

Extended summary

Design and Development of Control Solutions for Multi-Variable Process Optimization

Curriculum in Ingegneria Informatica, Gestionale e dell'Automazione

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Abstract. The research activity has been focused on the development and implementation of solutions for the control and optimization of interacting systems. The application fields considered are the Home & Building Automation (HB&A) and automation in petrochemical industry. In the field of H&BA, a controller for coupled thermal and lighting comfort and for indoor air quality has been developed, which is, in this interconnection, highly innovative. The goal pursued in the design of the control system is to obtain the maximum energy savings and comfort for the user. Through an efficient use of "cross-fertilization" it was possible to adopt within the Home & Building Automation, control techniques acquired from the industrial automation field. In particular, for the development of the control system control architectures based on advanced PID interconnection have been developed. Successively problems related to the optimal tuning of industrial controllers, evaluation of stability and the increase of the control system performances,



have been analyzed thoroughly. Advanced multivariable control techniques were finally analyzed. Through the use of a bank of models, identified by step tests on the real process, a Gain Schedule-Model Predictive Control has been developed. This control methodology is well suited to multivariable control process and optimization which allow including constraints in the solution computation. Another issue concerns the modeling and control of highly industrialized and automated processes like the refinery plant "api" in Falconara Marittima. In particular, we have addressed the problems of the visbreaking column optimization and the furnace combustion optimization used in petrochemical plants to preheat the column feed. In addition, an innovative PID architecture has been designed and implemented on a DCS system to fulfill required specifications. In particular, it has been developed a Discrete Fuzzy Smoother that allows avoiding the overshoot.

Keywords. Home & Building Automation System, Advance PID control, petrochemical control automation and MPC control.

1 Introduction

Until the early 1960s, the field of process control was based almost entirely on mechanical, electrical or pneumatic analog controllers, which were usually designed using linear single-input single-output considerations. Hardware limitations, economic cost, and the dearth of applicable theory usually precluded anything more complex than these simple schemes. Over the last fifteen years there has been a dramatic change in industrial process and in general in automated process. Now they are predominantly continuous with large throughputs, highly integrated with respect to energy and material flows, constrained very tightly by high-performance process specifications, and under intense governmental safety and environmental emission regulations. All these factors combine to produce more difficult process control problems as well as the requirement for better controller performance. Excessive environmental emissions or process shut-down due to control system failure can have catastrophic economic consequences because of the enormous multipliers characteristic of high-throughput continuous processes. This produces large economic incentives for reliable, high-quality control system in modern industrial plant.

Furthermore, the rising of energy prices, heightened environmental awareness and the growing number of regulatory guidelines such as the European ErP Directive have led people in the world of control automation to pay increasing attention to the topic of energy-efficient solutions.

At the same time, modern control theory has been under intense development, with many successful applications. The "optimal control theory" allows the design of control schemes which are optimal in sense that the controller performance minimizes some specified objective function. In addition to controller design, it provides methods for process identification and state estimation.

In today's fast-moving, highly competitive industrial and automated world, a company must be flexible, cost effective and efficient if it wishes to survive. In the process and manufacturing industries, this has resulted in a great demand for control systems/automation in order to streamline operations in terms of speed, reliability and product output. Automation plays an increasingly important role in the world economy and in daily experience. Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. In the scope of industrialization, automation is a step beyond mechanization.

In recent years, due to the increasing demand for efficiency and quality of products and the need to improve safety in the workplace, new control solution are playing a very important role in the field of process control. There are different solutions (in this thesis the advanced PID control and MPC control are examined), but with the same goals, that are:

- increase the productivity
- improve quality of the product
- improve the performance of the system from the control point of view
- increase plant/process safety
- consistent product quality with minimum production costs

• and, in the last five years the most important and considered, is the production cost reduction. Or in other terms: reduction in energy an raw material per unit of product



The topics introduced continue to be valid in the field of home and building automation. Thanks to the new legislations regarding the reduction of environment emissions also within the domotic research area the attention has shifted to systems with high energy efficiency. In the work that follows a home automation system for energy saving and user's comfort optimizing is presented.

2 Industrial Automation Control

2.1 PID Control Architecture

In the last 10 years the control philosophy in industrial environment, due to the global economic crisis, is changed from maximizing the process throughput, to a consistent product quality with minimum production costs or, in other words, the reduction in energy an raw material per unit of product.

To reach this goal some optimal control solution can be used, like an interconnection of advanced PID control architectures and/or the Model Predictive Control (MPC) solution.

