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Deliverable D4.12

BEMS user manual

WP4

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6	30/10/23	Adriana Bernardi (CNR-ISAC)	Final check and upload in ECAS

Disclaimer

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Publishable summary

The D4.12 “BEMS user manual” is a public document delivered in the context of WP4, Task 4.6: “Development of BEMS for GSHP integration with multiple renewable sources and of an application for easy management of energy” and describes the Building Energy Management System (BEMS) developed in the GEO4CIVHIC project.

Geothermal energy is an energy efficient source of energy for heating and cooling of buildings. To achieve Net Zero Energy, the electricity production of the heap pump (HP) needs to be provided by renewable energy.

A Building Energy Management System (BEMS) was developed to facilitate the integration and control of a Ground Source Heap Pump system supplied by locally produced renewable electricity. The optimised control is aimed at reducing operating costs of the system.

The document is a user manual of the BEMS. It presents its elements and describes how to integrate them in a Building Management System (BMS) to optimise operation cost when integrating a Ground Source Heap Pump (GSHP) with other Renewable Energy Sources (RES). The document is aimed at installer of GSHP and RES.

Abbreviations

GEO4CIVHIC	Most Easy, Efficient and Low Cost **Geo**thermal Systems **for** Retrofitting **Civ**il and **Hi**stori**c**al Buildings
BEMS	**B**uilding **E**nergy **M**anagement **S**ystem
BMS	**B**uilding **M**onitoring **S**ystem
COP	**C**oefficient **o**f **P**erformance
GA	**G**enetic **A**lgorithm
GSHP	**G**round **S**ource **H**eat **P**ump
HP	**H**eat **P**ump
MCU	**M**easurement **C**ontrol **U**nit
RES	**R**enewable **E**nergy **S**ources
SoC	**S**tate **o**f **C**harge
ToU	**T**ime **o**f **U**se
XGBoost	e**X**treem **G**radiant **Boost**ing

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Introduction

Geothermal energy is an efficient source of energy for heating and cooling of buildings. To achieve Net Zero Energy, the electricity production of the heap pump (HP) needs to be provided by renewable energy.

A Building Energy Management System (BEMS) was developed to facilitate the integration and control of a Ground Source Heap Pump system supplied by locally produced renewable electricity. The optimised control is aimed at reducing operating costs of the system.

This document is a user manual to the BEMS system developed for multi-renewable integration in the GEO4CIVHIC project. It first gives an overview of the BEMS (Chapter1). The input data necessary for the control algorithm are then described in Chapter 2. Chapter 3 describes the installation and setting of the BEMS. Finally, Chapter 4 illustrate how the BEMS was integrated in the BEMS of a real building.

Note that the software presented in the deliverable is property of TECNALIA.

1 BEMS Overview

The GEO4CIVHIC BEMS is designed for systems with the following elements:

- A GSHP that provides heating and cooling to a building.
- A renewable electricity production system (e.g. a photovoltaic panel or a eolic system).
- A Building Management System (BMS) that centralise monitoring and control of the previous elements.
- Time of Use (ToU) energy tariff.

Figure 1 shows the different elements of the BEMS. There is a control algorithm that can be configured through an interface. The optimization algorithm is a genetic algorithm (GA) that optimize the use of an electrical battery on a 24-hour horizon based on the renewable production and the demand prediction, the current state of charge of the battery and the energy cost. The control procedure is written in a file that is sent to the BMS for execution.

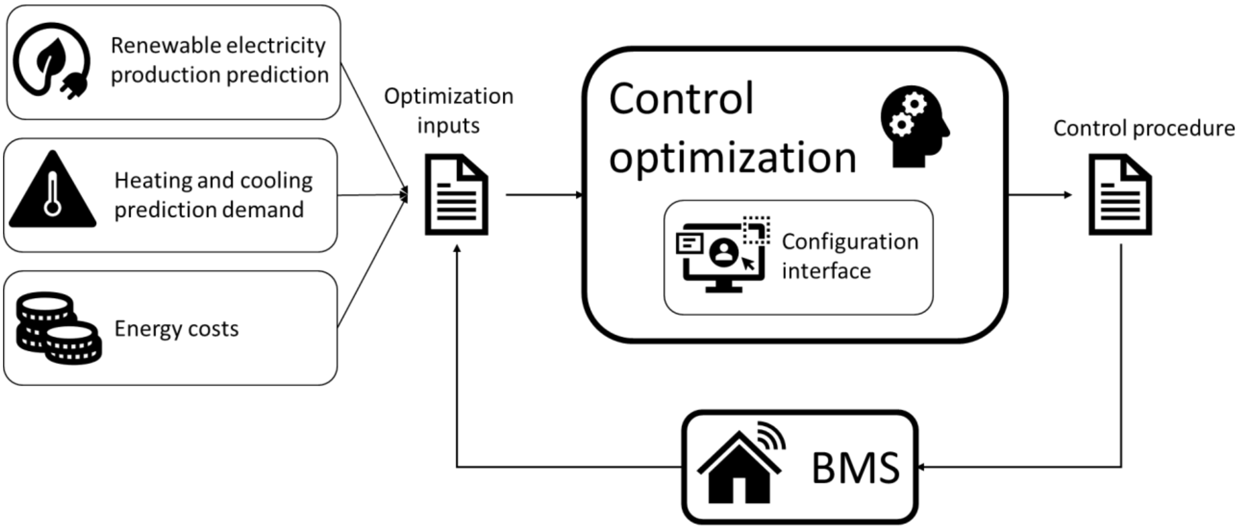


Figure 1 - Smart control workflow

In its current configuration, the optimisation algorithm does not take into account the possibility to sell energy to the grid.

