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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

UNIVERSITÀ DEGLI STUDI DI PALERMO

UNIPA contribution for the NEST-Network 4 Energy Sustainable Transition SPOKE 6 – ENERGY STORAGE

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NEST

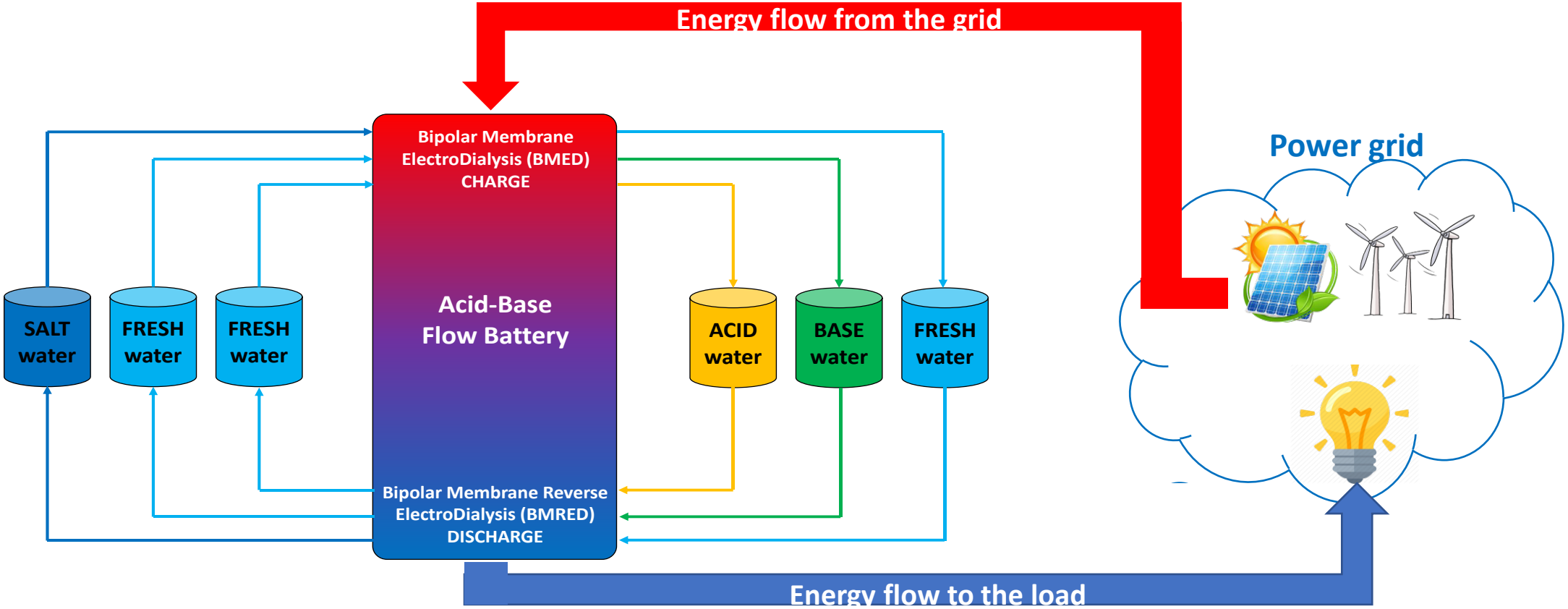
NETWORK FOR ENERGY SUSTAINABLE TRANSITION

Evento: "M'Illumino di Meno"

Sala Magna Complesso Monumentale dello Steri (Piazza Marina, 61 - PALERMO), 16 febbraio 2024

SUMMARY

THE ACID/BASE FLOW BATTERY (AB-FB) NEW TECHNOLOGY



Operation principle of the AB-FB tech.