2.1.1 Pid in PLC/DCS Control System

All controllers can be run in two modes: manual or automatic. In manual mode the controller output is manipulated directly by the operator, typically by pushing buttons that increase or decrease the controller output. A controller may also operate in combination with other controllers, such as in a cascade or ratio connection, or with nonlinear elements, such as multipliers and selectors. This gives rise to more operational modes. The controllers also have parameters that can be adjusted in operation. When there are changes of modes and parameters, it is essential to avoid switching transients. The way the mode switching and the parameter changes are made depends on the structure chosen for the controller.

Since the controller is a dynamic system, it is necessary to make sure that the state of the system is correct when switching between manual to automatic mode. When the system is in manual mode, the control algorithm produces a control signal that may be different from the manually generated control signal. It is necessary to make sure that the two outputs coincide at the time of switching.

This is called *bumpless transfer*. Bumpless transfer is easy to obtain for a controller in incremental form. The integrator is provided with a switch so that the signals are either chosen from the manual or the automatic increments. Since the switching only influences the increments there will not be any large transients.

In figure 1 a standard PID configuration for PLC or DCS control system is shown. In this configuration anti-wind-up and bumpless transfer are implemented in a single scheme.

In table 1 are highlighted the solution adopted to avoid the wind-up phenomena in the advanced PID control structures. Table describes some proposal solution to be used in industrial environment by automation engineer and these solutions are used in the case studies proposed in chapter 3.





Figure 1: PID with tracking mode

The Table 1 is useful to configure on PLC/DCS control system advanced PID control solution, where the causes about the wind-up phenomena is not only the actuator saturation, but also the regulators mode in the particular configuration. For example main PID in cascade configuration should be in AUTO mode, while the slave PID should be in RSP (remote set point) mode. If the slave PID change mode from RSP to MAN or AUTO some "tracking" precautions must be taken. The table 1 summarizes all this precautions for cascade, split range, valve position, override and ratio control configurations.

Control Architecture	1° Situation	2° Situation	3° Situation	
Cascade	Main in MAN mode: SP (Master) aligned to CV (Mas- ter)	Slave in MAN mode: SP (Slave) aligned to CV (Slave) OUT (Master) aligned to SP (Slave)	Slave in AUTO mode: OUT (Master) aligned to SP (Slave)	
Split Range	Controller in MAN Mode: SP aligned to CV			
Valve Posi- tion	Master in MAN mode: SP (Master) aligned to CV (Mas- ter)	Slave in MAN mode: SP (Slave) aligned to CV (Slave)		
Override	Controllers in MAN mode: SP aligned to CV	Controllers disactive: Turn off the integral action		
Ratio	Master in MAN mode: SP aligned to CV (Master)	Slave in MAN mode: SP aligned to CV (Slave). OUT (Master) aligned to SP (Slave); OUT=SP/R	Slave in AUTO mode: OUT (Master) aligned to SP (Slave); OUT=SP/R	

Table 1 – Tracking management

2.1.2 Fuzzy PID Control

In order to obtain good performances from the point of view of the transient response behavior (limited overshoot, fast rising time, short assessing time with limited control efforts) different tuning approaches have been evaluated. In the following of this section the results of the application of Fuzzy logic techniques for the realization of a suitable smoothing of the controller set point are discussed. The adopted control scheme is based on a discrete fuzzy smoother (DFS) that, working on-line, is able to adapt its actions to the system behavior. The idea is to drive the system with a sequence of steps, so as to keep, at opportune stages, the input signal small. In this way, since the absolute value of the over-



shoot depends from the value of the step change, it is possible to limit the overshoot to proper small values. An advantage of this approach is that generally a shorter rising time can be achieved.



Figure 2: proposed DFS control scheme

Inputs to the DFS are: The set-point error SE = z0- z0s, where z0 is the required set point and z0s is the smoothed subset- point generated by the DFS; the error E = z0s-z, where z is the actual value of the controlled variable; the variation of the process variable is DY.

2.2 Gain Schedul – MPC

Industrial processes are in general highly nonlinear especially when operated over a wide range of operating conditions. The nonlinearity is generally related to reaction kinetics or nonlinearity of physical properties. Therefore, there is a strong motivation to control these processes with nonlinear controllers. However, there are not many general design procedures to deal with this task, and there are many difficulties to design such controllers because of the systems nonlinearity.

