Digital intelligent and scalable control for renewables in heating networks

Deliverable D3.4

# Report on the new technology monitoring and experimental campaign, and on the analysis of the data.

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## Executive summary

The deliverable D3.4 focuses on the operating results obtained from the application of the MPC controller at the trigeneration plant of the Hospital of Cona. In this respect, the baseline analysis is validated and the calculation reported with respect to the standard functioning of the plant, i.e. before the startup of the MPC controller. Thanks to the positive results obtained, the best practises in terms of real-time control of complex energy system could be identified, and the project extended to new plants in the future.

# 1. Introduction

This report is the Deliverable D3.4 of Work Package WP3 of the DISTRHEAT project, led by Siram Veolia. The work package "WP3 - Prototyping and demonstration for small DHC" aims at comparing the monitoring results of the Model Predictive Controller (MPC) with respect to the baseline, so that the best practices for the control of the system can be defined.

# 2. Baseline validation

The baseline for the Hospital of Cona is thoroughly described in Deliverable D3.2, where the regression models for energy consumptions and productions have been defined. According to the procedure identified, the models must be tuned on real data in order to be validated for the baseline comparison of the results. Therefore, after retrieving monthly measurements coming from remotized meters (and validated with records from manual readings), the baseline validation process has been carried out by applying the linear regression models on the data retrieved from January to December of the year 2021. The following R2 score have been computed:

| **Baseline** | **R2 Score** |
|---|---:|
| Cogenerator electricity production | 0.973 |
| Cogenerator gas consumption | 0.996 |
| Electricity consumption | 0.743 |
| Cogenerator thermal production for heating use | 0.937 |
| Absorption chiller cooling production | 0.782 |
| Natural gas consumption for heating use | 0.913 |

Table 1. R2 Score of the baseline analysis on real data.

As reported in Table 1, overall the quality of the regressions are extremely satisfactory, with exception of the absorption chiller cooling production (R2 Score = 0.782) and the electricity consumption (R2 Score = 0.743). Indeed, while the former is still acceptable in terms of regression constraints (R2 Score > 0.75), the latter is slightly below the threshold. This is explained by the fact that the electricity consumption has been modeled considering only the cooling degree days (i.e. the potential cooling demand) in the regression, thus neglecting other potential sources of consumption (i.e. machinery, lighting, heating, etc.). Nevertheless, being the R2 Score less than 1% from the target, the model has been accepted and validated.

# 3. Analysis of the results

After validating the baseline models, the results of the MPC can be analyzed thanks to a baseline comparison with the "standard" operations of the plant of the Hospital of Cona. In detail, the monthly variation of energy consumptions and productions with respect to the baseline from March to August 2022 are reported below.

| Month | Cogenerator gas consumption | Natural gas consumption for heating use | Cogenerator electricity production | Cogenerator thermal production for heating use | Electricity consumption |
|---|---|---|---|---|---|
| Mar | 0.8% | -4.1% | 0.8% | -4.44% | -5.3% |
| Apr | -0.2% | 9.3% | 0.9% | 0.51% | -3.6% |
| May | 0.5% | 34.8% | 0.7% | -0.84% | -4.1% |
| June | -0.3% | 11.2% | 1.3% | -5.81% | 7.6% |
| July | -2.0% | -26.3% | -1.3% | 7.08% | -12.2% |
| Aug | -0.8% | -6.7% | 0.1% | 4.69% | 2.7% |
| **Tot** | **-0.28%** | **3.38%** | **0.48%** | **-0.30%** | **-1.90%** |

Table 2. Monthly variation of energy consumptions and productions with respect to the baseline, computed with MPC data from March to August 2022.

As shown in Table 2, despite a slight increase in natural gas consumption for heating use (due to a more intensive use of the cogenerator), electricity consumption has been reduced by better exploiting the absorption chiller during summer. Overall, the economic balance computed following the procedure described in Deliverable D3.2 and normalized with respect to the total economic balance of 2021, is reported below in Table 3. For a global overview, the baseline variations are reported. The period considered is again from March to August, comparing the standard functioning of 2021 and the MPC functioning of 2021 with the baseline computations.

| **Baseline analysis** | **Standard** | **MPC** |
|---|---|---|
| Cogenerator gas consumption | -0.04% | -0.28% |
| Cogenerator electricity production | -0.39% | 0.48% |
| Cogenerator thermal production for heating use | -1.24% | -0.30% |
| Natural gas consumption for heating use | -1.65% | 3.38% |
| Electricity consumption | 5.70% | -1.90% |
| Economic balance | 23.25% | 7.83% |

Table 3. Comparison between standard and MPC functioning with respect to the baseline.

In the "Standard" column, the percent variations of 2021 data which have been calculated on the same data. As expected, the highest errors among the regressions is attributed to the electricity consumption, which has the lowest R2 score. On the other hand, the economic balance derives from a computation that includes calculated energy consumptions and productions (as highlighted in Deliverable D3.2) and that explains the higher percent variation. Nonetheless, it is clearly evident that the application of the MPC controller had a positive impact on the economic performance, reducing the operational costs thanks to a lower electricity consumption and despite the higher consumption of natural gas for heating use. Indeed, on the one hand the cogenerator operated for more hours and, on the other, the absorption chillers contribute more to reduce the electricity consumption during the summer period.

# 4. Conclusions

All things considered, considering the characteristics of the application and the increasing volatility of the energy prices in which we are operating, the application of the MPC showed a clear positive impact on the plant's economic performance, acting both in the production and in the consumption side. The evidence and the data coming from the MPC functioning will be useful not only to understand the behavior of an automatic and optimized system in comparison with a standard BMS, but also to help us define the best control strategy for complex plant in the future.