AB-FB technology advantages (compared with other ESS)

- It is an **environmentally friendly tech.**, **without issues regarding operation safety** [1] (since it does not use dangerous storage mediums and pollutants for its operation)
- **Wide availability of raw materials for mass production of this tech.** (since only water solutions and membranes are needed)
- **Extremely flexible and modular design** of an AB-FB system
- **Desirable durability** (since no storage medium degradation should occur)
- **Economically promising tech.**, with a good trade-off in terms of energy density and cost, **in competition with the leading technology for large-scale energy storage** [1]
- **Very low self-discharge rate**; this aspect makes the technology suitable also for a long-term energy storage (such as an inter-seasonal storage, for instance useful in the case of integration with PV systems).

[1] *M.C. Díaz-Ramírez, M. Blecua-de-Pedro, A.J. Arnal, J. Post, Acid/base flow battery environmental and economic performance based on its potential service to renewables support, J Clean Prod. 330 (2022). https://doi.org/10.1016/j.jclepro.2021.129529.*

AB-FB TECHNOLOGY DRAWBACKS

- **relatively long response time** (involved by the water flows inside the battery), if compared to other energy storage technologies designed to ensure very short response time (such as the Ultra-Capacitors)

- **relatively large amount of space required for the installation**, as it depends on the energy density (which, for the AB-FB technology, is significantly lower than that of Li-ion batteries).

Notice:
The former drawback involves that the AB-FB tech. is not suitable for power grid services like the primary frequency control, although it could be successful used for other services which does not need extremely fast actuation time (such as tertiary frequency control and additional reserve functionality).

The latter drawback implies the AB-FB tech. is not suitable for applications where a space saving is required (like in the EV on board applications), but it is well suited for all the applications where the space is not an issue, such as commercial and/or utility-scale applications.

Competitive applications for the AB-FB technology

In literature [2] three competitive applications for the AB-FB are individuated:

I. **Energy Storage Systems for Light-Commercial applications** (such as small office buildings, workshops / shops), providing for instance the integration of a rooftop PV system

II. **Distribution Network decongestion and Voltage Management**, through multiple AB-FB systems connected at Low Voltage grid weak points (such as residential areas), also with the aim to increase the renewable energy sources penetration, by improving the grid flexibility and stability

III. **Bulk energy storage to support generation**, with AB-FB large-scale installation at the power grid generation points, in particular where electrical energy is generated from renewable sources to face the issue of the renewable energy intermittent nature (by allowing the balance between electrical energy generation and demand).

[2] *J. Muñoz-Cruzado-Alba et al., «Power Grid Integration and Use-Case Study of Acid-Base Flow Battery Technology», Sustainability, vol. 13, fasc. 11, Art. fasc. 11, gen. 2021, doi: 10.3390/su13116089.*

RESEARCH LINE PROPOSED

From literature a need results for in-depth experimental studies aiming at testing the behavior of AB-FB based energy storage system in a real grid scenario, therefore the UNIPA research group proposes the development of the fundamental research activities below, in the context of the SPOKE 6, WP 6.2 and 6.3, of the NEST project:

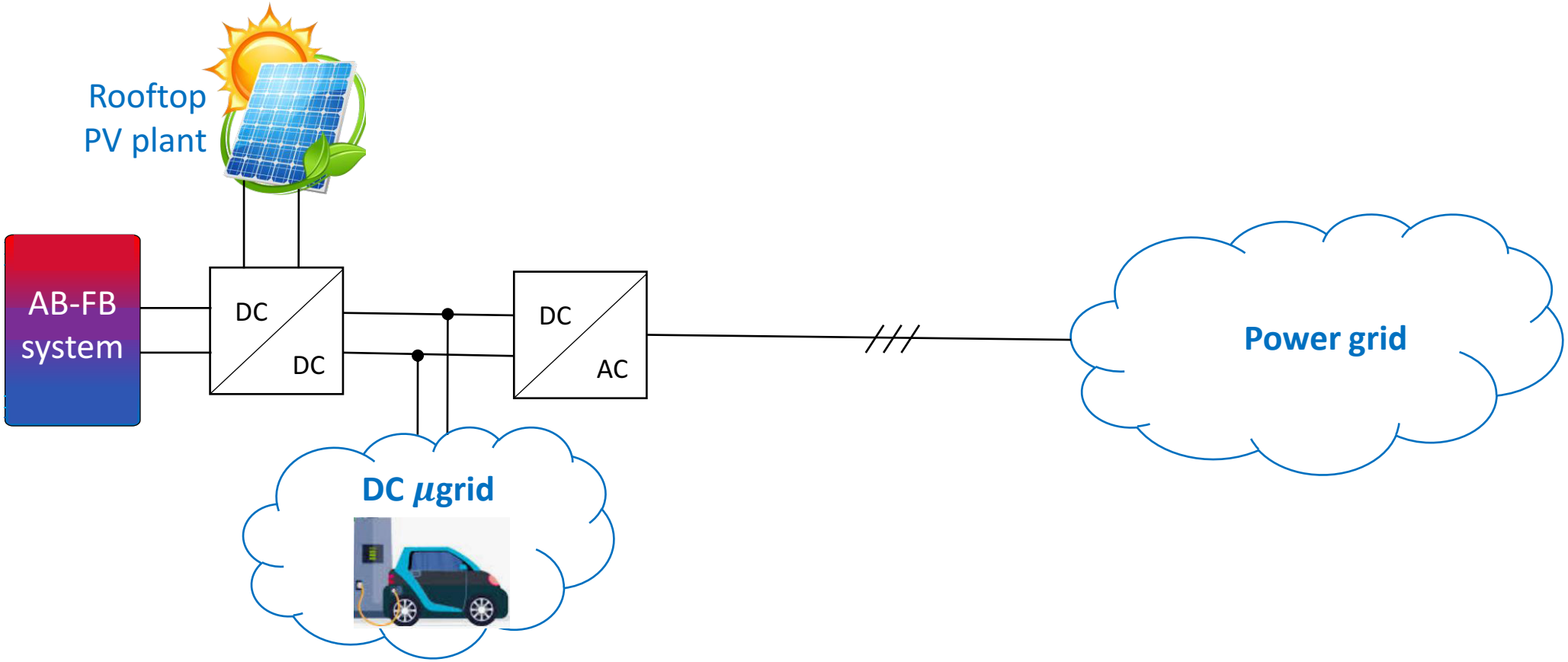
1. **Development and improvement of an Acid Base Flow Battery** (by foreseeing also a contribution regarding the modeling of such battery)

2. **Development, testing and characterization of power converters for Acid Base Flow Batteries interfacing to the grid**

3. **Multi input Power Electronic Converters and control for hybrid Energy Storage Systems**