For model-based control design problems for highly nonlinear processes, the first difficulty is to obtain a good simple model of the processes under study. Relatively simple empirical models can be identified from process input/output data. The second major difficulty is that although the nonlinear models used in this thesis are easy to identify, the design to obtain the desired performance for such models using nonlinear control theory is not straightforward.

Gain-scheduling is a common engineering practice used to control nonlinear plants in a variety of engineering applications. Review the traditional gain scheduled process control. A typical gain-scheduled design procedure for nonlinear plants is as follows:

- The designer selects several operating points which span the range of operation of the process.
- At each of these operating points, the designer constructs a linear time-invariant approximation of the plant and designs a linear compensator for the linearized plant model.
- In between operating points, the parameters or gains of the compensators are then interpolated, or scheduled, thus resulting in a global compensator applicable to the whole window of operation.

Since the local designs are based on linear time-invariant approximations to the plant, the designer may be able to guarantee that at each operating point, the feedback system has the needed feedback properties, such as stability and performance of the local linear model. However, since the actual system is nonlinear, the overall gain-scheduled system may not satisfy the stability and performance margins for the actual nonlinear process. In other words, one typically cannot assess a priori the guaranteed stability and performance properties of this traditional gain-scheduled design. Rather, any such properties have to be inferred from extensive computer simulations.



Robust synthesis of MPC. The basic philosophy in the literature for optimizing the performance of MPC-based design algorithms that explicitly account for plant uncertainty is to modify the on-line minimization problem to a min-max problem, where the worst-case value of the objective function is minimized over the set of plants that account for the nominal model and uncertainty.

This research deals with the application of robust control theory for the design of control techniques such as gain scheduling Model Predictive Control (GSMPC). The robust gainscheduled MPC design approach proposed in this work addresses some of the above problems efficiently. The transfer function model, which depends nonlinearly on the manipulated variable *u*, is used to generate the process predictions. As a result, these output predictions take into account explicitly the model uncertainty and approximate the feedback from the uncertain plant. In this work, to avoid the nonlinear optimization formulation, it is proposed to do predictions with step response models as done for the linear case. However, to account for the process nonlinearity, instead of using one step response model, a family of step response models will be defined for different sub-ranges based on the values of the manipulated variable *u*. This approach results in a simple gain-scheduled MPC strategy.

3 Case Studies

This chapter describes the main topics studied during the research period, related to Home & Building Automation and industrial control in the petrochemical filed. In detail in section 3.1 an H&BA control system is presented with ttwo different control design solutions. In section 3.2 an advanced PID control architecture developed to minimize the head pressure of a visbreaking column is presented. A further case study is described in section 3.3 concerning the problem of a furnace combustion optimization in petrochemical environment.

3.1 H&BA Advance PID Control Strategy

In this section improvements of the control system of the Building and Home Automation system are described. In particular, control solutions as a new thermal control policy, an anti-glare logic, and a logic for accounting of the solar radiation are introduced. The scope of the controller is the coupled regulation of the room temperature, the room illuminance and regulation of the IAQ. As in the previous solution the system assuring the reduction of energy consumption while considering user comfort as well.

The control scheme allows to obtain enhanced control performances and add more functionalities. The actuation of the windows (open and close) is removed from the standard control architecture and is elevated to a supervisory level to manage the Indoor Air Quality. In this control configuration the windows actuation are thus to be considered a disturbance for the control system. Two different control policies are considered: Energy Saving control mode and Comfort mode. When the (Energy) saving mode is selected the only specification is the reduction of energy consumption while optimization functions that takes into account constrains derived by the preservation of the user comfort are considered in the Comfort mode. The regulation of the rolling shutters requires handling possible conflicting requirements of interconnected thermal and lighting controllers. Depending on the desired



user policy (Energy Saving or Comfort) the rolling shutters control logic has to adapt. The Personal Comfort Logic (PCL) module described in the sequel is in charge of the choice of the control signal that best fits to the current state of the system.

Thermal and lighting decoupling action. Lighting control has the same scheme described in section before and also the thermal control system uses the same logic scheme, consisting of three interconnected PID controllers in the same way as previously described. In this scheme the TC0102-PID controls the thermostat for the activation of the heat pump, while the TEC00103-PID and MPC0102 PID are respectively the temperature limiter and the controller for the optimization of the heat pump control effort. Both control systems act on the rolling shutter to adjust the room illuminance and the room temperature. Thus, it is necessary to identify a logic that manages the possibly contrasting shutters requirements coming from the thermal and lighting controllers. At this purpose, the coupling of the thermal and lighting control outputs are handled by a Personal Comfort Logic (PCL) module as depicted in figure 4. The internal logic of this module determines the policy of the selection for the input signals depending on the actual system configuration.

