UNIVERSITA' DEGLI STUDI DI NAPOLI FEDERICO II

The University of Naples Federico II was established in *1224* through an Imperial Charter of Frederick II Hohenstaufen, King of Sicily and Holy Roman Emperor. It was the first publicly funded university in Europe.

Nowadays the university offers courses in essentially all academic disciplines, leading to *150* graduate level degrees. Research facilities provide support to all these courses. Students are given the opportunity to pursue intellectual development as well as the acquisition of professional skills. Current student enrollment nears *97.000* and the academic personnel, at this time, is *3.121*.

The university is made up of three divisions, which operate as semi independent bodies for the teaching and research management of *13* schools and *82* departments grouped, within each division, according to academic and research profiles. Thus, the *Division of Science and Technology* includes: the *School of Sciences* (which, in turn, includes the Schools of Mathematics, Physics and Natural Sciences), the *School of Engineering*, and the *School of Architecture*. The Division of *Life Sciences* includes: the *School of Medicine and Surgery*, the School of Pharmacy, the School of Veterinary Medicine, the School of Agricultural Sciences and the recently established School of Biotechnological Sciences. The Division of *Social and Human* Sciences includes: the *School of Economics*, The *School of Law*, the School of Liberal Arts, the School of Political Sciences and the School of Sociology.

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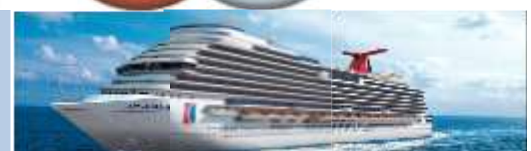
DIPARTIMENTO DI INGEGNERIA ELETTRICA E TECNOLOGIE DELL'INFORMAZIONE

TReLab

Transportation Research Electrical Laboratory



Non c'è nulla di immutabile, tranne l'esigenza di cambiare

Eraclito (filosofo)

TReLab, Transportation Research Electrical Laboratory

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The TReLab is active in power electronics, electrical drives and energy storage devices, in modeling and simulation of electrical transportation systems, including control strategies and control circuits. TReLab focuses its research activities along three principal axes:

Power Electronics oriented to the development of new Electrical Drives and Converter topologies for traction applications *(Railway, Aircraft, Ship and EV)*. In particular, TReLab is focused on the development of *Modular Multilevel Converters* integrated with new *Energy Storage Devices* and Renewable Energy Sources for Ultrafast EV Charging Station.

Control, simulation and test of AC Electrical Drive up to 250 kW. In particular, TReLab is focused on the testing of Asynchronous and AC Brushless Drives for Electric Traction Applications.

Design, realization and test of Laboratory Scale model in order to simulate complex Electromechanical systems. In particular, TReLab is focused on development of electromechanical simulator for Light Railway Vehicle and Metro network .

Research Topics

Topic	Application	Skill	Object
Wireless Power Transfer **EV - Ultrafast Charging** *Projects: I-ECO, MICCA* *Partnerships : Eutecne, PNPLab, Edison*	**Road Vehicles**	*Energy Management* *Integration* *Prototyping*	*RIPT converter* *MMC topology & SC* *Storage Devices* *PM motors*
Energy Saving *Projects: SITRAM , SFERE* *Partnership : Ansaldo STS & Hirachi* www.sitram.it	**Railway**	*Model* *Control* *Designing*	*Storage SC, LiC* *Dc/Dc Converters* *PM Brushless* *MMC topology*
High Performance **Mechatronic Actuators** *Projects: PON Umbra* *Partnership : Umbra Group*	**Aircraft**	*Model* *Control* *Designing*	*PFC Converters* *PM Brushless* *Embedded Drives* *SiC devices*

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P. Franzese
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A. Di Pasquale

Partnerships

Industry
SPSCAP - Italy
Ansaldo STS -Italy
Hitachi– Italy
Samso – Italy
Leonerdo– Italy
Edison - Italy

University
REVT Lab UT Dallas –US
LAPLACE,Tolosa- France
FCLAB of UTBM - France
EESE Birmingham - UK
DAEIMI, Cassino - Italy
DEEI, Trieste – Italy
ETEC PoliMi - Italy
DIETI, UniNa- Italy
DIIE, SUN- Italy

Spin Off
PnPLab - Italy

Research Center
CRIAT - Italy
CNR Istituto Motori – Italy
Enea- Italy

Events

ESARS-ITEC
Every two years starting from 2001

IEEE - ESARS International Conference on Electrical Systems for Aircraft, Railway, Ship & Road Vehicles
Next Edition
Venice 6rth - 9th
December 2022

