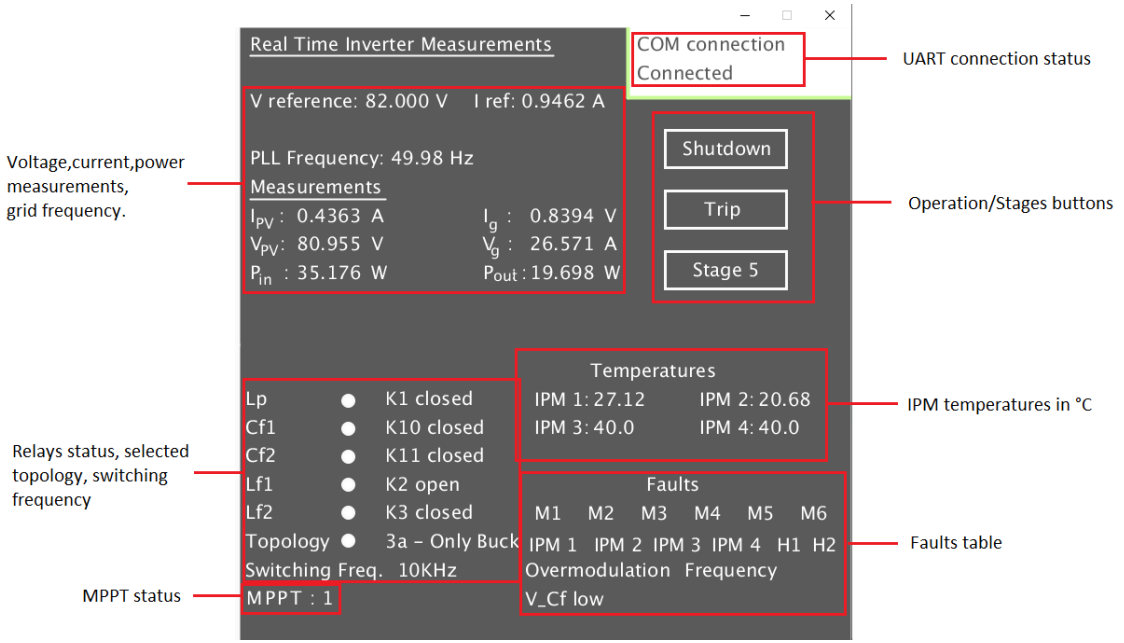
4G



The Buck-Boost PV inverter developed in the eSOLAR project (III)

Graphical User Interface (GUI) operations:

- GUI based on cloud server
- PV inverter monitoring & control
- Optimizations based on MATLAB/Simulink
- Data logging in text files with timestamp