Each of the four states of the PCL automaton represents the implemented control policy: coupled control action and override configured in low(high)-pass mode in the Min (Max) state or assigned priority to thermal (lighting) controllers in the other two states, respective-ly. Events are combinations of the selected pairing of Heating/Cooling and Saving/Comfort modes which takes into consideration possible temperature and lighting thresholds. When the system is in Saving (Energy) mode the object is to reduce power consumption.



Figure 3: building automation system control scheme

In this case the requested control efforts are mostly achieved by the actions of the shutters thus reducing the use of the heat pump. On the contrary, when in Comfort mode, the system assigns higher priority to the lighting control aiming at achieving the desired set point by means of the natural illumination. In order to meet user possible personal comfort preferences, such as for example limitation of the shutter position within assigned range limits, specific management constraints are implemented. The inclusion of this feature increases the degree of user interaction with the system. It's important to note that if the shutter can't meet the required control effort due to the imposed limits, the heat pump will be activated. The coupling automaton contains a condition "XC001–Direct solar radiation Presence Check" that evaluates the presence (conduction factor plus convection factor plus irradiation factor not equal zero) of direct solar radiation on the glass. While, if the direct



solar radiation can be assumed absent or negligible, the logic selects the rolling shutter control signal computed by the lighting control system.



Figure 4: personal comfort logic automaton

The logic takes account of two aspects that is the presence of direct solar radiation on the glass wall and the composition of the thermal conduction/convection and the heat radiation contributions. When the sum of these two components is positive then it means that the heat flow comes from outside into the environment, otherwise, if the sum is negative, the heat flow has opposite direction. Combining these two components it is possible to obtain empirical information on the heat flow input due to solar radiation that intervenes in the coupling logic previously described and also completes the control policy for the management of the shutters.

Anti-Glare action. The logic "XC002–Anti-glare" evaluates from the rising position of the sun (azimuth and solar height, based on the latitude of the current location) the possibility to having glare into the environment. Then, according to the sun's position the actuations to the rolling shutter are calculated, allowing the user to avoid direct glare. This value is inserted into the control by using override selection logic.

LAQ control System. As previous anticipated another new feature, the Indoor Air Quality, is inserted into the supervision system. To obtain this characteristic the windows actuation is considered. An intelligent logic that evaluates the air quality (presence of CO₂ and formal-dehyde) so to control the windows opening or closing has been considered. The logic design takes into account two aspects: observation of the imposed limit of pollutions (due to a limit availability of sensor) while preventing the increase of energy consumption (for example with an over actuation of the windows). The control system works whit a estimation of the formaldehyde and of the CO₂ emissions produced respectively by furniture and people. In case of the availability of a sensor, value estimation is replaced by sensor measurement. These emission have been chosen because they are the two primary sources of pollution in closed environment. Figure 5 shows the adopted control scheme with two regulation loops, and an override selector that allows maintaining the pollution values under fixed levels.



Figure 5: the IAQ control system



3.2 GSMPC in H&BA System

Following the "cross-fertilization" methodology a new completely revised controller based on the model predictive control approach has been developed.

In particular gain scheduler control architecture has been adopted in order to deal with nonlinearities of the system. Robust controller (GSMPC) is the focus of the current section. The main subject of this chapter deals with the analysis and design of the nonlinear closed-loop control system. As a result, control architecture for an H&BA system based on the gain scheduling philosophy, is presented. The work comprises an identification step from plant data and the finding of the optimal model parameters. The objective is to design a control system that allows obtaining satisfactory performances reducing the need for energy-consuming sources while reaching good control performances and energy efficiency by making the best of the advantages of intelligence building management.

At the heart of any MPC lies a process model. In this case, following the standard industrial procedure, an open loop identification procedure has been adopted in order to acquire information on the system model.

A step test in a real system was performed, using sensor and actuator measurements in the H&BA laboratory realized in the LISA Lab in University Polytechnic of Marche. The test consists in forcing persistent excitation condition for the three main inputs of the system (Heat Pump, Shutter and Dimmer), in order to obtain a reliable model estimation.

To handle the non linearities a gain scheduling approach has been adopted in developing the model predictive controller (GSMPC), which is based on a bank of models dependent on thermal and light solar radiation. To obtain these models several step tests were made.

