Integration of a new thermal energy storage in electrical grids: power supply and control options

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MAGALDI dependable energy storage

SAPIENZA UNIVERSITÀ DI ROMA

Thermal energy storage for industry decarbonization

1 Context

Problem: global warming and climate change

International efforts: decarbonization targets (CO_2 emissions reduction)

Solution: development of renewable energy sources (especially wind and solar)

Fact: power varies with weather conditions

Effect: power system problems, low adequacy and stability

Increasing risk of blackouts and outages

Solution: use of energy storage systems

2 Techonology overview

Innovative technology for thermal energy storage

Developed by the Italian company Magaldi Power

Energy is stored as sensible heat ...

... into a fluidized bed of solid particles ...

... enclosed in a metal container, called «module»

Module walls have thermal insulation for minimal heat loss

3 System components

The system can exchange
✓ electric energy («Power»)
✓ thermal energy («Heat»)

... depending on the components included

A. Electrical heaters for electric energy input

B. Serpentine tubes for thermal energy input or output (through a heat transfer fluid)

In many applications the heat transfer fluid is superheated steam

C. Steam turbine and generator for electric energy output (through Rankine cycle)

4 System configurations

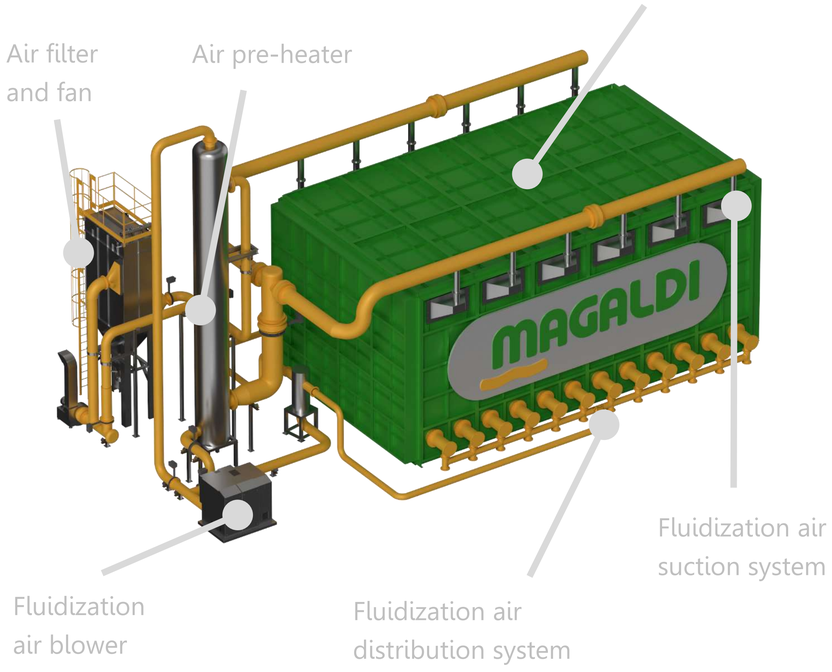
With all the components, the system is a hybrid energy hub with 2 inputs and 2 outputs

In many applications, only 1 input and 1 output are needed

MGTES

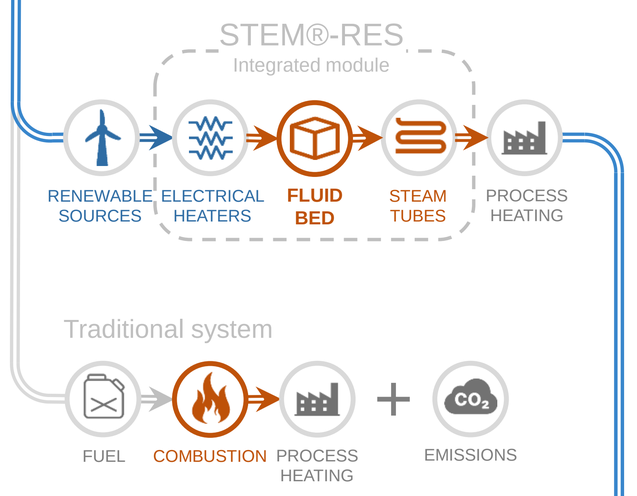
Magaldi Green Thermal Energy Storage

Integrated module



5 Power-To-Heat applications

High decarbonization potential for energy-intensive industrial plants



6 Features and benefits

Provides grid services to the power system, through demand side response

Cost-effective, since uses poor and easy-to-find materials

Modular system, multiple modules can be used together

Safe operation, no dangerous or poisonus materials

Eco-friendly, with low impact on environment

7 Heaters power control options

Power control using:
✓ DC/DC converters

DC-supplied resistors

AC-supplied resistors

Power control using:
✓ On Load Tap Changers (OLTCs)
✓ Star-Delta reconfiguration

Since they are resistive elements, heaters can be supplied with AC or DC

Heaters must act as a controllable load: a power control mechanism is needed

8 Heaters power supply options

Two different electrical energy sources are considered in this work

a PV plant
or other DC source

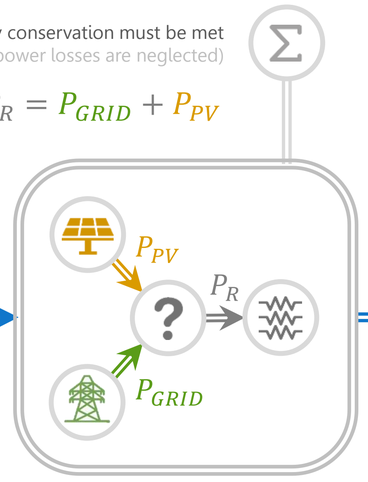
Most competitive resistors supply: DC with DC/DC power conversion system