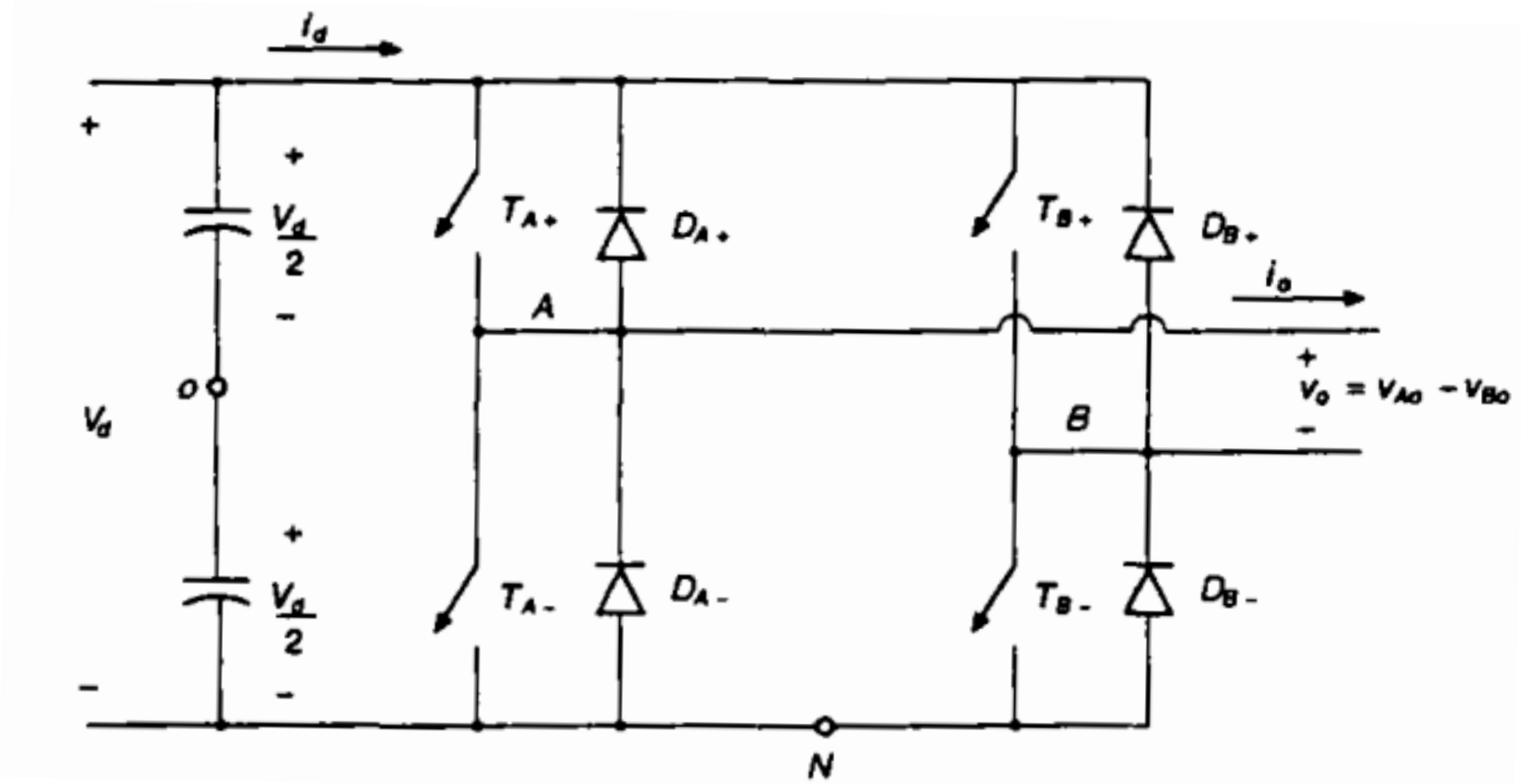
A POSSIBLE SYSTEM TO STUDY THE AB-FB IN A REAL GRID SCENARIO

A system (see fig.) for Light-Commercial applications, integrating an AB-FB based energy storage system with a rooftop PV plant could be designed and built, in order to test the behavior of the AB-FB in a real grid scenario.



PROPOSAL FOR THE AB-FB INTERFACING TO THE GRID

A viable solution for the AB-FB interfacing is the use of the so-called "H-bridge" (or "full-bridge") power converter topology:

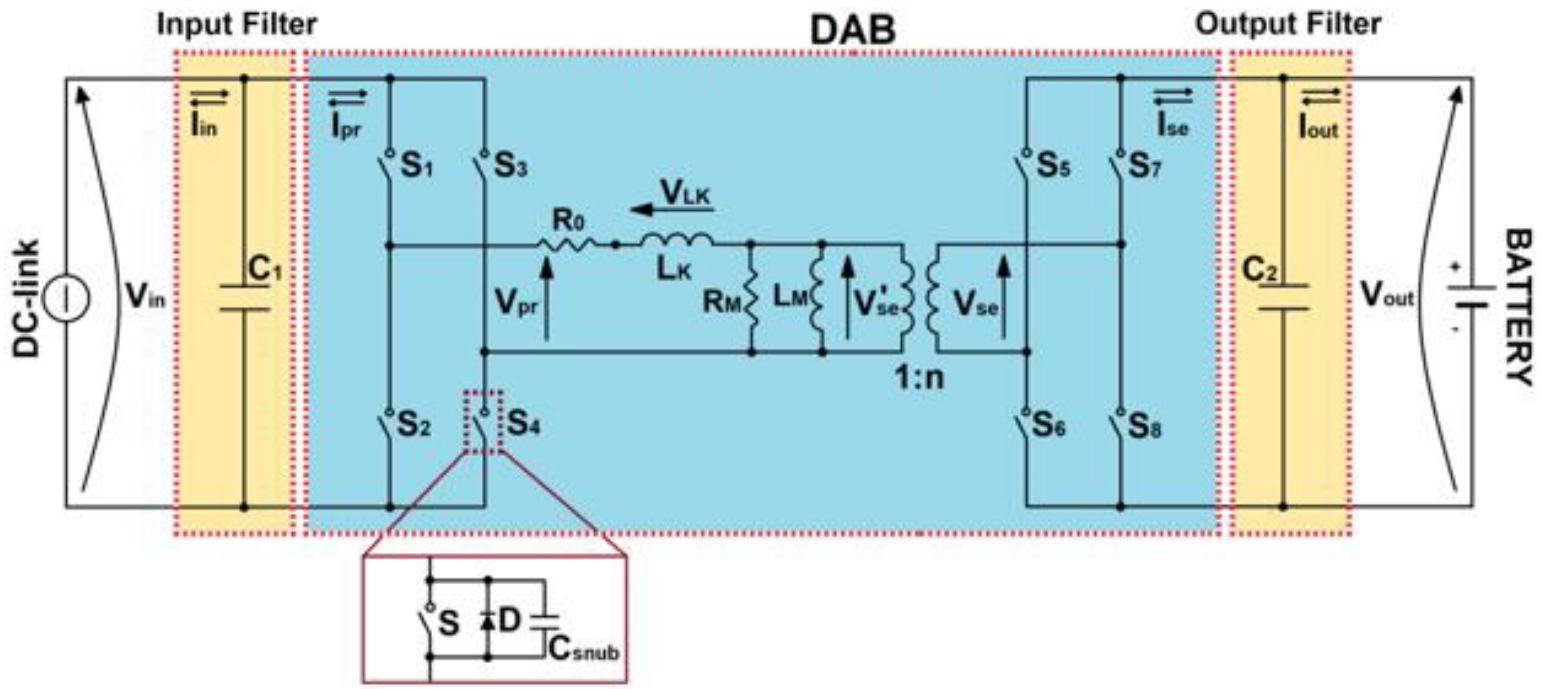


[5] *Figure from N. Mohan, T. M. Undeland, W. P. Robbins, e F. Castelli Dezza, ELETTRONICA DI POTENZA CONVERTITORI E APPLICAZIONI. HOEPLI, 2005, p. 209.*

Main valuable features:

- modularity and power scalability;
- possibility of implementing multi-input and multi-output solutions to manage different energy sources and electrical loads;
- bidirectional power flow managing allowed;
- high power converter efficiency and dynamic performance (reachable via adequate design and static switch control strategies).

