



PHOTOVOLTAIC INVERTER 3-PHASE CSI – CEA – TRAININGS

TECNALIA, SAN SEBASTIAN
CRICURSA, BARCELONA

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Anthony BIER, CEA



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3-phase current-source inverter

Characteristics

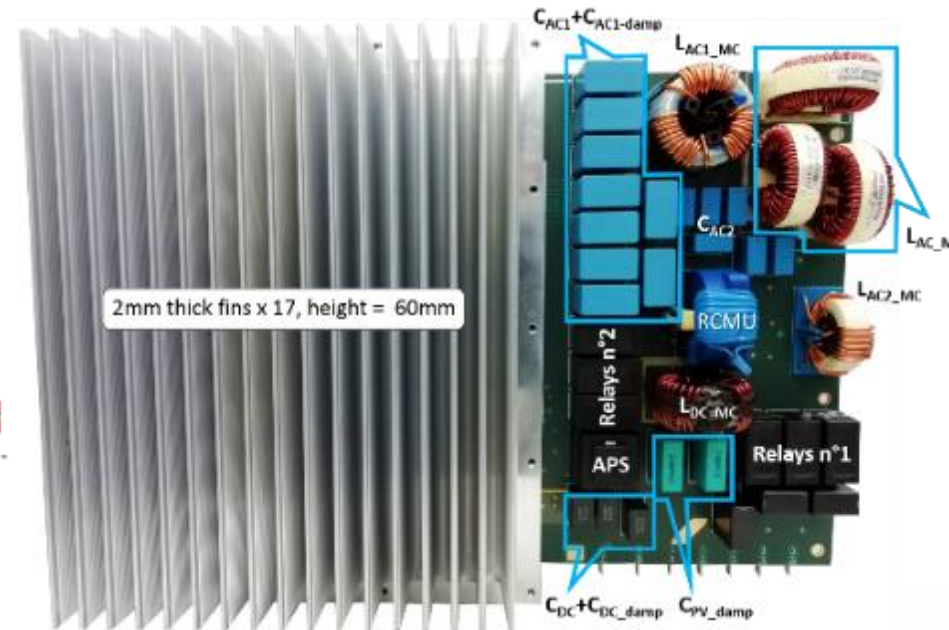
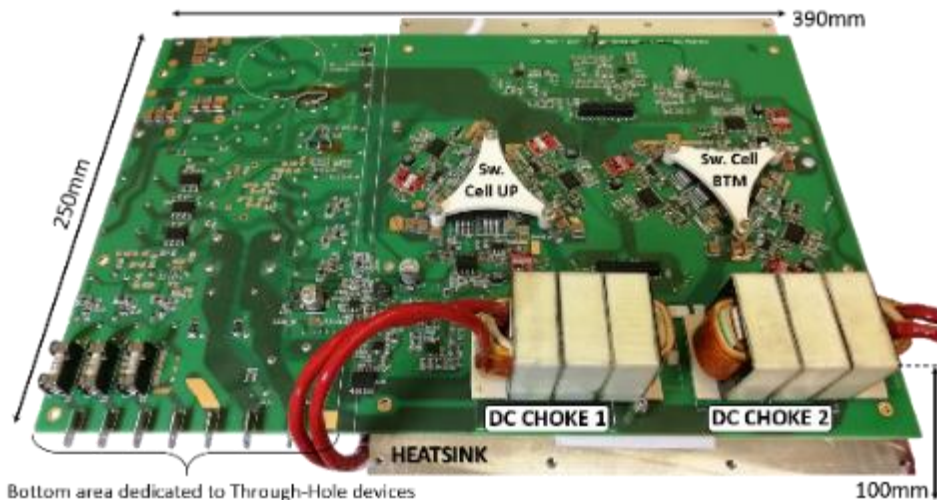


- Power : 5 kW
- Topology : Silicon carbide based 3-phase transformer-less current-source inverter
- Maximum PV voltage : $400 V_{DC}$
- Assigned grid AC voltage : $400 V_{ACrms} / 50 \text{ Hz}$
- Switching frequency : 125 kHz
- Maximum efficiency : 98 %