2 BEMS input data

This chapter list the input data that are necessary to take advantage of the GEO4CIVHIC BEMS.

2.1 State of charge of the battery

One of the inputs of the BEMS is the current state of charge of the battery. It is a number between 0 and 1 that reflect the percentage of charge of the battery at the beginning of the optimisation.

2.2 24-hours heating and cooling demand prediction

Another input is a 24-hour prediction of the energy demand provided by the HP. It is used to calculate the electricity demand. The heating and cooling demand can come from a building energy model or based on historical data. A predictive energy demand model has been developed in the GEO4CIVHIC project. See D4.11 *“Optimised BEMS for GSHP and other RES control in historical and civil buildings and Application for a friendly and easy management of the energy systems”* for detail.

2.3 Renewable electricity production prediction

Another necessary input is the renewable electricity production prediction. It is used to estimate which part of the HP electricity demand can be covered by the renewable source and to see how much excess can be expected to be stored in the battery.

The most straight forward way to get the renewable electricity production prediction is to calculate it based on meteorological predictions. We suggest using the following equations, but other methods are acceptable.

PV panel

$$P_s = \eta_p S_p \Phi_t^s (1 - 0.005\,(T_t^a - 25))$$

Where:

- P_s is the power generation of the PV panel [kW]
- η_p is the performance coefficient of the solar panel [0-1]
- S_p is the surface of the solar panel [m^2]
- Φ_t^s is the solar irradiance [kW/m^2]
- T_t^a is the outdoor temperature [ºC]

Wind turbine

$$P = 0.5\, C_p\, \rho\, \pi\, R^2 V^3$$

Where:

- P is the power generation of the wind turbine [W]
- C_p is the coefficient of performance [0-1]
- ρ is the air density [kg/m^3]
- R is the blade length [m]
- V is the wind speed [m/s]

2.4 ToU energy tariff

The optimization algorithm is designed for Time of Use (ToU) energy tariffs. ToU energy tariffs have a different energy cost for each hour of the day based on market tariffs. This is what enable to take advantage of the battery, buying energy when it is cheaper.

A Python library has been developed to read the energy tariff from the Entsoe transparency platform[1], the central collection platform for electricity generation, transportation, and consumption data for the pan-European energy market. To use the library, a token for the Entsoe transparency platform is necessary.

The step to configure the Python library are the following:

1- Register on the Entsoe transparency platform

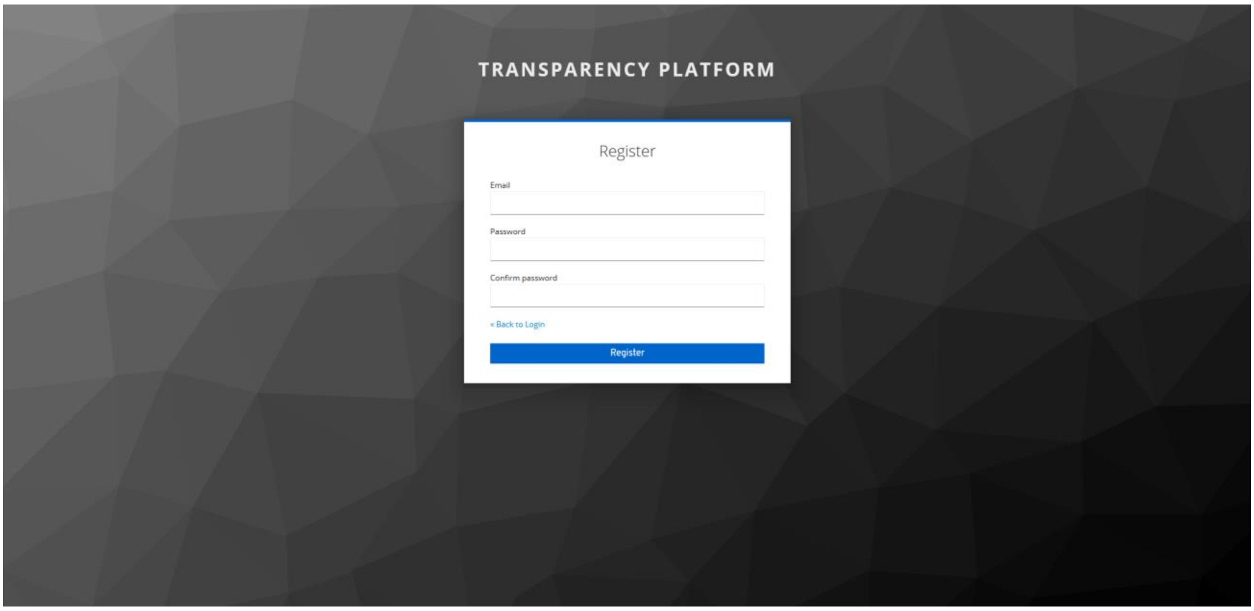


Figure 2 – Registration screen of the Entsoe transparency platform

2- Send an email to transparency@entsoe.eu with “Restful API access” in the subject line.
3- Save the example of configuration file *token_tempale.ini* available with the library as *token.ini*
4- Replace `put_here_your_entsoe_key` with your Entsoe token.