EV- TEST DRIVE

In collaboration every year with Electrical Engineering Degree

PLAYERS
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Porche
Nissan
Renault

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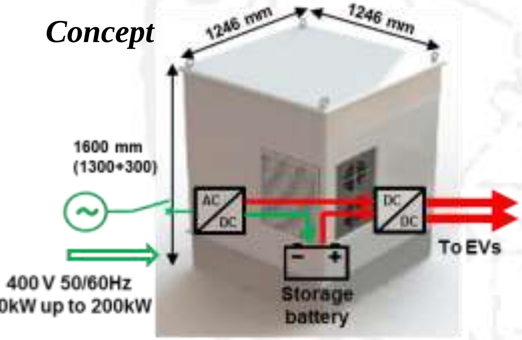
TReLab, Transportation Research Electrical Laboratory

Project

E-UltraFast Charging Station

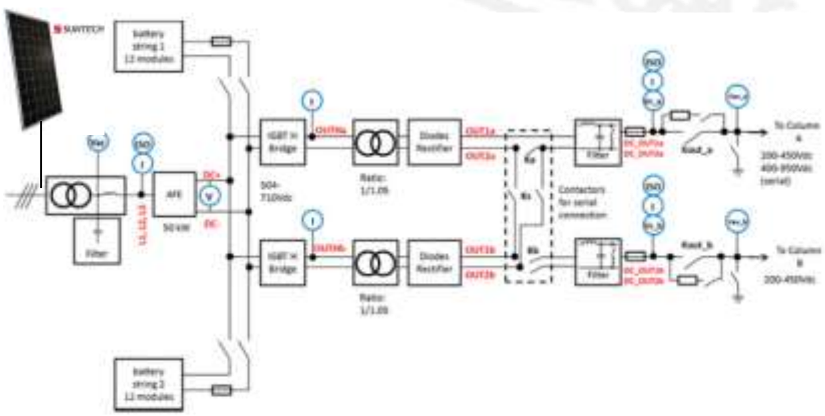
Concept



Main features
• Input : Public Electrical Network (50kW up to 140 kW) • Input : PV up to 100kW
• Integrated storage battery 158 kWh, to deliver large power to the Electric Vehicles: up to 320 kW
• Output current to Electric Vehicles up to 400 A
• Ambient temperature: -20 °C / +45 °C
• Low acoustic noise
• Easy access for high maintainability

High flexibility functionalities
Equipped with two charging strings:
✓ Two cars independently charged: 2x160 kW @ 400 V, 400 A
✓ One car charged with combined operation of the strings: 320 kW @ 800 V, 400 A

PV & Power Converter Architecture



DATI IMPIANTO	
Potenza Picco	101,36 kWp
Produttività	1.233 kWh/kWp
Numero moduli	332
Produzione attesa	124.600 kWh

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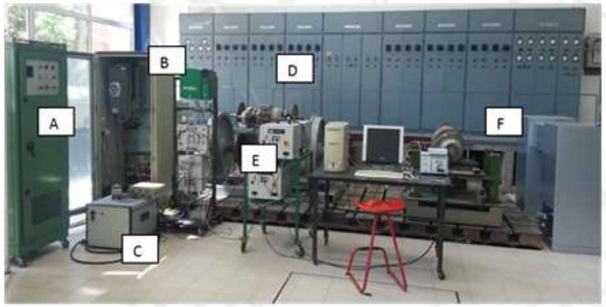
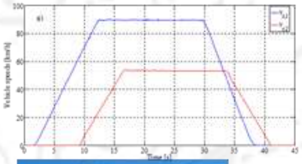
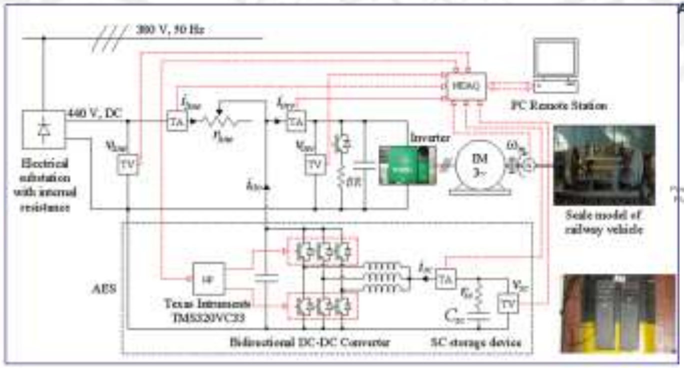


