

LABO - Institut Pascal, Axe PHOTON

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Title of PhD subject

Modeling and Design of a Multi-Energy Source and Multi-Storage System for Nanogrids

Summary :

This project is part of the broader energy transition and represents a major challenge in the field of energy storage, particularly for renewable energy systems. Renewable energy sources are intermittent and depend on several parameters, including sunlight, temperature, wind speed, wind direction etc. Therefore, it is essential to adapt energy management strategies to make optimal use of renewable energies, especially through appropriate storage systems.

This project will be the first national-scale initiative to offer a multi-vector storage system for nanogrids, based on batteries, supercapacitors, and sand batteries. The aim is to optimize energy storage and minimize losses associated with intermittent energy production, particularly during peak generation periods.

Sand batteries are an innovative thermal storage technology first developed in Finland. They enable the conversion of surplus electricity from renewable sources into thermal energy (heat), which is then used to raise the temperature of the sand inside the storage tank. Heat transfer networks installed within the tank subsequently transport the stored thermal energy to the connected heating system.

In this project, the main storage system will rely on batteries and supercapacitors, while excess green energy will be stored in sand batteries, considered an auxiliary storage solution. The platform will be a small experimental setup designed to enable the coexistence of a multi-vector storage system serving smart nanogrids. The term “smart” refers to the intelligent energy management strategies that will be developed as part of this PhD thesis for very small local networks.

In summary, this storage system combines electrochemical, electrostatic, and thermal storage for nanogrids. A review of the literature shows that, to date, no such energy storage system exists for nanogrids. Two recent articles introduce the concept of a multi-vector system, but they do not involve a combination of several storage technologies for nanogrids.

1) Sampson Tetteh, Gabriel Juul, Mika Järvinen, Annukka Santasalo-Aarnio, "Improved effective thermal conductivity of sand bed in thermal energy storage systems", Journal of Energy Storage, Volume 86, Part B, 2024, 111350, ISSN 2352-152X, <https://doi.org/10.1016/j.est.2024.111350>.

2) Abdollah Younesi, Hossein Shayeghi, Adriano Sciacovelli, Pierluigi Siano, "Scenario-based sensitivity-driven energy storage optimization for economic and carbon efficiency in multi-vector energy communities", International Journal of Electrical Power & Energy Systems, Volume 171, 2025, 111007, ISSN 0142-0615, <https://doi.org/10.1016/j.ijepes.2025.111007>.

This project will also serve as a strong foundation for advancing toward large-scale storage capacities by combining several high-capacity storage approaches. It will contribute to the development and validation of an innovative concept for nanogrid applications. Following this PhD thesis, a larger-scale project will be considered, and the work carried out will enable the Pascal Institute to validate the concept through experimental results. Such a thesis represents a major asset in the field of renewable energy storage and constitutes a significant scientific challenge in the diversification of innovative storage solutions for intermittent energy sources. Moreover, this project could open new avenues for industrial-scale exploration, including emerging technologies related to this concept, as well as new implementation, maintenance, and control techniques.

A collaboration with the University of Picardy will be considered for the experimental aspects and certain equipment, in order to validate the concept of a multi-storage system with small storage capacities (from a few hundred watts to a few kilowatts). The objective of this thesis is to develop a small-scale platform (TRL 3 or 4) to validate the concept initially, and then progress toward a larger storage scale in a subsequent project call at the regional, national, European, or industrial level.