THE DUAL ACTIVE BRIDGE (DAB) DC / DC INNOVATIVE CONVERTER TOPOLOGY [6], [7]



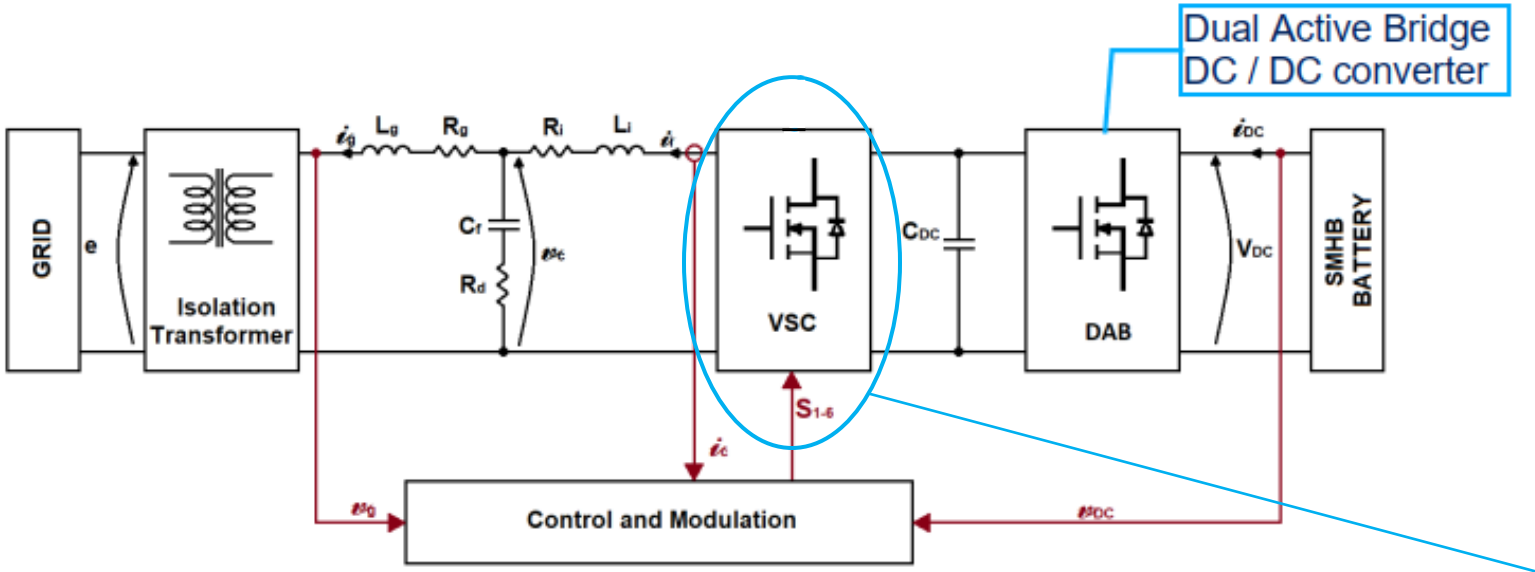
Main features obtained via the DAB converter:

- bidirectional power flow (via control strategies based on the so-called phase-shift modulation);
- high dynamic performances (very short response times to the set point variation);
- high power converter efficiency reached (of 98%, thanks to the Zero Voltage Switching DAB operation).

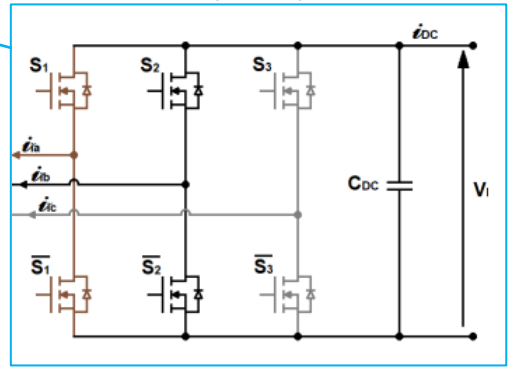
[6] M. Boi, R. A. Mastromauro, A. Floris, e A. Damiano, «Integration of Sodium Metal Halide Energy Storage Systems in Telecommunication Microgrids: Performance Analysis of DC-DC Converter Topologies», Energies, vol. 16, fasc. 5, Art. fasc. 5, gen. 2023, doi: 10.3390/en16052169.

