ERIGrid Test Case Canvas v2

Title: **Home Energy Management System Validation in Real Time (HEMSVRT)**

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Object under Investigation (*OuI*)

The component(s) (1..n) that are to be qualified by the test

This proposal focuses on running a scenario in a Power Hardware-in-the-Loop (PHIL) setup with physical equipment at TECNALIA (load and/or PV system) to validate the following OuIs:

- Cloud-based optimization solver for operational schedule: The mEH operational tool will be evaluated for its effectiveness in managing operational schedules and, then, uploading the power schedule output in the cloud environment.
- Remote communication systems: The communication/ICT systems responsible for remote communication will be tested to ensure reliable data transmission and reception between the cloud-based tools and physical/emulated systems.
- Controllers of energy resources: The controller's ability to manage, control and measure especially physical energy resources will be assessed to ensure effective implementation of the mEH scheduler power setpoints.

Function(s) under Investigation (*FuI*)

The referenced specification of a function realized by the OuI:

- FuI#1: Optimal energy management of a multi-carrier smart home (at mEH level and EH level)
- FuI#2: (Bidirectional) communication from/to the cloud-based database in real-time
- FuI#3: Remote control and communication of physical controllable resources under testing

Domain under Investigation (*DuI*)

The relevant domains of test parameters and connectivity.

- Communication/ICT (emulated/physical)
- Electrical carrier (emulated/physical)
- Heat carrier (emulated)
- Gas carrier (auxiliary, emulated)

Target metrics (*TM*)

Measures retrievable from SuT required to quantify each of the identified test criteria:

- TM#1: Power set-point per each resource and mEH (related to FuI#1)
- TM#2: Data transfer, data loss, data availability, comms delay time, response time, etc. (related to FuI#2 and FuI#3)

According to TM#1, there are some outputs and results related to the mEH operational tool. To understand which parameters should be measured, several Key Performance Indices (KPIs) are identified:

- Reduction in primary energy demand and consumption
- Flexible energy unlocked
- Increase in self-sufficiency
- Reduction in total annual cost
- Reduction in daily and annual CO2 emissions
- Energy savings for the consumers
- Increase of penetration of RES in the local generation mix
- Internal Rate of Return (IRR) calculated for the energy systems deployed in the mEH/EH

Test Objectives

Why is the test needed? What do we expect to find out?

The aim of the lab test case is to verify the performance of the operational tool at mEH level (micro- Energy Hub) in real time. The mEH operational tool is designed to improve the cost-efficiency and self-sufficiency of a local community through a strategy management and real-time operational planning. The main objectives of this use case are twofold:

1. Increase Efficiency: By employing a strategic operational approach that leverages the estimated flexibility of different assets, the efficiency of the mEHs is maximised. This strategy involves adjusting the operational parameters of each asset (day-ahead schedule) to ensure that they are functioning at their optimal capacity, thereby reducing energy wastage, and improving overall energy output.
2. Enhance Self-Sufficiency: In conjunction with efficiency improvements, the use case also aims to increase the self-sufficiency of the mEHs. This is achieved through a real-time operational plan that dynamically adjusts to the energy production and consumption patterns of the EH. By continuously monitoring and adjusting operations in real time, the reliance on imported energy can be minimized.

Additionally, in order to implement this operation control in real time, remote and local communication infrastructure should be properly configured, in which day-ahead or real-time operational schedule (power set-points of controllable consumption and generation) is provided by the operational tools and upload to a common database in a cloud environment. The objective of this lab test case is to validate the (bidirectional) communication between the mEH operational tool located in the cloud and final (un)controllable energy resources (both emulated and physical).