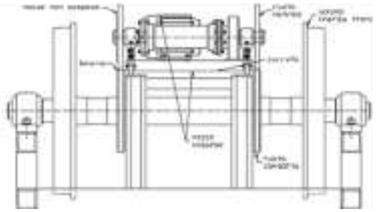


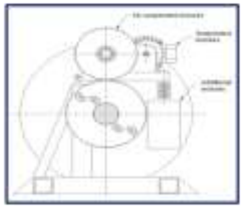
Sirio – Wayside and On-Board ESS for Tramway Simulator

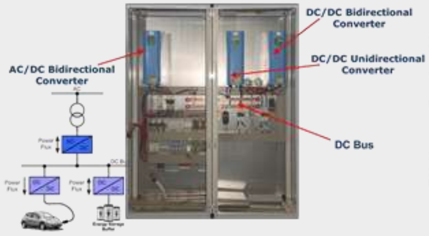
Objective : it aims to reproduce the electrical power flows of dc-double track tramway line during regenerative braking operation of Sirio-vehicle equipped on-board with energy storage device. It is possible to simulate regenerative substation making use supercapacitors devices, too.

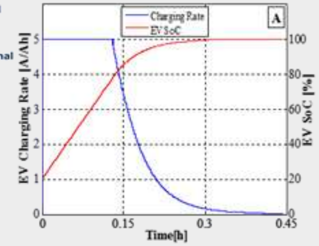
Simulator parameters	
Equivalent Inertia	3,7[kgm²]
Max Angular speed	800 [r/min]
Scale factor	200
Dc Voltage	440 [V]
Rated Motor Power	5,5 [kW]
SC Capacitance	1,65 [F]
SC ESR	1 [Ω]
SC module Voltage	150 [V]
Storable Energy	5 [Wh]
DC/DC Power Converter	20 [kVA]





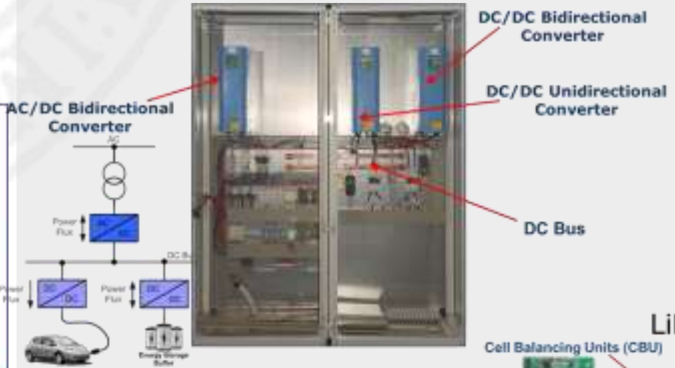


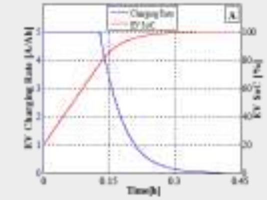




UltraFast EV - Charging Station

Objective: Assess the efficiency and charging performance of UltraFast Charging Systems using an auxiliary stationary energy storage devices based on Lithium Ion technologies.





Published results:

➤ Veneri, O.; Capasso, C.; Ferraro, L.; Del Pizzo, A.: "*Performance Analysis on a Power Architecture for EV Ultra-Fast Charging Station*" –Proc. of 4th Int. Conf. Clean Electrical Power ICCEP 2013, Alghero, Italy,, 11 – 13 June 2013.

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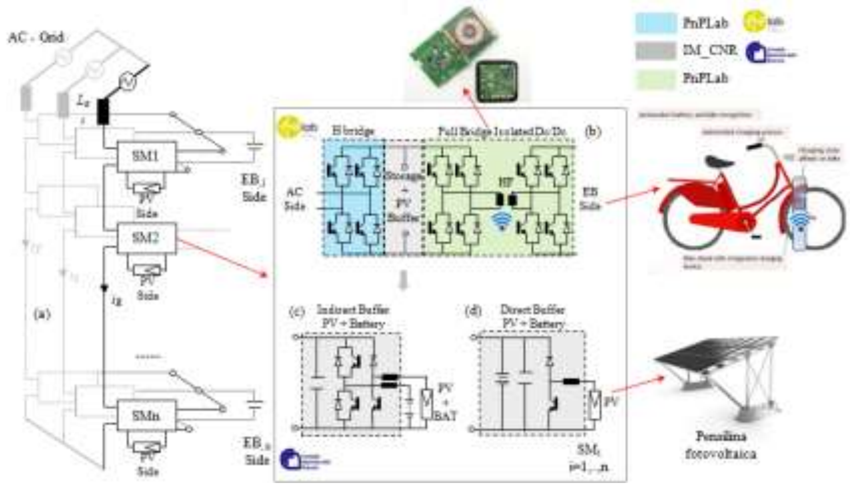
Project