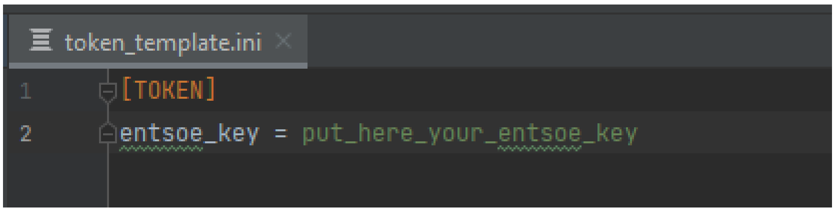


Figure 3 – Energy price library configuration file

The main function of the library is `get_day_ahead_price_between_dates`. It returns the energy prices between two dates for the specified country. The full documentation of the available functions of the library can be found in Appendix A.

[1] https://transparency.entsoe.eu

3 BEMS installation and configuration

This chapter explains how to install and configure the GEO4CIVHIC BEMS. The BEMS is a Python executable developed for Python 3.9.

3.1 Input format

The BEMS read the input information necessary (see previous chapter) from a JSON file. Figure 4 shows an extract of the JSON structure. A full example can be found in Appendix B.


```
{
  "0": {
    "variable": "battery_soc_init",
    "values": {
      "0": {
        "FechaHora": "01/01/2023 0:00",
        "value": "0.2"
      }
    }
  }
  "1": {
    "variable": "demand",
    "values": {
      "0": {
        "FechaHora": "01/01/2023 0:00",
        "value": "0"
      },
      "1": {
      "2": {
      "3": {
      "4": {
      "5": {
      "6": {
      "7": {
      "8": {
      "9": {
      "10": {
      "11": {
      "12": {
      "13": {
      "14": {
      "15": {
      "16": {
      "17": {
      "18": {
      "19": {
      "20": {
      "21": {
      "22": {
      "23": {
    }
  },
  "2": {
  "3": {

}
```


Figure 4 – Input JSON extract

The file needs to be saved as `input.json` in the data folder of the software.

3.2 Control algorithm configuration

The different parameters of BEMS algorithm can be set in the set-up interface (Figure 5). The parameters that can be set are the following:

1. <u>Heat pump</u>:
    - A performance map of the heat pump in a csv file with the following columns: compressor and auxiliary power [kW], condenser power [kW], COP [-].

2. Renewable electricity generation: the BEMS can work for either solar panel or wind generation. If you have both, the sum of the production needs to be summed in the input file.
    - *Solar panel*: the area of the panel in square meter and its efficiency as a number between 0 and 1.
    - *Wind power*: the generation power in kW.
3. Battery:
    - The battery capacity in kWh.
    - The efficiency of the battery as a number between 0 and 1. This is to consider the losses when charging and discharging the battery.
    - The maximum charge or discharge that can take place in one hour in kW.

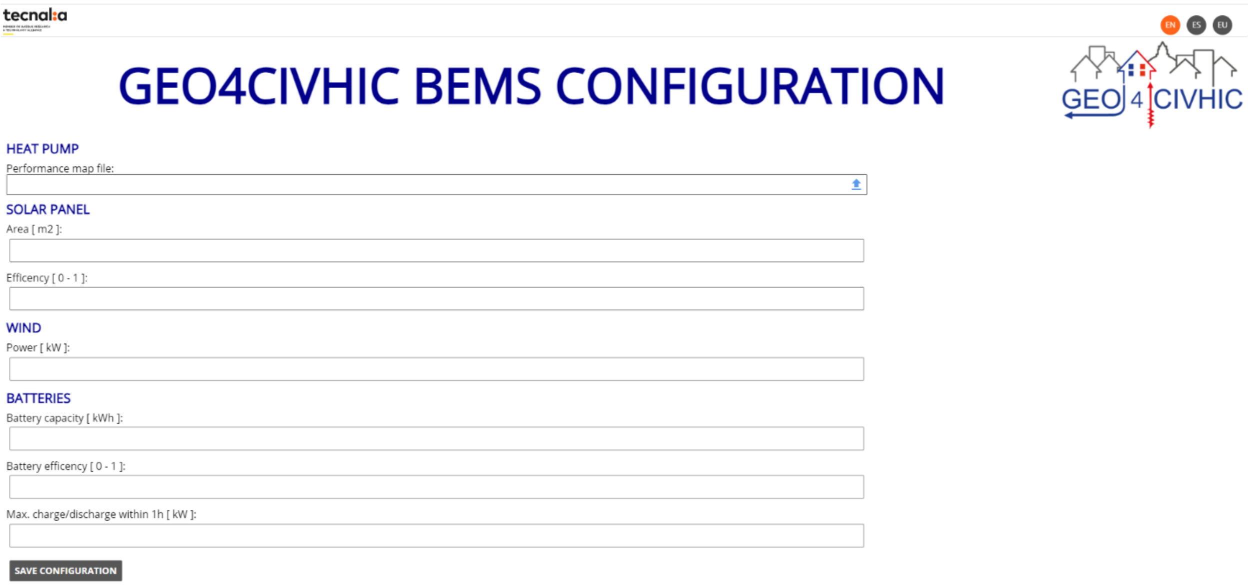


Figure 5 – GEO4CIVHIC BEMS configuration screen

3.3 Control order

The control order of the BEMS is outputted in a JSON file. Figure 6 shows the structure of the file. The control orders correspond to:

- -1: discharge the battery to supply the heap pump (HP)
- 0: do nothing
- 1: charge the battery from the grid

```
{
  "control_order": {
    "0": -1,
    "1": 0,
    "2": 0,
    "3": -1,
    "4": 0,
    "5": 0,
    "6": -1,
    "7": 0,
    "8": -1,
    "9": -1,
    "10": -1,
    "11": 0,
    "12": 0,
    "13": 0,
    "14": -1,
    "15": -1,
    "16": -1,
    "17": -1,
    "18": -1,
    "19": 0,
    "20": -1,
    "21": 0,
    "22": 0,
    "23": -1
  }
```


Figure 6 – BEMS output file example

The file is saved as `output.json` in the data folder of the software. Note that the optimisation algorithm is designed for only the first order to be executed and the optimization to be repeated every hour. The 24 hours are still passed to the BMS as back up in case there would be some down time from the BEMS, but the BMS should have a rule-based back up system for the case the down time is more than a couple of hours.

4 Example of integration in KUBIK BEMS

The GEO4CIVHIC BEMS has been integrated in Tecnalia's KUBIK building control system. KUBIK is an experimental building developed by TECNALIA located near Bilbao, Spain. This section gives an overview of the results. More detail can be found in D4.11 *"Optimised BEMS for GSHP and other RES control in historical and civil buildings and Application for a friendly and easy management of the energy systems"*.

4.1 Monitoring and control

The GEO4CIVHIC HP has been installed and integrated in KUBIK's physical and virtual installations (Figure 7). This section describes the different element of the system relevant for the experiment carried out for the GEO4CIVHIC project.

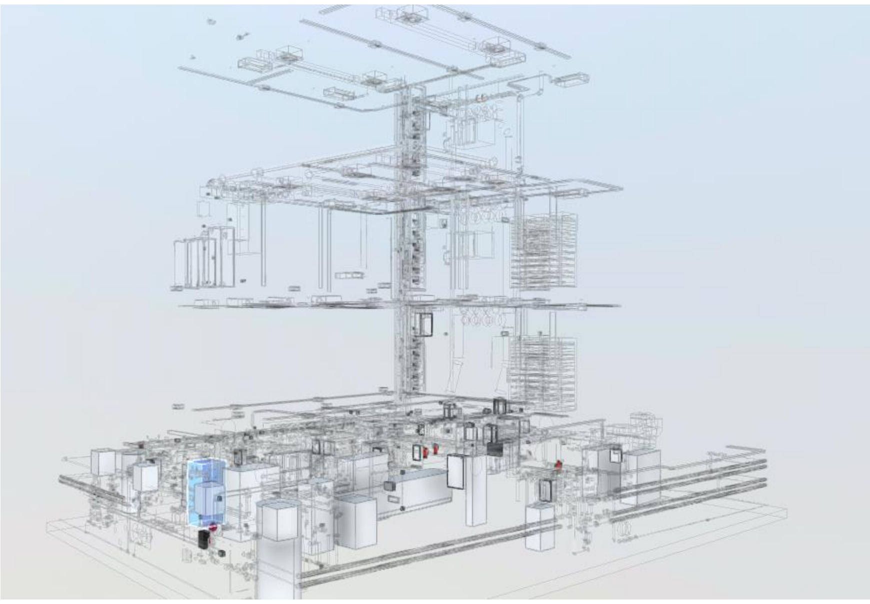


Figure 7 – Digital twin of KUBIK systems

Beyond the element that could be set in the BEMS interface, several elements of the system could be configured. Figure 8 and Figure 9 show the control settings implemented for the HP in the KUBIK Scada system where several operating modes are available (manual, auto and remote).