[7] Figure from M. Boi, R. A. Mastromauro, A. Floris, e A. Damiano, «Integration of Sodium Metal Halide Energy Storage Systems in Telecommunication Microgrids: Performance Analysis of DC-DC Converter Topologies», Energies, vol. 16, fasc. 5, Art. fasc. 5, gen. 2023, doi: 10.3390/en16052169.

A FEASIBLE AND HIGH EFFICIENCY SOLUTION FOR ELECTROCHEMICAL ESS INTERFACING TO THE AC POWER GRID: A SIC-BASED VSC



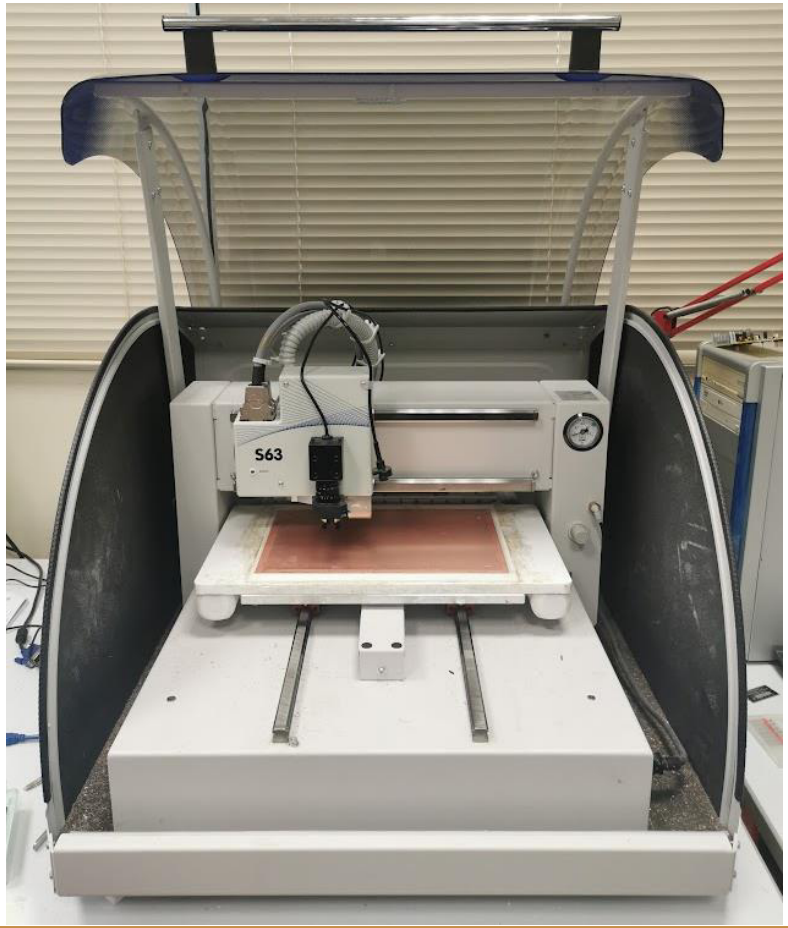
SiC-based
Voltage Source Converter
(VSC)