Inductive Charging Station for Ebike Clever mObility

ebike

Modular converters for e-bike charging station



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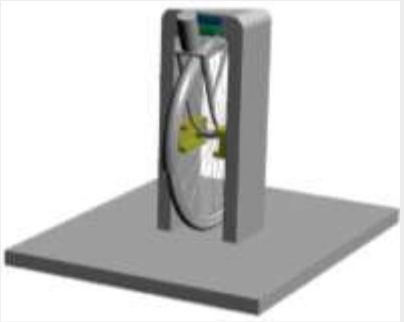
Attacco Modello T di cicli-stazione

Attacco Modello U di cicli-stazione



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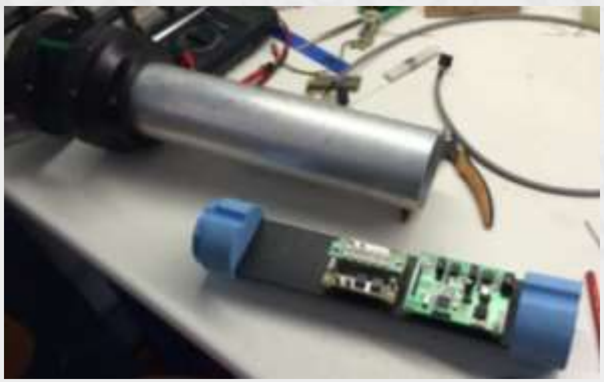
Project - IECO

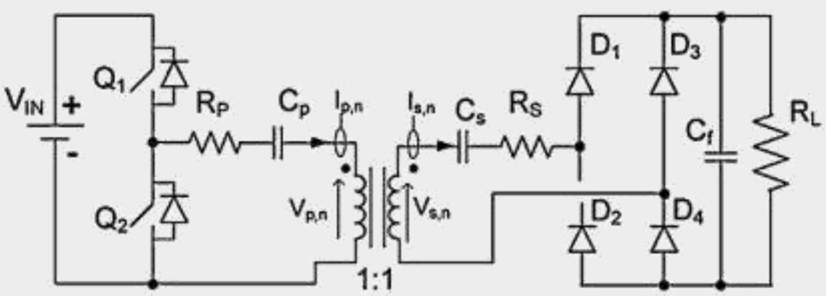
Inductive Charging Station for an E-bike Clever Mobility

Innovative Charging Syetem

WPT- Wireless Power Transfer

- The most successful system is that based on RIPT (Resonant Inductive Power Transfer)





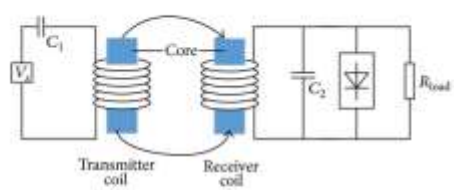
Technical Specifications

- P_n : ~500 *W*
- V_{in}: 50 *V*
- V_{out}: 42 *V*
- Resonant frequency: 40 *kHz*
- Pad distance: ~ 2 *cm*

Control Strategy

The developed control strategy is based on the adjustment of the duty-cycle of the PWM signal sent to the MOSFETs of the primary circuit to ensure that the output voltage at the secondary (i.e., voltage on the battery) follows the desired reference.
The proposed algorithm has been implemented on dsPIC of the MICROCHIP, while the communication between primary and secondary is wireless (wireless) via two XBee antennas on ZigBee protocol. Communication with the dsPIC takes place on UART (Universal Asynchronous Receiver-Transmitter).