Design

Printed circuit board

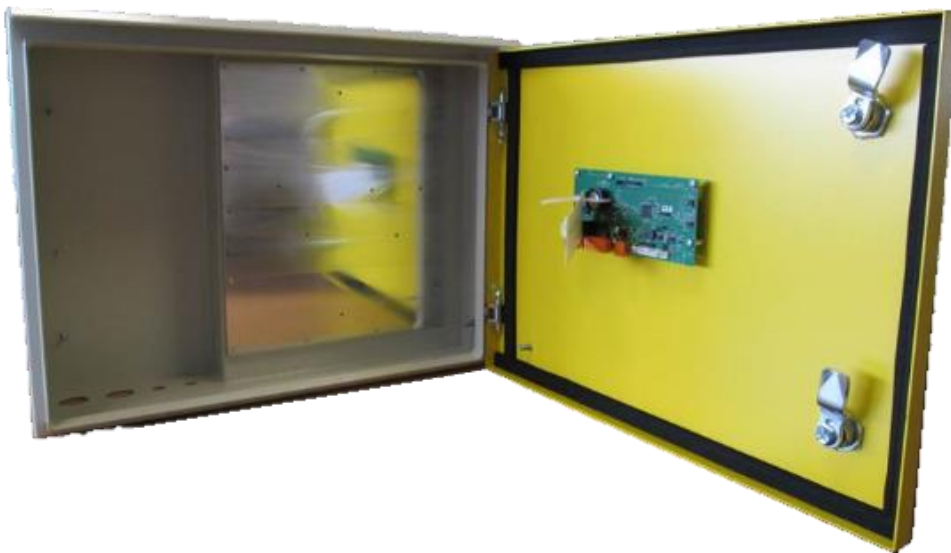
- Top-side:
 - Surface mounted component
 - Switching cells
 - Power supply
 - Switches drivers
 - Measuring channel
 - ...
 - DC chokes
- Bottom-side:
 - Through-holes mounted component
 - Differential and common-mode filtering
 - Relays
 - RCMU
 - Heatsink



Design

Enclosure

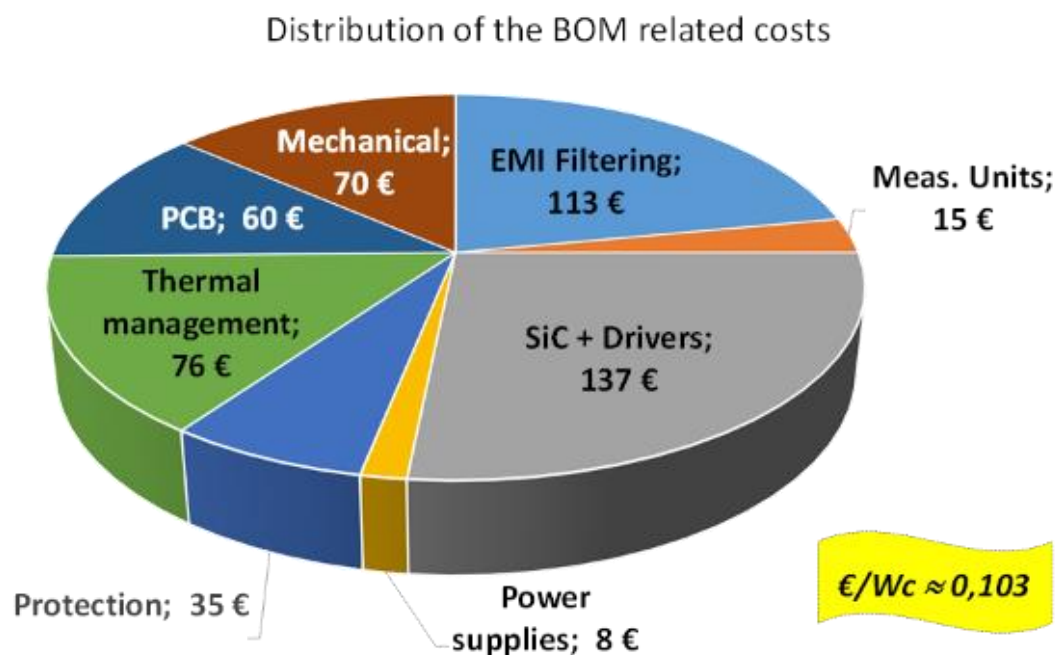
- Front-side
 - Metallic cabinet with key-locked door
 - Human-to-machine front interface
 - Holes for cable connections
- Back-side
 - Heatsink
 - Fixture system for wall mounting