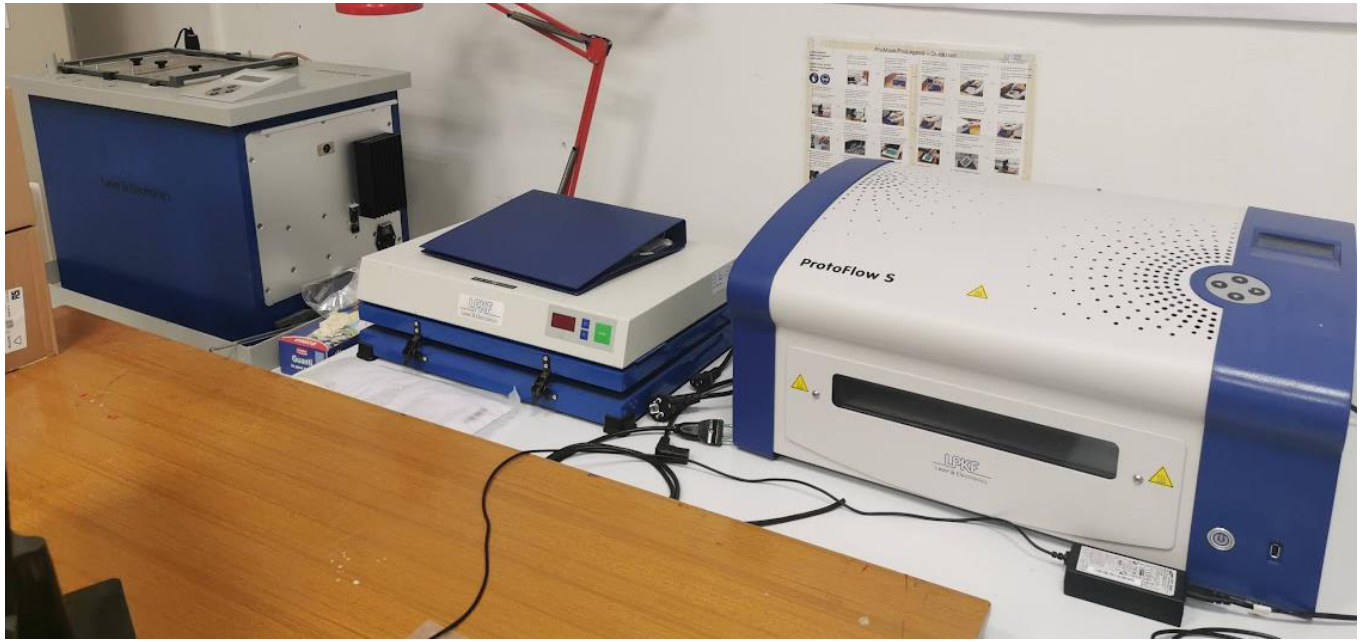


[7] Schematics adapted from M. Boi e A. Damiano, «Evaluation of SiC-Based Three Phase Power Converter for Microgrid Applications», in IECON 2022 – 48th Annual Conference of the IEEE Industrial Electronics Society, ott. 2022, pp. 1–7. doi: 10.1109/IECON49645.2022.9968968.

EQUIPMENT AVAILABLE AT THE RPLAB-RAPID PROTOTYPING LABORATORY OF UNIPA (Viale delle Scienze, Ed. 9)

RP LAB RAPID PROTOTYPING LABORATORY





ONGOING ACTIVITIES AT UNIPA IN THE CONTEXT OF SPOKE 6

The UNIPA researchers, involved in the NEST project, in the fields of electrical and chemical engineering are working in close collaboration to carry on the research activities in the context of the SPOKE 6 of the project.

Currently, the following main activities are in progress:

- modeling and testing of an AB-FB lab-scale unit, aimed at the electrical characterization of such an innovative electrochemical ESS;
- semi-experimental activities regarding innovative control strategies for controlling three-phase grid connected inverter.

Overview of the experimental set-up for testing the AB-FB lab-scale unit (mounted at "Laboratorio di teoria dello Sviluppo dei Processi Chimici", Viale delle Scienze Ed. 6)

ACTIVITIES FORESEEN AND FUTURE PERSPECTIVIES

The following future activities and perspectives are foreseen hopefully:

- realization at UNIPA of an AB-FB pilot-scale prototype (with rated power of the order of some hundreds of Watt in discharge phase) (similar to the one shown in fig.),
- integration and testing of such pilot-scale prototype in a real micro-grid scenario.

EDBM pilot-scale system available at "Laboratorio Grandi Esperienze" – UNIPA (Viale delle Scienze, Ed. 6)

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Thanks for your kind attention

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