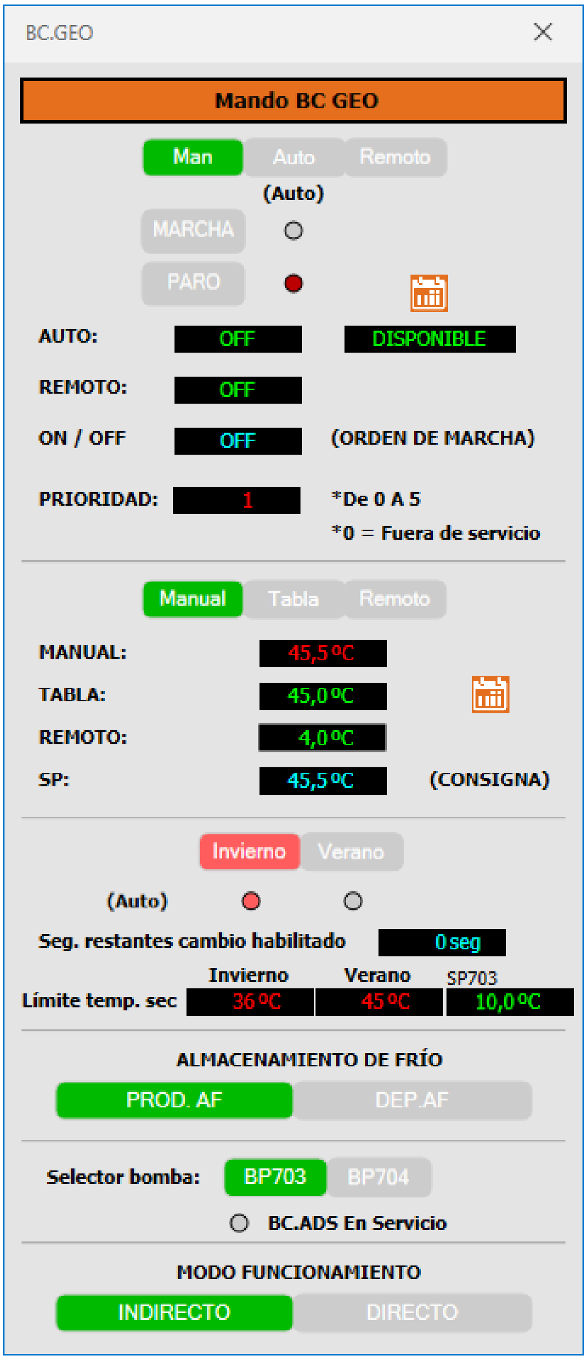


Figure 8 – HP control panel

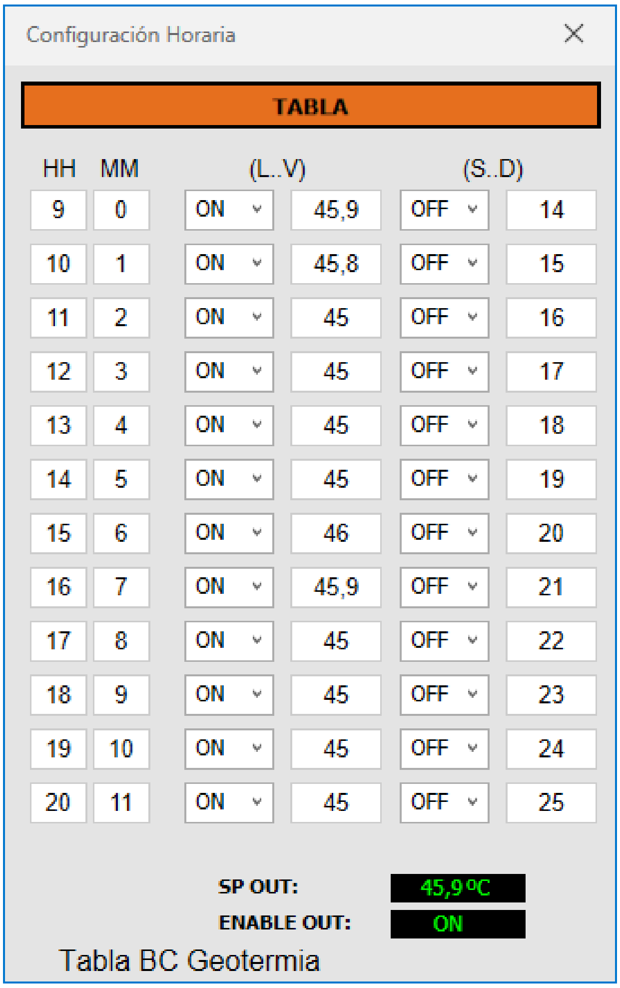
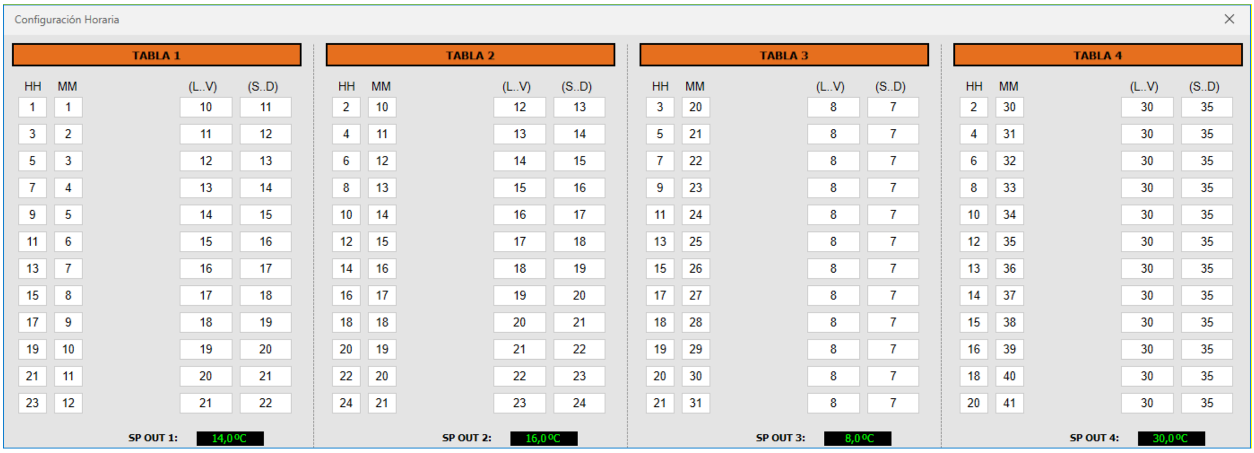


Figure 9 – HP schedule panel

The demand of the HP was coming from FCUs and a ventilation system. Figure 10 shows how the schedules and set point of the FCU were configures. Up to 4 predetermined schedules can be set.