Design

Bill of materials

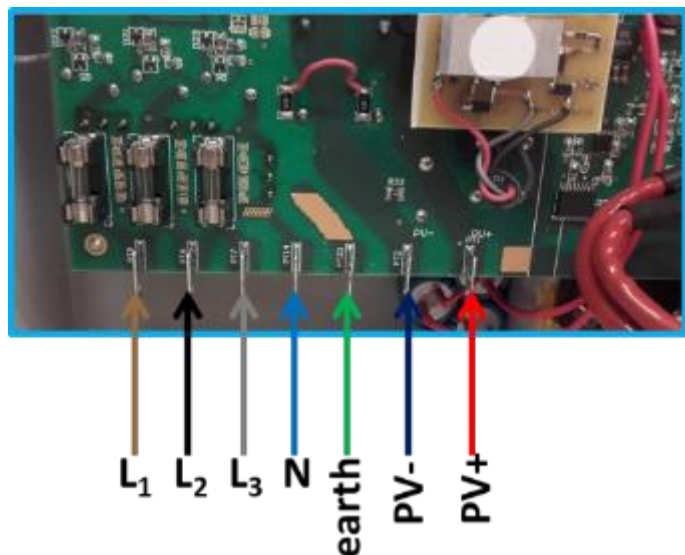
- Costs repartition of the inverter components



Connection

DC and AC cables

- Plug connectors for:
 - 3-phase AC cables
 - Neutral
 - Earth
 - DC plus and minus PV cables

