# MODELLING AND OPTIMIZATION OF A MICRO COMBINED HEAT AND POWER PLANT

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Abstract: Most electrical power in developed countries today is produced by large centralized power plants. With the technology progress, micro combined heat and power generators (ranging from 1 to 10 kW) are becoming available. Tomorrow, they will produce electricity and heat at home, locally. This paper presents a method of handling these new kind of power plants. The solution based on dynamic programming schedules the use of the micro CHP and of the hot water tank in order to minimize the operating costs. An on-line implementation of the algorithm is proposed and tested on a validation model. 

Keywords: Dynamic programming, dynamic models, Energy management systems, Energy control, Non linear control, On-line Control, optimal control, Power generation, Predictive Control

## 1. INTRODUCTION

Recent progress in technology has made possible the development of micro Combined Heat and Power (mCHP) for dwellings and small buildings. These systems, which produce electricity, heat and hot water, might soon replace the traditional boilers. Internal combustion engines are already available, and more efficient technology will be available in the near future. Stirling engines and Rankine cycle could be marketed in two or three years while fuel cell technology could appear after 2010. The two main drivers for the development of mCHP are (i) the liberalization of the gas and electricity markets (utilities could propose commercial packages including mCHP to attract customers) and (ii) the increasing importance of environmental policies aimed at reducing greenhouse gas emissions. Peacock (2005), for instance, shows how the use of the mCHP can contribute significantly to the reduction of the CO2 emissions. In parallel, the technology has improved enough for mCHP to be reachable (better reliability and lower prices).

EdF is an integrated energy company with activities stretching from power plant generation to gas and electricity commercialization for industrial and residential customers. EdF has studied the O&M improvements of its centralized power plants and is now investigating how to optimize the distributed resources. In Mondon (2005), the problem of an isolated mCHP fleet is addressed. The system consists of 200 houses equipped with mCHP, thermal and electrical storage devices, and is not connected to the grid. Compared to a reference case with electricity generated by centralized combined cycles and thermal needs satisfied locally by traditional gas boilers, the studied system, once optimized, reduces the yearly gas consumption by more than 6%. Apart from the mCHP fleet optimization, EdF is investigating the benefits of an optimal control to meet the thermal and electrical needs of a single dwelling by the means of a mCHP and a support boiler. This kind of system is likely to appear sooner than the mCHP network solution because of the lower investment cost. Priority use of mCHP is adopted generally but Entchev (2003) suggests a solution based on fuzzy logic to improve the performance of such a system.

In the present paper, we propose a predictive control based on the dynamic programming to optimize the operations. The dynamic programming is indeed a very general method that can accept nonlinear models, logical and continuous description, and is suited for small systems.

The section 2 presents the process we want to control and the simulation model that has been developed to test our optimization scheme. The section 3 presents the optimization problem itself. It involves a design model whose dynamics are simpler than the dynamics of the simulation model and a set of equations corresponding to the constraints. The results of the optimization and a validation on the detailed model are discussed in the section 4 before a conclusion that will indicate the further investigations

## 2. PROCESS DESCRIPTION & VALIDATION MODEL

### *2.1 Process Description*

The studied system is shown in Figure 1. It consists of a dwelling equipped with a mCHP and a support boiler fed with gas. The mCHP produces heat to meet the thermal needs and electricity. When the thermal power is not enough, a support boiler is activated. The heat produced by the machines is used to warm the water that circulates in the pipes and is sent either to the radiator or to the water tank. According to the electric consumption, the electricity is either consumed in the house or sold to the electrical network. If the electricity production is not sufficient, the missing amount can be bought. An electricity meter is supposed to measure the purchased and the sold electricity

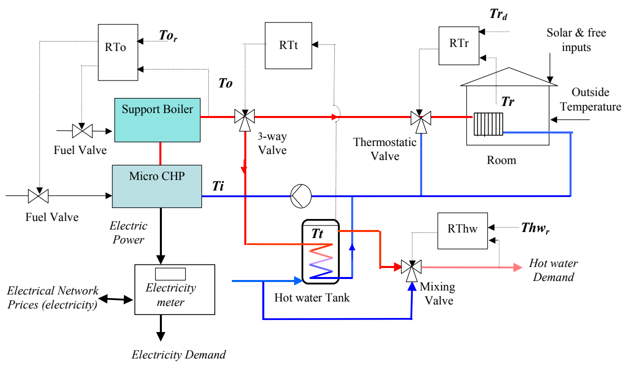


Fig. 1: Process Description

The system is regulated by several loops represented in Figure 1. The room temperature *Tr* is regulated by the thermostatic valve and the hot water temperature *Thw* by the mixing valve. The temperature at the boiler output *To* is controlled at a set-point $To_r$ which depends in general on the outside temperature. The regulation uses in priority the mCHP following the scheme proposed in Figure 2. The tank water temperature *Tt* is maintained between 60°C and 80°C by the 3-way valve located at the boiler output. The volume of the tank is 250 l.

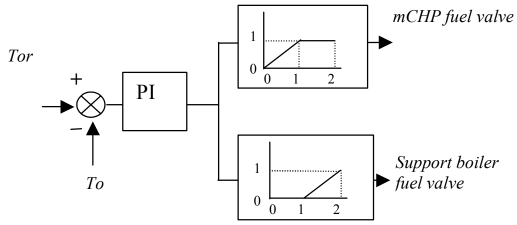


Fig. 2 : classical mCHP control strategy

### *2.2 Validation Model*

A model of the process has been developed to test our control law. This validation model is based on physical laws (pump, valve, pipe, tank, radiator, boiler). This model is useful because it allows easier testing of the control at the design stage. Indeed, as the model runs much faster than real time (some of the dynamics involved in our problem are rather slow), the use of a model saves plenty of time. The validation model has been built using SIMBAD, a Matlab-Simulink library for Building and HVAC (Heating Ventilating Air Conditioning) systems. SIMBAD is available at the address http://software.cstb.fr/.

The first level of the Matlab-Simulink validation model is given in Figure 3.

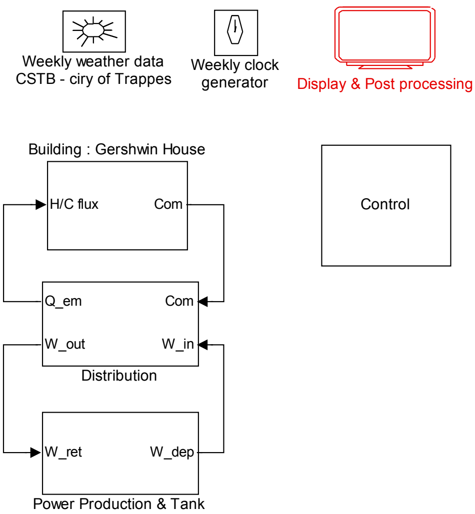


Fig. 3 : Simulink™ Validation Model

The first module provides the weather at Trappes, a city near Paris. The *Control* block contains the regulations presented in the previous paragraph. The parameters of the regulations have been tuned using the software EasyPIDTuning presented in Faille (2003). The *Building* block contains the simplified equation of a house. The *Distribution* block simulates the circulating pipes and the radiator as presented in Figure 1. The Module *Power Production &Tank* contains a model of a mCHP. This model is a black box developed with data obtained on machines (Stirling Engine, Fuel cell,…) tested in EifER and EdF Laboratories. The static parts of these models are functions of the