Distributed energy resources (DERs) are regarded as the silver bullet for achieving a net-zero carbon society. The key technology for integrating massive DERs is the **microgrid (MG),** which corresponds to a localized power system capable of operating in island or grid-connected mode. MG can manage its onsite DERs. MG is regarded as the alternative to the conventional large power system, which delivers electricity through long distance transmission lines.

Generally, an MG is operated in the grid-connected mode, i.e., connected to the distribution network. When some extreme events (e.g., natural disasters) occur, MG can be disconnected from the distribution network, and (if possible) re-connect with its neighbor MGs for constituting the **MG cluster**. An MG cluster significantly improves the system resilience by allowing MGs to share energy with their counterparts to balance the cluster's load.

Different from conventional fossil fuel generators (e.g., microturbines), DERs are integrated into MG through power electronics converters. These power electronics converters have from power system point of view some drawbacks like low inertia, limited fault current contribution, susceptibility to changes in network impedance and voltage disturbances, and control complexity, which results in control and stability issues for the MG. Overall, the MG with a high penetration level of power electronics is vulnerable since any small disturbance could evolve into a large-scale blackout. This vulnerability is further exacerbated for the MG cluster with a high penetration of power electrics, as a disturbance inside one MG could easily spread into other MGs and result in the whole system crash. Therefore, the conventional model, control, and operation method cannot be used in the MG cluster since they fail to accurately consider the power electronics.

The **scientific objective** of this project is to study and propose advanced control algorithms at the power converter level, MG level, and MG cluster level that allow a safe and stable operation of an MG cluster with high penetration of power electronics under varying grid and load conditions.

To achieve the scientific objective, the project is divided into **four key tasks**, summarized below:

a) The first task will develop **comprehensive models** of the power electronics converters of the MG based on typical and well-known control algorithms. The modeling is then extended to the MG level, as well as the MG cluster level. As an MG can be composed of several power converters, each one with its own control algorithms, the final objective of this task is developing reduced-order models that will be employed for stability analysis.

b) Based on the stability analysis of the MG cluster based on well-known controllers, in the second task, **new control algorithms** at the power electronics converter, MG, and MG cluster will be developed. The different control algorithms will be tested to ensure scalability, robustness, and adaptability under various operational scenarios, enhancing system stability and performance.

c) Typically, the stability control and operation of traditional MGs are two independent tasks. The third task has as an objective to **embed the stability constraints into the operational model** of the MG, ensuring sufficient regulation margins for the power electronics MG.

d) Finally, task four focuses on verifying the modeling, control, and operation of the MG cluster through **scaled-down laboratory setups**. The Polish team will be focused on the experimental verification of the operation and stability of a single hybrid MG. On the other hand, the Chinese team will be focused on the stability and management of the MG cluster.

This research project will provide key support for the significant theoretical and methodological issues that urgently need to be addressed in the dynamic quantitative analysis and stability control of MG clusters, such as:

a) Establish a dynamic/transient unified modeling method covering levels of power electronics, MGs, and MG clusters.

b) Propose effective control strategies at various levels, including the level of power electronics, AC-DC hybrid MGs and multi-agent MG clusters.

c) Construct an operation model that considers stability constraints for MG clusters under resilience enhancement.