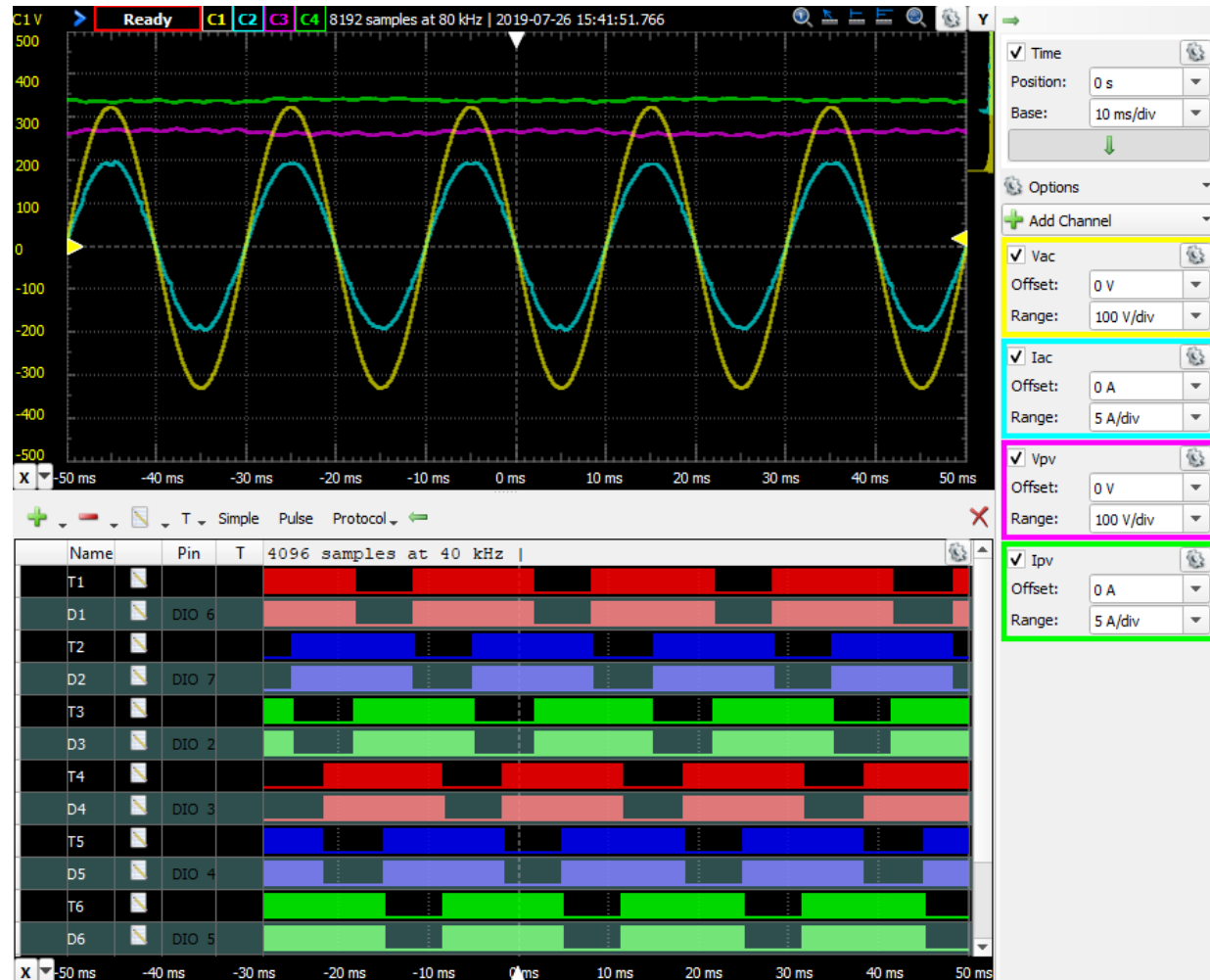


Test

Electrical normal-mode operation

Electrical waveforms analysis for operation under normal conditions test:

- PV voltage V_{PV}
- PV current I_{PV}
- Grid voltage V_{AC}
- Injected grid current I_{AC}