In figure 6 the linear function (blue line) relating thermal solar radiation and the gain of the room temperature and shutter transfer function is shown. In the same figure, the quantization performed on the gain values is depicted.



Figure 6: relationship between thermal solar radiation and gain on room temperature transfer function

Table 2 shows, the resulting gain-scheduled MPC controllers are implemented on-line where the computed tuning parameters are scheduled on the manipulated variable.

	MV/DV	Heat Pump [W]	Dimmer [%]	Shutter [%]	External Temperature [°C]
CV	Lim- its	-4000 ÷ 4000	$0 \div 1$	$0 \div 1$	/
Room Tem- perature [°C]	22÷24	T.F PDC	/	T.F. SAF _{RT}	T.F. T_{EXT}
Room Illu- minance [Lux]	280÷ 320	/	T.F. DIM	T.F. SAF _{re}	/

Table 2 - Control Matrix MV, CV and DV



The performance of the controller are greatly dependent on how well the dynamics of the system is captured by the input–output model that is used for the design of the controller. In the following of this section the specific features of the MPC controller design are described. Figure 7 shows the control scheme used for the GSMPC application. The architecture consists of two main modules: the MPC controller and the Gain/tuning Scheduler module. The first one realizes the controller specification and optimization, while the second one realizes the model and tuning parameters scheduling.



Figure 7: GSMPC control scheme architecture

The gain-schedule philosophy is implemented dividing the range of solar radiation (for light and thermal process) into five intervals. For each interval the Gain/Tuning Scheduler selects the appropriate models and tuning parameters (computed off line). This selection is handled using a dead band that allow to avoid excessive "chattering" between the model and tuning parameters selection.

In the present case study we have decided to select a controller sampling period equal to 5 seconds, in agreement with thermal and light control requirements. Consider that for the thermal system this sampling period could be considered too small, but for light system it's on the border line. To have good performance in light control we describe in the following how we have selected the controller tuning weight parameters.

Another main problem in the design of a GSMPC control system is the selection of the: controller sampling period, the control horizon and the prediction horizon.

Systematic guidelines to select these parameters P (prediction horizon) and M (control horizon) to obtain closed-loop stability are not available in the literature, but the following guidelines can help in finding first trial values:

- Choose the control interval such that the plant's open-loop settling time is approximately 20–30 sampling periods (i.e., the sampling period is approximately one fifth of the dominant time constant).
- Choosing a too large value for the control horizon M, may result in an excessive control action. Conversely, a smaller value of M reduces the "predective" performance of the controller but may lead to a controller relatively insensitive to model errors.
- Increasing P, the prediction horizon, it results in more conservative control action which has a stabilizing effect but also increases the computational effort.

In general, decreasing M relatively to P makes the control action less aggressive and tends to stabilize a system. The control horizon has been set equal to 7 minutes and the prediction horizon equal to 50 minutes.

The following rules have been conceived for the tuning of the GSMPC system:

• Assign high value to the output weights $(w_{i,j}^y)$ to ensure that the variable deviates as little as possible from the set point. A higher value has been assigned to the weight of the illumination environment to ensure faster response.



- The input weights $(w_{i,j}^u)$ relating to the dimmer and the heat pump should be different from zero, while the roller shutter weight must be set to zero (because it must be freely moved within its limits)
- The rate weights $(w_{i,j}^{\Delta u})$ relating to the dimmer should be set to zero while the heat pump weight must be small (thus allowing a fast move, if necessary); the shutter weight needs to be bigger than the other two actuations (we do not want to move it too quickly).
- When performing the gain schedule tuning parameters:
 - a) Live unchanged the weights $w_{i,j}^{y}$ of CVs,
 - b) MV weights $w_{i,j}^{u}$ on and $\Delta MV w_{i,j}^{\Delta u}$ on should adapt to the solar radiation: Weights $w_{i,j}^{u}$ of shutter grows slightly on solar radiation increases.
 - Weight $w_{i,i}^{\Delta u}$ of shutter variation increase with solar radiation.

Finally, following these rules tuning was carried out with te "tuning advisor" made available by Matlab which guarantees a robust tuning of the system control.

4 Results

In this section a discussion on the simulations results of the designed controllers detailed in the previous, are shown. First for the H&BA system, advanced PID control architecture was presented and successively a MPC controller was designed. To account for the operation range discretization a gain schedule approach has been adopted for the MPC design (GSMPC). The results show that the system performance for GSMPC depends on the number of discretization range and optimal tuning. Some a priori knowledge about the process nonlinearity may be helpful to guide this discretization step.