Configuración Horaria

TABLA 1 HH	MM	(L.V)	(S.D)
1	1	10	11
3	2	11	12
5	3	12	13
7	4	13	14
9	5	14	15
11	6	15	16
13	7	16	17
15	8	17	18
17	9	18	19
19	10	19	20
21	11	20	21
23	12	21	22

SP OUT 1: 14,0ºC

TABLA 2 HH	MM	(L.V)	(S.D)
2	10	12	13
4	11	13	14
6	12	14	15
8	13	15	16
10	14	16	17
12	15	17	18
14	16	18	19
16	17	19	20
18	18	20	21
20	19	21	22
22	20	22	23
24	21	23	24

SP OUT 2: 16,0ºC

TABLA 3 HH	MM	(L.V)	(S.D)
3	20	8	7
5	21	8	7
7	22	8	7
9	23	8	7
11	24	8	7
13	25	8	7
15	26	8	7
17	27	8	7
18	28	8	7
19	29	8	7
20	30	8	7
21	31	8	7

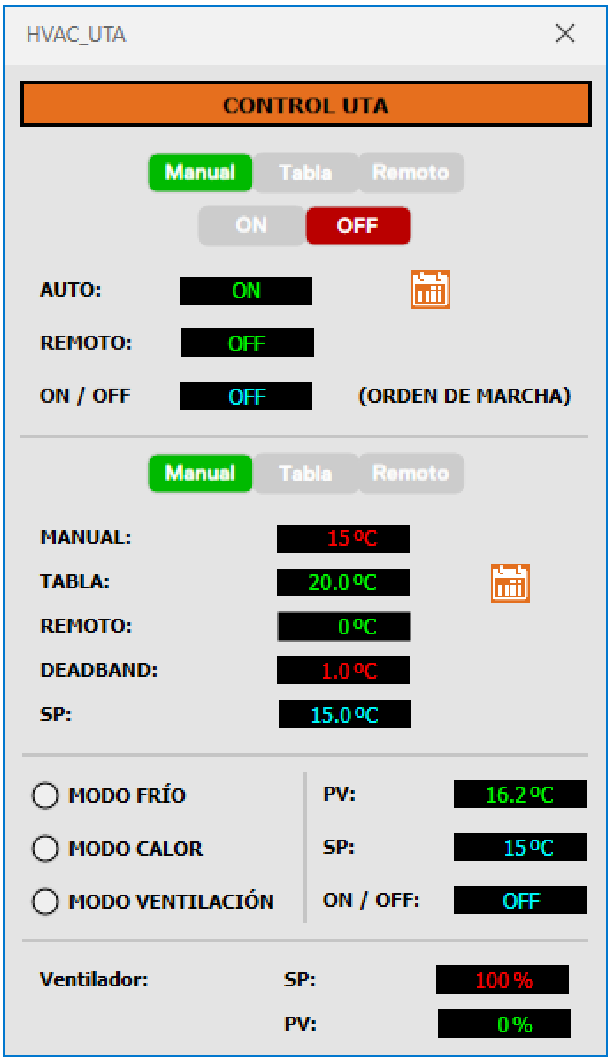
SP OUT 3: 8,0ºC

TABLA 4 HH	MM	(L.V)	(S.D)
2	30	30	35
4	31	30	35
6	32	30	35
8	33	30	35
10	34	30	35
12	35	30	35
13	36	30	35
14	37	30	35
15	38	30	35
16	39	30	35
18	40	30	35
20	41	30	35

SP OUT 4: 30,0ºC

Figure 10 – Operating schedules of the FCU

Figure 11 and Figure 12 show the control panel of the AHU and the MCU respectively.