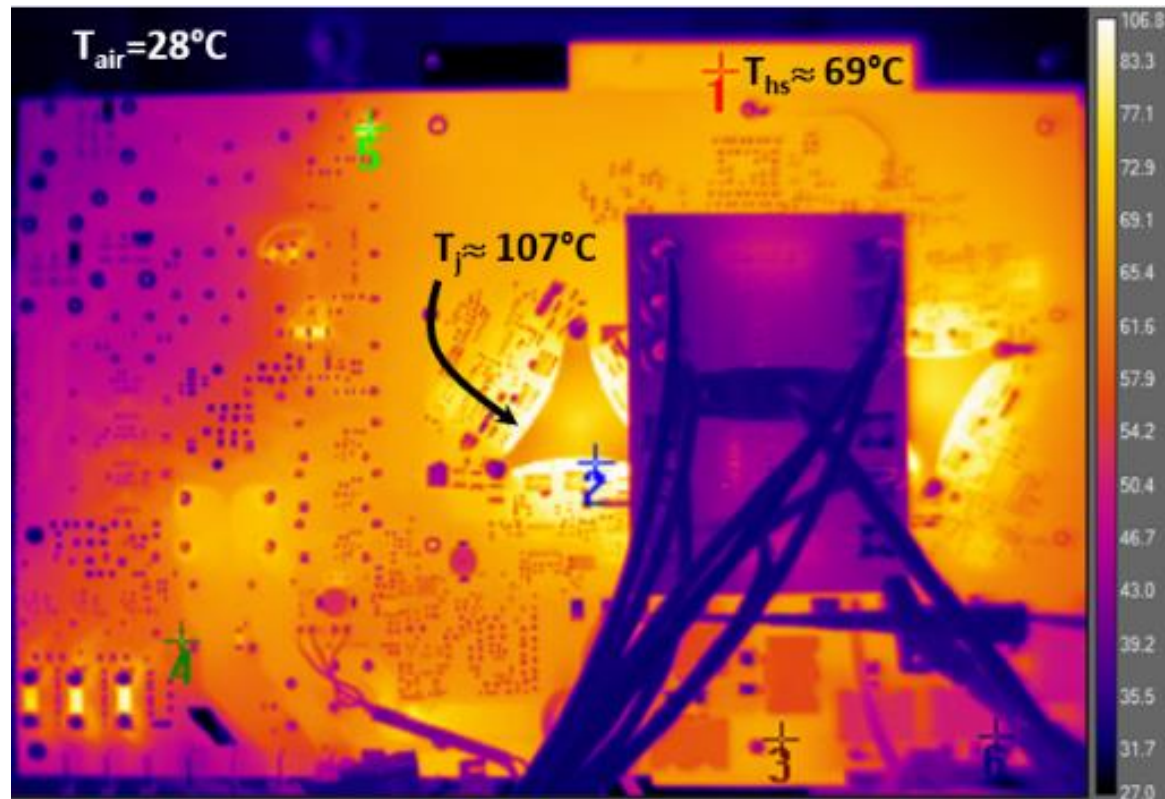


- Control signals for the 12 CSI switches

Test

Thermal management

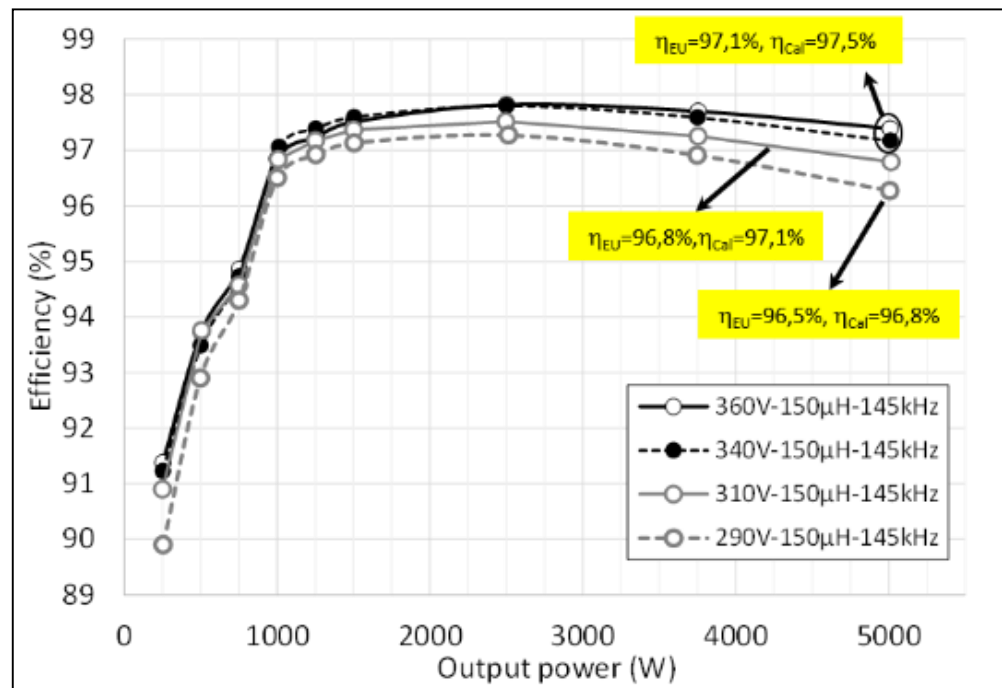
- Checking of several component temperatures along operation cycles for different powers at steady states
- At rated power (5 kW):
 - $T_{\text{air}} = 28^{\circ}\text{C}$
 - $T_{\text{heatsink}} = 69^{\circ}\text{C}$
 - $T_{\text{switches_junction}} = 107^{\circ}\text{C}$



Test

Efficiency

- Conversion efficiency measurement according to the EN50530 standard
- European weighted efficiencies:
 - 96,5% at 290 V_{PV}
 - 96,8% at 310 V_{PV}
 - 97,1% at 340 V_{PV}
 - 97,1% at 360 V_{PV}
- Californian weighted efficiencies:
 - 96,8% at 290 V_{PV}
 - 97,1% at 310 V_{PV}
 - 97,5% at 340 V_{PV}
 - 97,5% at 360 V_{PV}
- Maximum efficiency : 98%