Power transmission and wireless communication



ZigBee

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DIE TI. UNI NA VERSITA' DEGLI STUDI DI NAPOLI FEDERICO II
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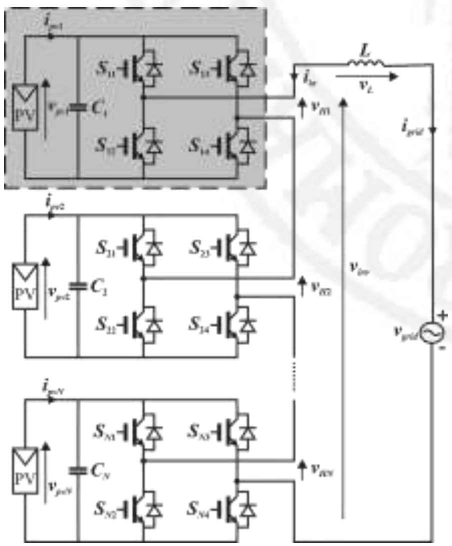
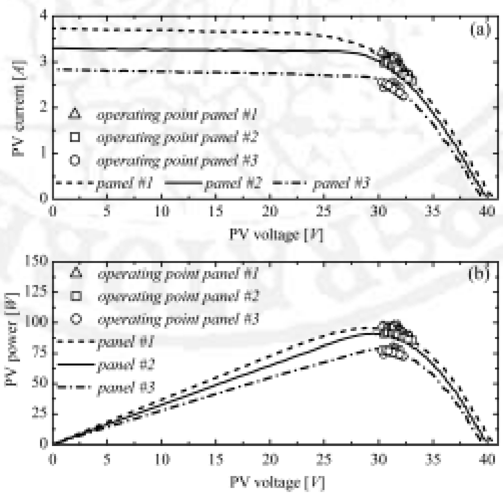
Progetti

2. **Power Converters for Distributed PV Sources :**

a. Static converters with integrated and/or distributed storage system, from photovoltaic source;

b. Modular static converters with integrated storage system for the generation of electricity from renewable sources also with micro-inverter technology.





Distribution Converters

- *Maximization of power in all operating conditions*
- *Modularity and scalability of the system*
- *Compliance with standards for applications with direct connection to the electricity grid*
- *Dedicated MPPT algorithms*
- *Digital control circuits on FPGA*

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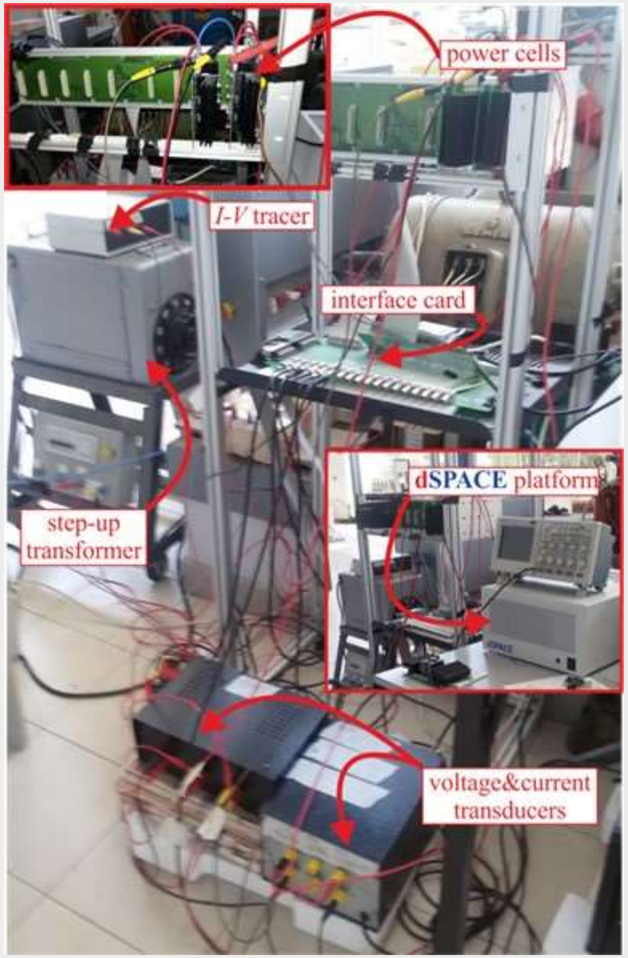
CHB (Cascaded H-bridge)
Power Converters of PV Sources



Advantages

- Modular Concept
  - ✓ Possibility of up-grade power
  - ✓ Simplicity of maintenance
  - ✓ Multilevel output waveform
  - ✓ Total harmonic distortion reduction (THD)
  - ✓ Higher quality of output voltages and currents compared to traditional topologies
  - ✓ Reduction of the dimensions and weight of the output filters
- Individual MPPT => greater MPPT efficiency

