

The Hierarchical Control Structure of the Catalytic Cracking Unit

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Abstract: The catalytic cracking unit is an important plant in benzene processes, and is characterized by a high degree of complexity. The catalytic cracking operation imposes a hierarchical onset of the automatic control systems. In the first part of this paper is presented a critical analysis of the hierarchical control concepts for complex technical systems. In the second part there are presented the author's researches regarding the hierarchical control of the catalytic cracking.

Keywords: hierarchical control structure, hierarchical concepts, catalytic cracking process.

1. Introduction

At present, the elaboration of modern hierarchical control systems for complex technical systems is a challenge in the field of automatics. The creation of modern hierarchical control systems is one of the most important solutions for improving the economic performances of this plant.

Complex system characteristics, such as: dimension, geographical location, the variety of objectives creates problems concerning their control. These difficulties can be diminished if the global approach is replaced with a hierarchical one. This implies dividing a complex problem into more simple sub-problems that can be organised in a hierarchical structure (i.e. a structure containing several levels) [1].

The fluid catalytic cracking unit (FCCU) represents a practical example, relevant for the development and checking of the hierarchical concepts for complex technical systems, because it has multiple hierarchical control levels (some by automatic means, others by manual manipulation) and also for its dynamics corresponding to these hierarchical levels having an order of magnitude from tens of seconds to tens of hours. The objective of this work is to elaborate a hierarchical control structure of the catalytic cracking.

2. Hierarchical control concepts

In the field of advanced automatic control of complex industrial processes, the research in the last fifteen years has been oriented towards two directions: hierarchical control concept and Plantwide concept.

The basic notion of the hierarchical control is to decompose a given large scale system into a number of small scale subsystems, and coordinate these subsystems solutions until feasibility and optimization of the overall system is achieved through a multilevel iterative algorithm.

There are three basic structures in hierarchical (multilevel) systems depending on the model parameters, decision variables, behavioural and environmental aspects,

uncertainties and the existence of any conflicting goals or objectives.

1. Multistrata Hierarchical structures. In this multilevel system in which levels are called strata, lower-level subsystems are assigned more specialized descriptions and details of the large scale complex system than the higher levels [2].

2. Multilayer Hierarchical Structure. This structure is a direct outcome of the complexities involved in a decision-making process. These concepts imply that the solution of the complex problems are substituted by solution of the sequentially arranged in family. The solution of the original problem is achieved when all sub-problems are solved [3].

3. Multiechelon Hierarchical Structure. This is the most general structure of the three and consists a number of subsystems situated in levels such that each one, as discussed earlier, can coordinate lower-level and be coordinated by a higher-level one. The distribution of the control task in contrast to the multilayer structure is horizontal.

The field of plantwide control is divided into two different approaches:

1. A mathematically oriented approach. Within this approach there are some methods that use structural information about the plant as a basis for control structure design [4, 5, 6].

2. A process oriented approach. In this approach there are presented methods that try to decompose the problem into manageable parts that are based on using process insight. The process oriented approach has proposed heuristics for plantwide design based upon case studies and their experience. This approach has two main drawbacks. The first is: the insight gained from a specific case study may be too narrow to make the conclusions general. Secondly, since the control objectives are often unclear the rules that are proposed have a weak basis [2].

3. Hierarchical control of the craking catalytic unit

Cracking catalytic plant is a system with a high complexity. Process structure of the catalytic cracking includes the next subsystems: reactor, regenerator and main fractionator, see figure 1 [7].

From a certain point of view, the process equipments can be decomposed in to three subsystems: reactor subsystem, regenerator subsystem and the subsystem associated main fractionator. This decomposed of the subsystems appear in natural way.