Most of the design results and all of the simulation results in this chapter show that the gain-scheduled MPC controllers provide a minor control effort, and soft variation on the manipulated variables (figure 10).

In figure 8 and 9 the optimal gain-scheduled MPC controller and the PID controller are compared. The results show that the PID controller gives a more reactive behavior than the optimal GSMPC controller, at the expense of a more aggressive control action.



Figure 8: GSMPC room temperature (blue) vs. advanced PID control room temperature (green), summer sea-





Figure 9: GSMPC room illuminance (blue) vs. advanced PID control room illuminance (green), summer season

The motivation of this behavior is due to the fact that it has been chosen to design GSMPC so to avoid the undesired behaviors about an excessive illumination inside the environment due to saving mode selection. This is obtained suitably designing the MPC object function and the tuning weights In order to perceive a control behavior that takes into accounts both user comfort and saving energy features.

On the other hand the optimal GSMPC allow having more robust performance, and other features are its ability to handle constraints. With this control solution is the controller itself that guarantee the maximum energy saving and user comfort, satisfying the requirement inserted in terms of actuation limit, output setpoint and limits and actuation rate of change. Nevertheless, thanks to flexibility on MPC tuning and parameters selection, it would be possible to define a saving and/or comfort scenarios acting on controlled variables limits and weight parameters.



Figure 10: GSMPC control effort (blue) vs. advanced PID control effort (green), summer season

5 Conclusion

A supervision and control system based on a thermal and lighting interconnected model for an intelligent management of a heat pump, artificial lights, rolling shutters actuators (RS) and glass windows opening and /or regulation of the IAQ is proposed.

Advanced industrial control system has been developed and regards applications in the oil refinery field. In particular, the problems of minimization of the head pressure of a visbreaking column and of a furnace combustion optimization are studied.



Petrochemical process, thermal and light systems in a building environment are highly nonlinear, especially when operated over a wide range of operating conditions. It is of a great significance to design high performance controllers for efficient control of these processes to achieve closed-loop system's stability and good performance.

Firstly, the control problem of the H&BA system has been approached adopting advanced PID control architecture was presented and then GSMPC controllers was designed using different number of operation range discretization. The results show that the system performance for GSMPC depends on the number of discretization range and optimal tuning. Some a priori knowledge about the process nonlinearity may be helpful to guide this discretization step, i.e., more sub-ranges are needed if the system in a particular operation range is highly nonlinear.

On the other hand the optimal GSMPC having features like the ability to handle constraints, non-minimum phase processes and its straightforward applicability to large, multivariable processes, allow the achievement of more robust performances.

The control solution presented on this Ph.D thesis were designed and developed during the three years of research in the laboratory LISA in University Polytechnic of Marche, where the supervision and control system SIRENIA was installed.

The last aspect remarks the economic recovery introduced by the proposed control solutions. For the H&BA system energy saving is estimated to be about 23 % of economic cost reduction.

The main contributions of research work are:

• A new approach in the field of home and building automation control: in the present thesis a coupled control system that ties the thermal, lighting control and IAQ control has been developed. While, at the current state of the art, the temperature and lighting control of the environment are managed separately, the proposed control system provides a solution that considers the coupling of the various subsystems. Thinking of a possible implementation in office buildings or hotels the proposed control system would allow enormous benefits.

• The cross-fertilization concept was applied to transfer control architecture normally used in industrial automation control: advanced PID structure and MPC control, on home and building automation control system. Using this philosophy it is possible to design control system described in the previous point.

In particular, a GSMPC approach to control H&BA system is proposed to ensure better control performances. This approach in the presence of constraints on input and output variables allows a simplified design of the controller

• a "heuristic control program" used to handle tuning of PID regulator in real plant/process environment has been designed and developed in Matlab. The program is made available to system engineers for the daily maintenance and sustenance of control PID systems tuning.

• Finally, to fulfill a specific requirement on the PID transient behavior, i.e. suppression/limitation of the overshoot in the output response, an application of fuzzy logic techniques is presented. The adopted control scheme is based on a discrete fuzzy smoother that, working on-line, is able to adapt its actions to the system behavior by suitably smoothing of the controller set point. This structure was used mainly in PID control structure on petrochemical plant were the overshoot are the main problem in transient response, and can generate control oscillation.



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