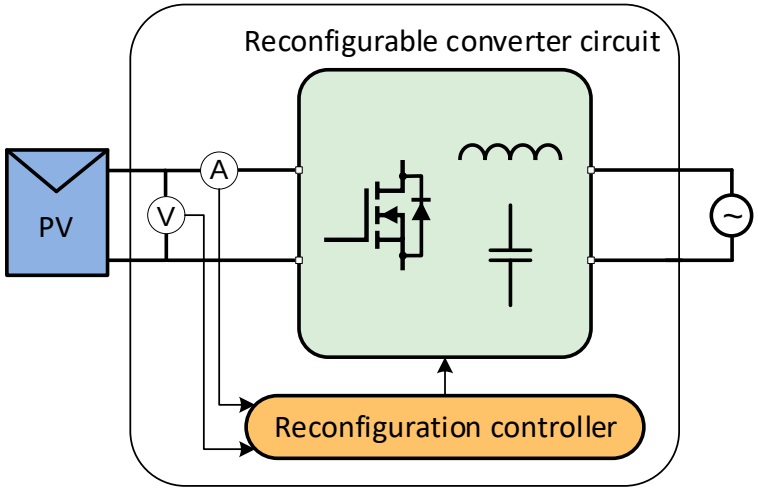


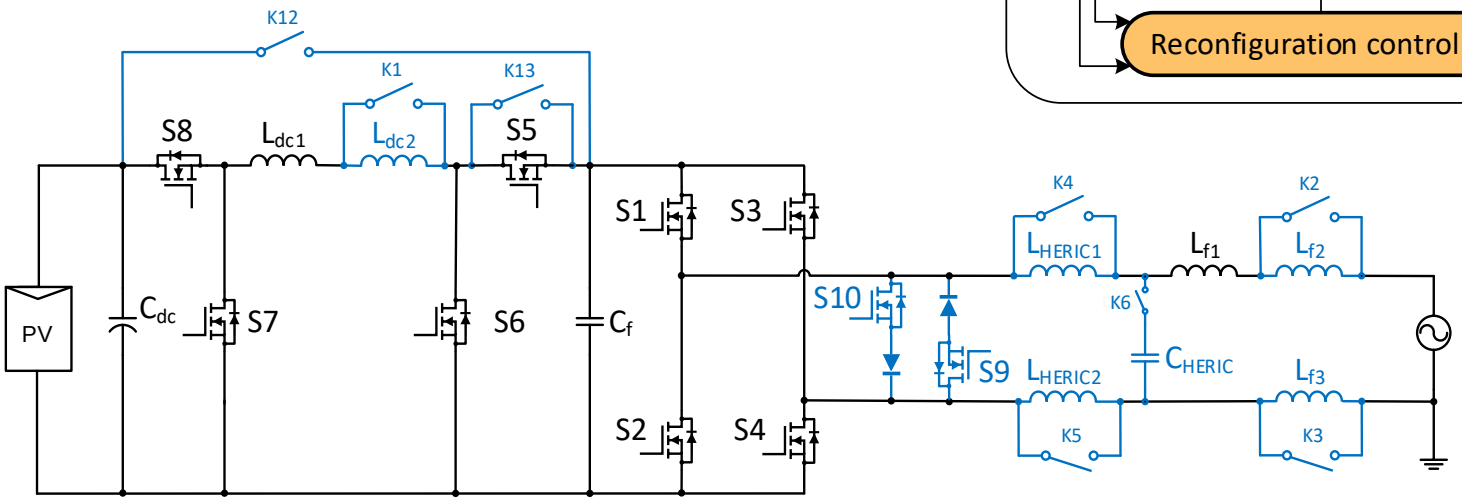
The Buck-Boost PV inverter developed in the eSOLAR project (IV)

Dynamic reconfiguration of the PV inverter power circuit for maximum efficiency

A DSP-based controller modifies in real-time:

- **Structure of the power circuit (topology)**
- **Values of filter inductors and capacitors**
- **Switching frequency**





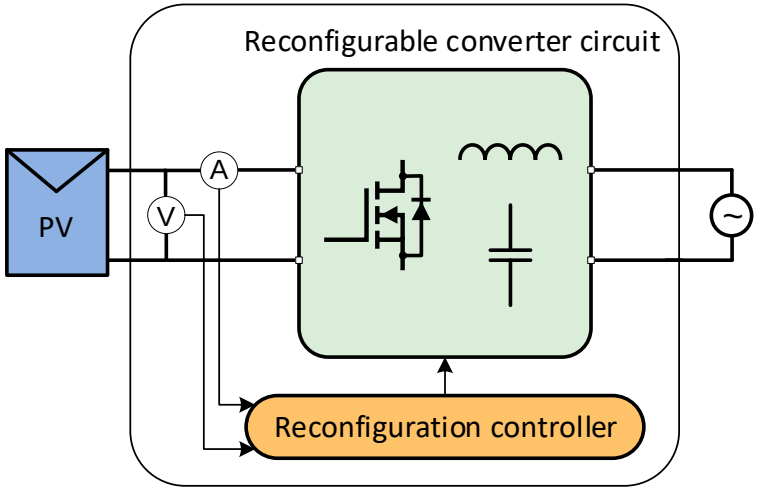
The Buck-Boost PV inverter developed in the eSOLAR project (V)

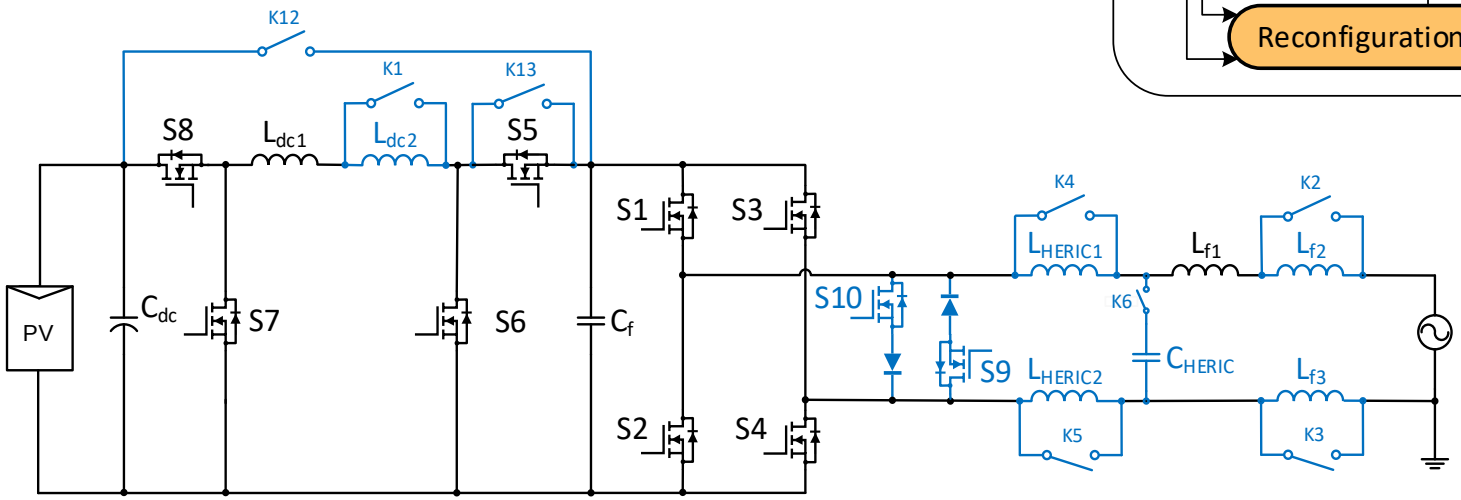
Experimental tests in a residential PV system:

Efficiency improvement by

1.46% up to 4.78%, depending on the

solar irradiance & ambient temperature

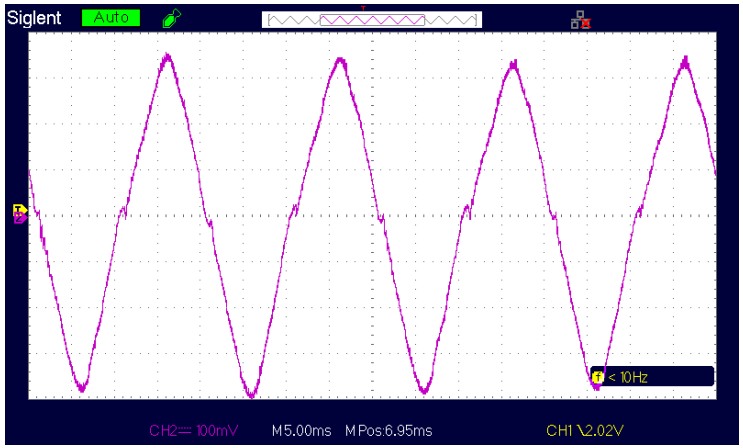




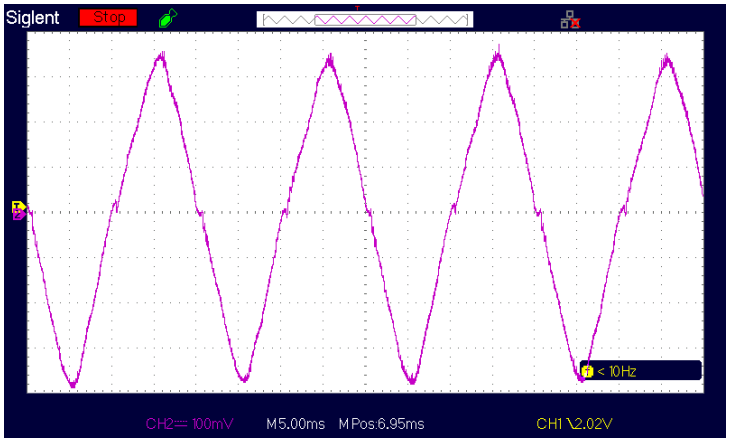
The Buck-Boost PV inverter developed in the eSOLAR project (VI)

Experimental tests in a residential PV system:

Total Harmonic Distortion (THD) of the output current is decreased by 2.8%



PV inverter output current with non-optimized control parameters



PV inverter output current after IoT-based optimization

Selected Publications

- ✓ F. Zheng, W. Wu, B. Chen and E. Koutroulis, "An Optimized Parameter Design Method for Passivity-Based Control in a LCL-Filtered Grid-Connected Inverter," in *IEEE Access*, vol. 8, pp. 189878-189890, 2020.
- ✓ G. I. Orfanoudakis, E. Koutroulis, G. Foteinopoulos, W. Wu, "Synchronous Reference Frame current control of Aalborg-type PV inverters", *23rd European Conference on Power Electronics and Applications (EPE'21 ECCE Europe)*, Ghent, Belgium, pp. 1-10, 2021.
- ✓ G. I. Orfanoudakis, E. Koutroulis, G. Foteinopoulos, "The role of diodes in the leakage current suppression mechanism of decoupling transformerless PV inverter topologies", *2021 10th International Conference on Modern Circuits and Systems Technologies (MOCAST)*, Thessaloniki, Greece, pp. 1-4, 2021.
- ✓ W. Wu, Z. Zhao, E. Koutroulis, H. S.-H. Chung and F. Blaabjerg, "Autoidentification Method of the "Trouble Maker(s)" for Internal Instability in Multiparalleled Inverters System," in *IEEE Trans. on Ind. Electronics*, vol. 69, no. 1, pp. 18-28, Jan. 2022.
- ✓ G. I. Orfanoudakis, G. Foteinopoulos, E. Koutroulis and W. Wu, "Design optimization of Aalborg-type transformerless PV inverters with focus on power quality," *2022 11th International Conference on Modern Circuits and Systems Technologies (MOCAST)*, Bremen, Germany, 2022, pp. 1-5.
- ✓ G. I. Orfanoudakis, E. Koutroulis, G. Foteinopoulos and W. Wu, "Evaluation of common-mode leakage current of Aalborg-type transformerless PV inverters," *2022 24th European Conference on Power Electronics and Applications (EPE'22 ECCE Europe)*, Hanover, Germany, 2022, pp. 1-10.

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