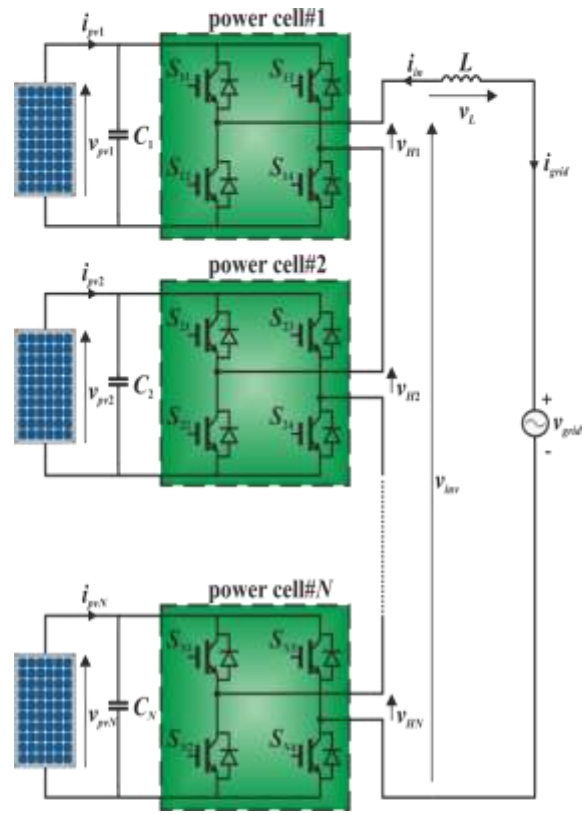
Drawbacks

- Greater circuit complexity => more elaborate control strategy with the need to guarantee stability even in conditions of imbalance to the dc-links (e.g., different temperatures and irradiation of the panels)
- Reduced range of tracking of the MPPT

Goal

Interfacing photovoltaic sources distributed to the electricity grid with a single-stage architecture and without a transformer (lower losses => greater efficiency, more compact structure)

Multilevel Modular Converter



Innovation Contribution

- Hybrid modulation strategy: mix of stair-case and adaptive type PWM
- Optimal system control: even in mismatch conditions, maximizing performance in terms of efficiency and THD and ensuring stability.

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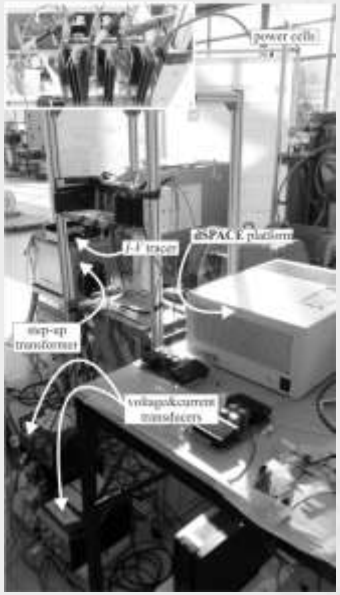
Pre-competitive Prototype



Power Moule
H-Bridge Configuration

Cell:

- P = 2 *kW*
- 4 power MOSFET

(V_{BD}=200 *V*, I_D = 54 *A* a *T*=100 °C)

- DC-link capacitance = 4.6 *mF*

Experimental Set-up

- P_n: 450 *W*
- N: 3
- P_{MPP} = 150 *W* (V_{MPP} = 29.5 *V*, I_{MPP} = 5 *A*)

Up-grade of the system in compliance with the CEI regulations (Tie-Grid Connected)

- Introduction of DC and AC side protection circuits
- Protection to prevent DC current input to the mains, protective conductor, isolating switch, network interface device.
- EMI filter.
- Circuit to avoid island operation (AI).
- Possible AC side isolation transformer.

on the road
towards
final product

Possible applications

- Photovoltaic shelters and installations on flat roofs
- (installations naturally affected by problems of auto shadowing (partial shading of uniform type))
- Island photovoltaic systems with integrated storage system
- Green building (e.g., photovoltaic windows, etc ...)

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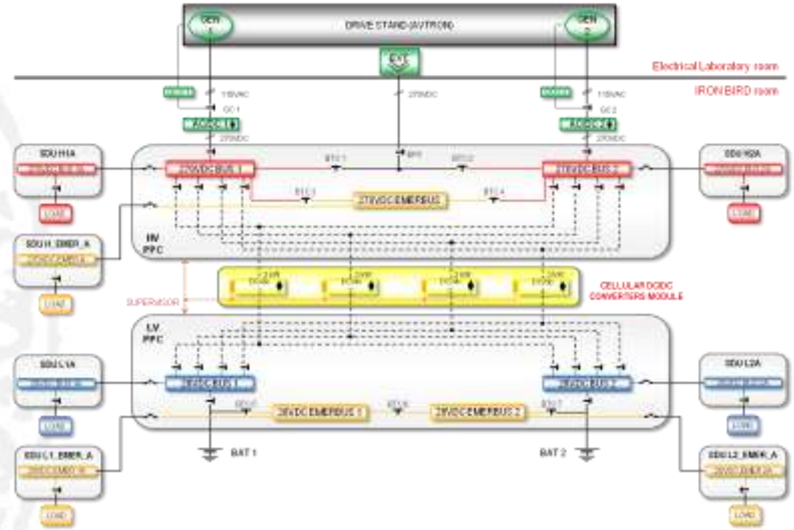
ASPIRE