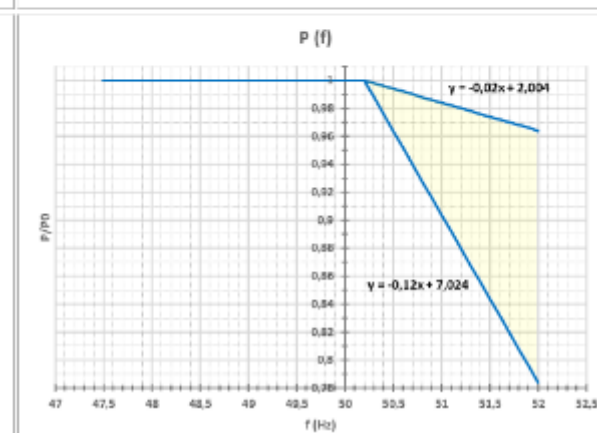
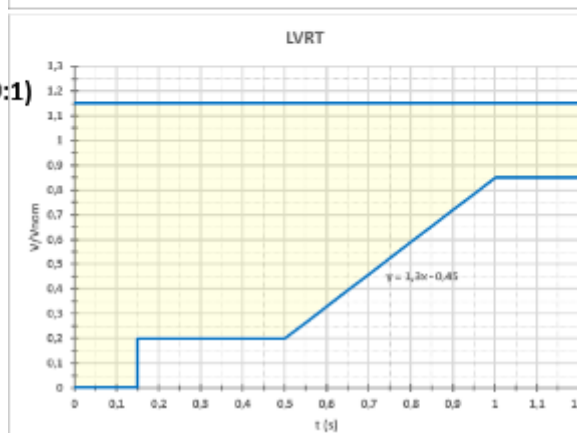
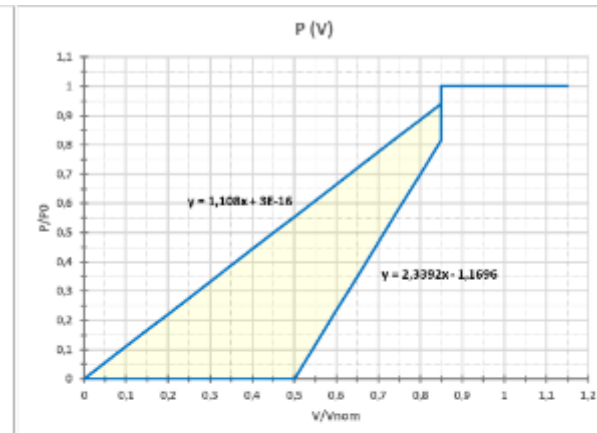
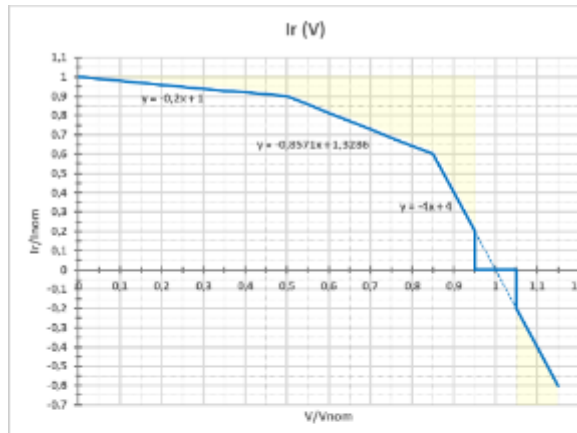
Test

Safety and Grid requirements

- Normal operation, grid requirement and safety standards to comply with:

- 1- Normal Operating Range
 - a. Voltage & Frequency Operating Range. (EN50438)
 - b. Under-frequency response (EN50438)
 - c. Over-Frequency response (EN50438)
- 2- Interface Protection
 - a. Under / Over Voltage Test (EN50438)
 - b. Under / Over Frequency Test (EN50438)
 - c. Main Loss Detection (Islanding) (IEC 62116)
 - d. Automatic Reconnection (EN50438)
- 3- Safety Protections
 - a. Residual current detection (IEC 62109:2)
 - b. PV array insulation resistance detection (IEC 62109:1)
- 4- Power Quality
 - a. Harmonic & Flicker (61000-3-2, 61000-3-3)
 - b. DC Current Injection (EN50438)
- 5- Low Voltage Ride Through (IEC 62910)
- 6- Reactive Power Delivery (EN50438)
- 7- MPPT Tests (EN50530)
- 8- Power Conversion Efficiency (EN50530)

- Standard profiles as described in PO12.3
 - Reactive current vs AC voltage level
 - Active power vs AC voltage level
 - Grid low-voltage ride through capability
 - Active power vs grid voltage frequency



Thanks for the attention