Purpose of Investigation *(PoI)*

The test purposes classified in with terms Characterization, Verification, or Validation

- PoI#1: Performance of the optimization under realistic conditions (characterization). The proposed project focuses on enhancing the operational efficiency and self-sufficiency of micro-Energy Hubs (mEH) through strategic management and real-time operational planning. The primary aim is to optimise the performance of each mEH by carefully managing the various assets based on a detailed analysis of their flexibility, usually done by a HEMS.
- PoI#2: Verification of effective communication from/to the cloud-based database
- PoI#3: Verification of remote control of controllable resources under testing

Test criteria *(TCR) Formulation of criteria for each PoI based on properties of SuT:*

- TC#1: Effectiveness of the optimization under realistic conditions
- TC#2: Reliable and stable communication from/to the cloud-based database
- TC#3: Capability of remote control of controllable resources under testing

Quality attributes *(QA) Threshold level for test result quality as well as pass/fail criteria.*

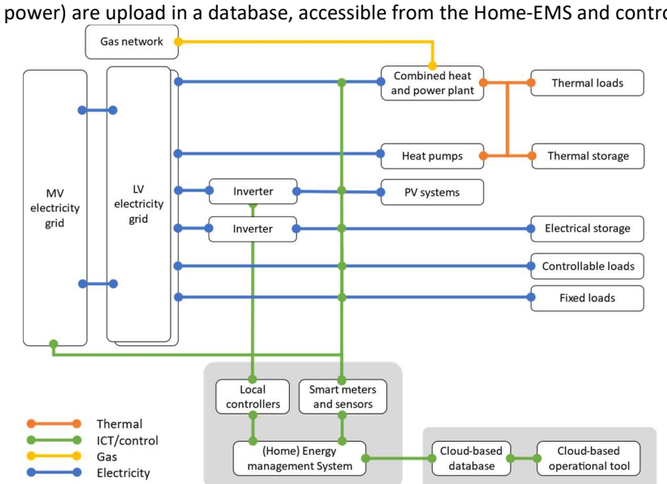
- *Related to TM#1:*
  - *Enhanced Self-Sufficiency per mEH compared to Base Case scenario*
  - *Increased efficiency per mEH compared to Base Case scenario*
  - *Reduction of energy cost per mEH compared to Base Case scenario*
  - *Optimization execution time of cloud-based solver less than i.e., 5 minutes*
- *Related to TM#2:*
  - *Avoid communication failures above 15 minutes from the database*
  - *Comms delay time less than i.e., 5 second from/to de database*

System under Test (*SuT*)

Systems, subsystems, components included in the test case or test setup.

The successful experiment relies on the integration of several key technologies. These technologies are crucial for enhancing the flexibility, efficiency, and self-sufficiency of energy systems. The integration of renewable energy sources such as PV panels and solar thermal systems is fundamental to generate clean, sustainable energy locally. Energy storage systems, including electrical and thermal storage systems, are essential for balancing supply and demand, storing excess energy, and providing backup power. Additionally, micro-Combined Heat and Power and heat pumps are considered to satisfy thermal load.

Additionally, local controllers and smart sensors are required to control and measure in real time the energy resources. Finally, the cloud-based mEH operational tool is required, whose output (schedule power) are upload in a database, accessible from the Home-EMS and controller.



Functions under Test (*FuT*)

Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.

- Power Flow algorithms in distribution networks
- Cloud-based optimization of multi-carrier scenario in real time (FuI#1)
- (Bidirectional) Communication and control between the tools and energy resources (FuI#2)
- Physical resources control: PV, load, HP, CHP, BESS (FuI#3)
- Maximum Power Point Tracker and other systems controller

Variability attributes *(VA)*

Identify relevant controllable or uncontrollable factors of the SuT and their required variability; refer to PoI.

- *Day-ahead market price (Partly Controllable attributes)*
- Design parameters of resources: nominal power, capacity (Partly Controllable attributes)
- Flexibility activation of controllable resources (Fully Controllable attributes)
- Control functionalities/parameters of controllable resources (Fully Controllable attributes)
- Forecasted consumption/generation profiles (Uncontrollable attributes)
- ICT (communication) and controller delays (Uncontrollable attributes)