<u>A</u>dvanced <u>S</u>mart-grid <u>P</u>ower D<u>i</u>st<u>r</u>ibution Syst<u>e</u>m

- Call JTI-CS2-2015-CFP02-REG-01-01
  “**Smart Grid Converter**”
- Consorzio **UNOTT** + **PNP Lab** + **UNINA2**
- Lead Industrial Partner – **Leonardo Aircraft Division**
- Budget - € 820.162, 00
- Durata– 36 mesi
- Stato attuale T0 + 16 M

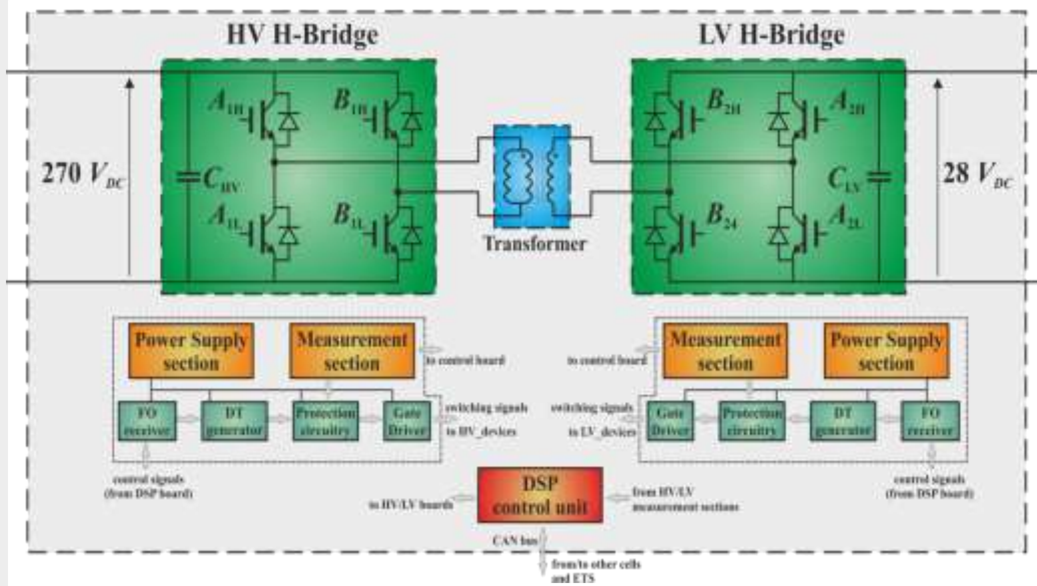
- The **ASPIRE** project responds to the call JTI-CS2-2015-CFP02-REG-01-01 "Smart-Grid Converter" within the ITD Green Regional Aircraft (GRA).
- The project aims to develop a smart EPDS with an Enhanced Energy Management for the GRA.
- The project aims to develop an innovative bidirectional DC / DC converter (cell), with advanced EM algorithms and fast communication protocols in order to obtain a smart EPDS for aircraft.
- The final product of ASPIRE is a multicellular DC/DC converter equipped with a decentralized supervisor and an advanced EM strategy adapted to the application of the Smart EPDS concept.

ASPIRE Integration to Iron-Bird of Leonardo



DAB Confiuration (Dual Active Bridge) of single cell for smart power converter of ASPIRE

ASPIRE cell



ASPIRE: Innovative aspects

- Use of WBG devices in gallium nitride (GaN)
- High power density
- High efficiency
- High switching frequency (hundreds of kHz)
- Advanced control strategy for the management of energy flows
- Converter design optimized to reduce weight and overall volume
- On-fly switching on / off capability with minimization of overcurrents and disturbances
- Extreme fault tolerance thanks to the modular architecture and the ability of the supervisor to quickly bypass a cell. The supervisor itself has a distributed nature that preserves it from failure conditions

ASPIRE: Main goals

- High power density of the overall system (drastic reduction in weight and dimensions)
- Development of an energy management strategy that reduces the demands in terms of overload of the main generators
- Ensure power flow even in the event of faults in the power converters and / or the communication system
- Compliance with the standards provided in aeronautical applications

Clean Sky 2 - Regional Aircraft IADP

Leonardo Aircraft

- MIL-STD-704F (power quality and operating voltage levels)
- EMI standards
- EUROCAE ED-14G (DO-160): Environment conditions and test procedures for airborne equipment
- MIL-STD-202G: Test methods for Electronic and Electrical Component Parts
- MIL-STD-45662: Calibration System Requirements
- MIL-HDBK-217F Notice2, Appendix A:Reliability Prediction of Electronic Equipment
- MIL-STD-1629A,24 November 1980 (Procedures for Performing A Failure Mode, Effects and Criticality Analysis)
- MIL-STD-882C, 19 January 1993 (System Safety Program Requirements),