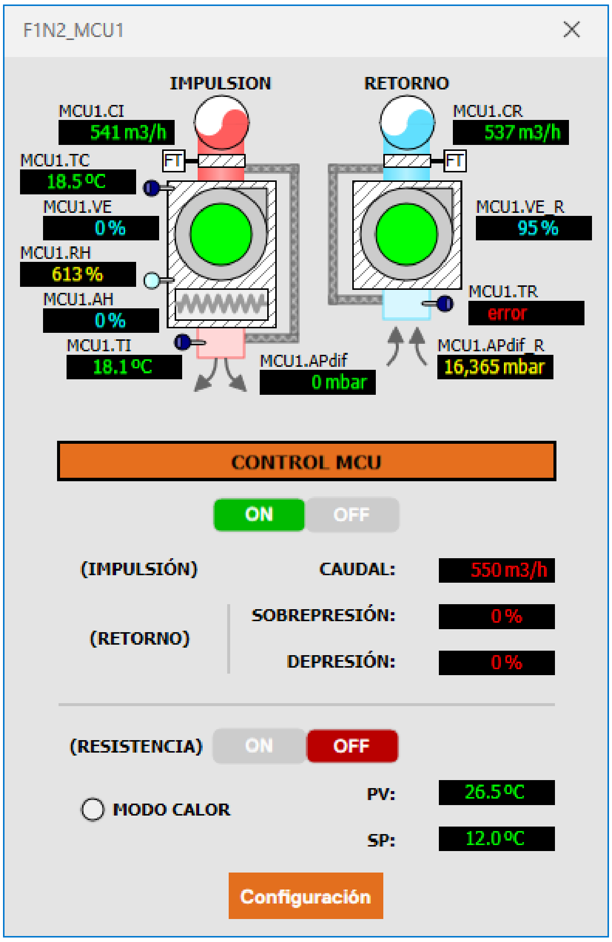


Figure 11 – AHU control

Figure 12 – MUC control

4.2 Input data & configuration

The test has been carried out with a solar panel case. The following configuration was used.

1. We are considering a PV panel of 4 m^2 with an efficiency of 0.1.
2. For the battery, we considered a battery of 15 kWh capacity and a maximum power of 5 kW and an efficiency of 0.9.
3. The performance map of the HP can be found in D4.11 “*Optimised BEMS for GSHP and other RES control in historical and civil buildings and Application for a friendly and easy management of the energy systems*”.

This configuration was set-up through the implemented software (Figure 13).

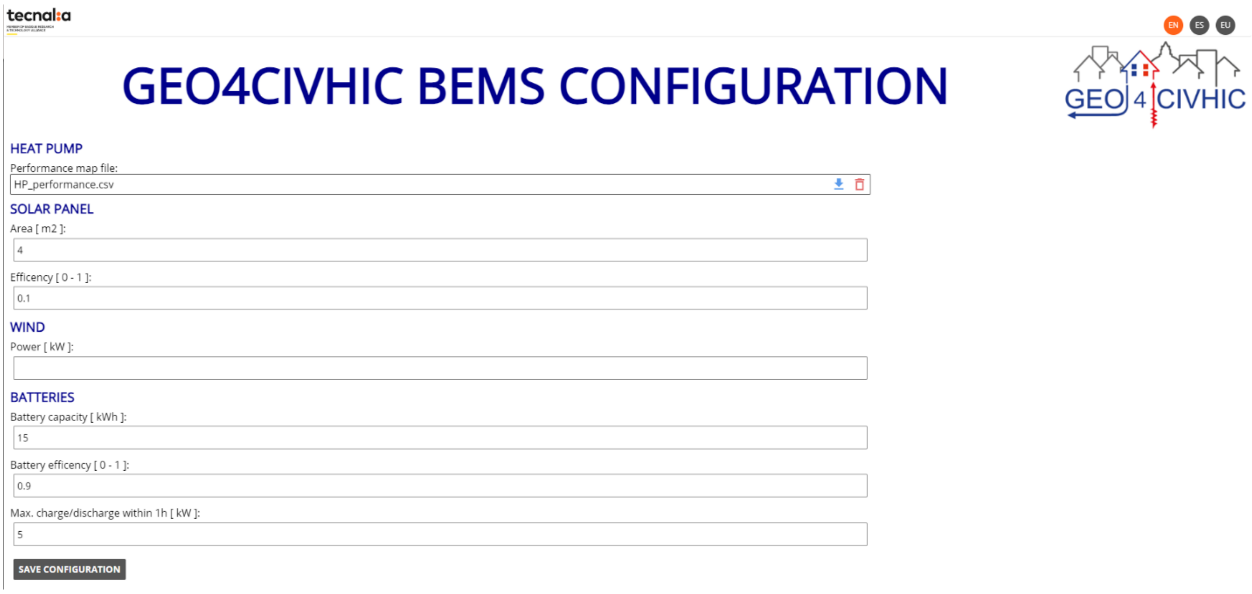


Figure 13 – GEO4CIVHIC BEMS configuration for the test

Conclusion

This document provides instructions for a BMS installer to integrate the GEO4CIVHIC BEMS in his control system to optimise the running cost of a multi-renewable system including a GSHP, a battery and a renewable electrical energy source (e.g. solar or wind).

The main steps for implementation are the following:

- Save the input data to the proper JSON format:
    - battery state of charge
    - 24 predicted electricity demand
    - 24 predicted electricity production
    - Day ahead energy prices
- Configure the BEMS through the user interface
- Read the optimization output

The BEMS runs an optimization every hour and return 24-values. Only the first one should be applied as a more optimal value will be calculated the following hour.

Appendix A: Energy price library documentation

digicon_enerprices

Search docs

Welcome to digicon_enerprices's documentation!

Indices and tables

Available functions

EntsoeHandler

EntsoeHandler.get_day_ahead_price_between_dat

EntsoeHandler.get_energy_generation_types()

EntsoeHandler.get_generation_per_type_between

EntsoeHandler.get_last_response()

EntsoeHandler.get_last_xml()

EntsoeHandler.localize_datetime()

EntsoeHandler.localize_datetime_to_string()

Available functions

The program reads data of energy prices and more from ENTSOE

class digicon_enerprices.entsoe_handler.EntsoeHandler(***entsoe_key***)

Bases: `object`

get_day_ahead_price_between_dates(***country_code***, ***start***, ***end***)

This function returns the day ahead prices between two dates (start, end) for a given country (using the country code).