the AC grid
with unidirectional power flow

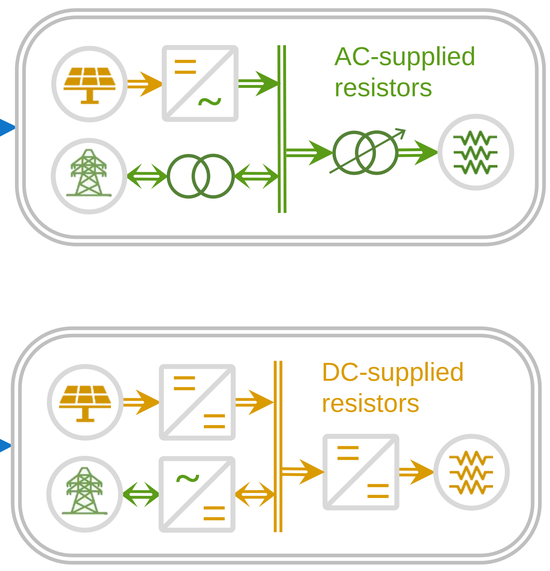
Most competitive resistors supply: AC connected with transformers + OLTCs

Energy conservation must be met (power losses are neglected)

$$P_R = P_{GRID} + P_{PV}$$



a PV plant + the AC grid
with bidirectional grid power flow



DC/AC inverter sizing: based on the PV plant

Most competitive solution if the grid provides the majority of power

$$P_{GRID} > P_{PV}$$

AC/DC converter sizing: based on grid connection

Most competitive solution if the PV provides the majority of power

$$P_{GRID} < P_{PV}$$

9 Research roadmap

✓ First ideas and concept design

✓ Preliminary studies, based on steady-state simplified models

✓ In-depth studies, based on dynamic complete models

✓ System simulation for performance estimation

✓ Scale-size prototypes at Magaldi factory in Buccino (near Salerno)

✓ Experimental tests on prototypes for models validation

WE ARE HERE

System optimization

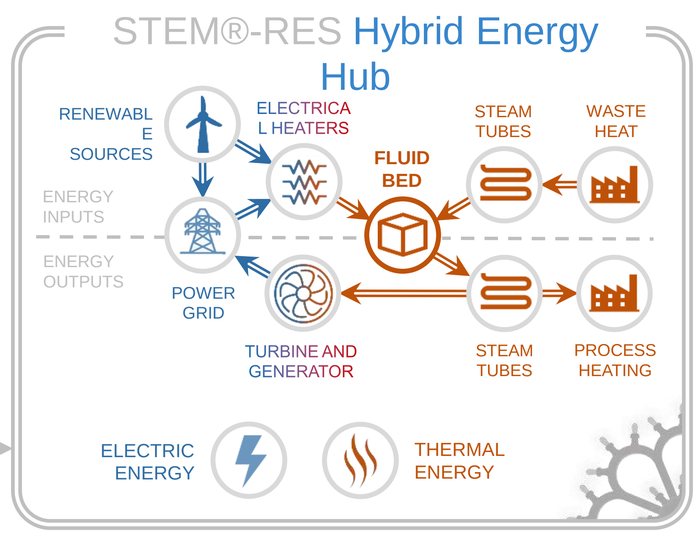
Commitment and construction

System operation, technology use

Publications

M. Scanzano, M.C. Falvo, A. Scafuri, F. Bassetti, L. Magaldi, *"Integration of a new thermal energy storage in electrical grids: power supply and control options"*, 2021 IEEE International Conference on Environment and Electrical Engineering (EEEIC21)

M.L. Di Somma, M.C. Falvo, G. Graditi, M. Manganelli, M. Scanzano, M. Valenti, *"Integration of renewable energy sources in transmission grids: issues and perspectives"*, 2021 IEEE International Conference on Environment and Electrical Engineering (EEEIC21)



Work in progress

Development of integrated software tools for:

System simulation and performance assessment
- ✓ technical: losses
- ✓ environmental: emissions reduction
- ✓ economical: total costs

Techno-economic optimization
- ✓ to increase efficiency keeping costs low
- ✓ to reduce costs, without consistent performance drop

Optimization of the operation
- ✓ to improve system control algorithms and energy management
- ✓ to find the best market strategy