PNPlab power naples prototype

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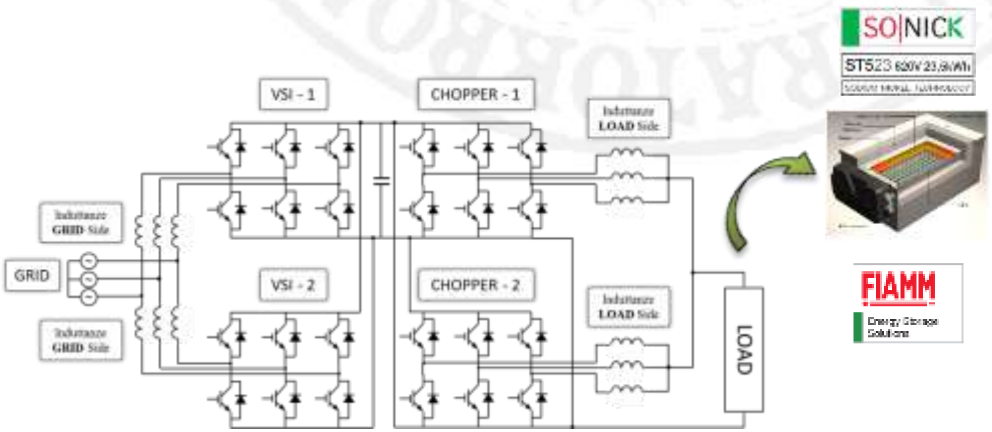
Progetti

Converters for the recharging of battery storage systems from the grid-connected

a. Rectifier stage in interlaced configuration with double Active Front End operating with a bus voltage equal to 850V, connected in cascade with a bi-directional buck-boost that re-presents the interlaced scheme.
b. Control of the conversion structure is aimed at ensuring full bi-directionality of the energy flows between the network and the storage system.
c. Interlaced configuration greatly increases system reliability and availability



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DC-link

Single Module

Prototype

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Overall advantages of the proposed architecture

<u>Modular Concept</u>

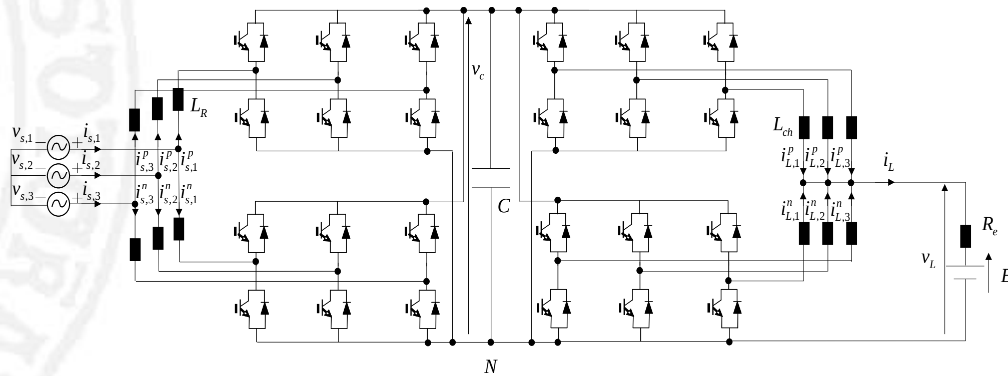
- ✓ High fault tolerance capacity (fault-tolerance).
- ✓ Dual-stage architecture through common DC link
- ✓ It decouples the AC / DC conversion from the DC / DC conversion allowing the conversion stages to be optimized without compromise

Possibile Applications

<u>Fast charging stations for electric vehicles on the road</u>

- Power levels in the order of 50 kVA ÷ 300 kVA
- Low distortion indices of line current
- Fast tracking of DC current / voltage references
- Fault-tolerance and high modularity for the simplification of maintenance operations

Project TS
Double-stage inverter for interfacing between the electricity grid and a battery storage system
Rated power 100 kW



- Processore ARM Cortex-A9 667 MHz dual-core, 1 GB di memoria no volatile, memoria DDR3 512 MB
- Chassis Artix-7 FPGA a 8 slot per elaborazione, controllo e temporizzazion personalizzati di I/O
- 2 Gigabit Ethernet, 1 USB Hi-Speed, 3 porte seriali