Parameters:

country_code – The 2 letters code of the country

start – The start date

end – The end date

Returns:

['date_from','date_to','price','measurement_unit','currency','country']

Return type:

The function returns the data as a pandas.DataFrame with the following columns

get_energy_generation_types()

Returns a dictionary where keys are the ones used in the ENTSOE API and the values are the description of energy source.

get_generation_per_type_between_dates(***countrycode***, ***start***, ***end***)

This function returns the generation per type between two dates (start, end) for a given country (using the country code).

Parameters:

countrycode – The 2 letters code of the country.

start – The start date.

end – The end date.

Returns: The function returns the data as a pandas.DataFrame with the following columns: ['date_from','date_to','timezone','country','country_code','measurement_unit'] + one columns per energy source type.

get_last_response()

Returns the last response obtained from the request

get_last_xml()

Returns the last formatted response obtained from the request

localize_datetime(***dtm***, ***timezone=None***)

Given a datetime it is casted to UTC, if the original datetime has not a tzone the local timezone is assumed.

localize_datetime_to_string(***dtm***)

Appendix B: Input JSON file format


```
{
  "0": {
    "variable": "battery_soc_init",
    "values": {
      "0": {
        "FechaHora": "01/01/2023 0:00",
        "value": "0.2"
      }
    }
  }
  "1": {
    "variable": "demand",
    "values": {
      "0": {
        "FechaHora": "01/01/2023 0:00",
        "value": "0"
      },
      "1": {
        "FechaHora": "01/01/2023 1:00",
        "value": "0"
      },
      "2": {
        "FechaHora": "01/01/2023 2:00",
        "value": "0"
      },
      "3": {
        "FechaHora": "01/01/2023 3:00",
        "value": "0"
      },
      "4": {
        "FechaHora": "01/01/2023 4:00",
        "value": "0"
      },
      "5": {
        "FechaHora": "01/01/2023 5:00",
        "value": "0"
      },
      "6": {
        "FechaHora": "01/01/2023 6:00",
        "value": "0"
      },
      "7": {
        "FechaHora": "01/01/2023 7:00",
        "value": "9.141"
      },
      "8": {
        "FechaHora": "01/01/2023 8:00",
        "value": "7.671"
      },
      "9": {
        "FechaHora": "01/01/2023 9:00",
        "value": "7.582"
      },
      "10": {
        "FechaHora": "01/01/2023 10:00",
        "value": "7.077"
      },
```

```
        "11": {
          "FechaHora": "01/01/2023 11:00",
          "value": "6.131"
        },
        "12": {
          "FechaHora": "01/01/2023 12:00",
          "value": "4.864"
        },
        "13": {
          "FechaHora": "01/01/2023 13:00",
          "value": "3.766"
        },
        "14": {
          "FechaHora": "01/01/2023 14:00",
          "value": "3.044"
        },
        "15": {
          "FechaHora": "01/01/2023 15:00",
          "value": "2.510"
        },
        "16": {
          "FechaHora": "01/01/2023 16:00",
          "value": "2.130"
        },
        "17": {
          "FechaHora": "01/01/2023 17:00",
          "value": "1.558"
        },
        "18": {
          "FechaHora": "01/01/2023 18:00",
          "value": "1.682"
        },
        "19": {
          "FechaHora": "01/01/2023 19:00",
          "value": "1.943"
        },
        "20": {
          "FechaHora": "01/01/2023 20:00",
          "value": "2.268"
        },
        "21": {
          "FechaHora": "01/01/2023 21:00",
          "value": "0"
        },
        "22": {
          "FechaHora": "01/01/2023 22:00",
          "value": "0"
        },
        "23": {
          "FechaHora": "01/01/2023 23:00",
          "value": "0"
        }
      }
    },
```

```
"2": {
  "variable": "production",
  "values": {
    "0": {
      "FechaHora": "01/01/2023 0:00",
      "value": "0.0"
    },
    "1": {
      "FechaHora": "01/01/2023 1:00",
      "value": "0.0"
    },
    "2": {
      "FechaHora": "01/01/2023 2:00",
      "value": "0.0"
    },
    "3": {
      "FechaHora": "01/01/2023 3:00",
      "value": "0.0"
    },
    "4": {
      "FechaHora": "01/01/2023 4:00",
      "value": "0.0"
    },
    "5": {
      "FechaHora": "01/01/2023 5:00",
      "value": "0.0"
    },
    "6": {
      "FechaHora": "01/01/2023 6:00",
      "value": "0.0"
    },
    "7": {
      "FechaHora": "01/01/2023 7:00",
      "value": "0.0"
    },
    "8": {
      "FechaHora": "01/01/2023 8:00",
      "value": "0.0"
    },
    "9": {
      "FechaHora": "01/01/2023 9:00",
      "value": "0.0021"
    },
    "10": {
      "FechaHora": "01/01/2023 10:00",
      "value": "0.0770"
    },
    "11": {
      "FechaHora": "01/01/2023 11:00",
      "value": "0.1990"
    },
    "12": {
      "FechaHora": "01/01/2023 12:00",
      "value": "0.2945"
    },
```

```
        "13": {
          "FechaHora": "01/01/2023 13:00",
          "value": "0.3462"
        },
        "14": {
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      "22": {
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      "23": {
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}
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