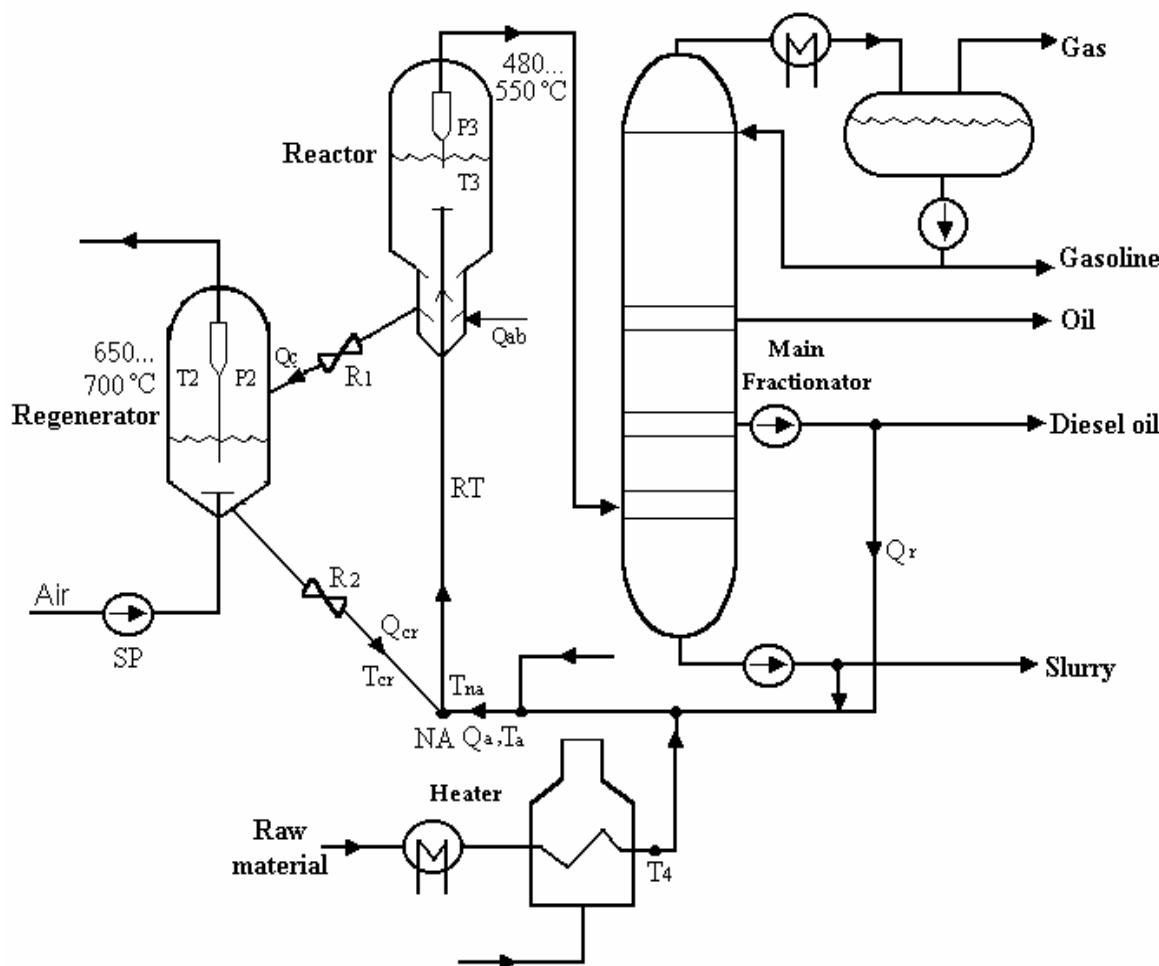


Fig. 1. The scheme of the catalytic cracking process.

The regenerator is decomposed into subsystems:

- The subsystem associated to the dense bed is located at the bottom of the regenerator, and realizes the combustion of coocks;

- The freedboard subsystem, this takes place after the burning reaction that oxidize carbon monoxide to carbon dioxide;

- The regenerator cyclones subsystem, this realized separation of catalyst by gases.

The reactor made base on the decomposed into three subsystems. This decomposition is made based on the physical-chemical phenomena associated with the reactor.

These subsystems are:

- The interfusion node subsystem; it is located at the bottom of the riser, and realizes the evaporation of the raw material;

- The riser subsystem; this materializes the evolution of the cracking reaction and has as results the products of reaction;

- The reactor-striper subsystem; it is located in the bottom of the reactor, and realizes dissociated product from catalyst [8].

Based on the critical analys's of the hierarchical control concepts associated to the complex systems, the authors chose the multiechelon structure for the elaboration of the hierarchical control structure for the catalytic cracking process, figure 2.

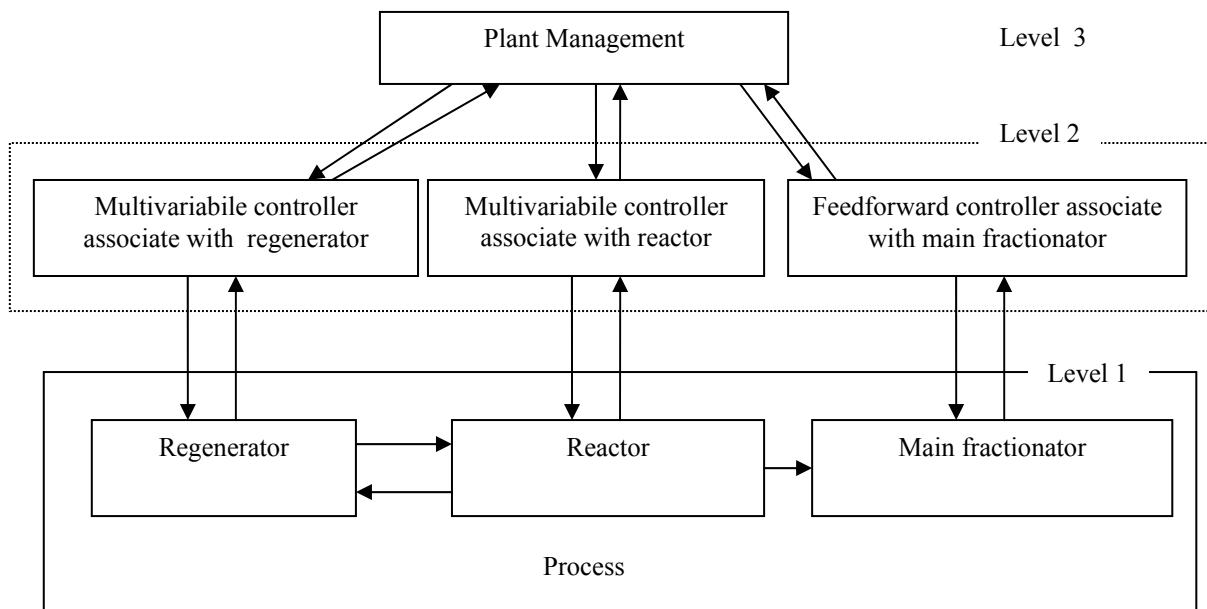


Fig. 2. The hierarchical control structure of the catalytic cracking unit.

The hierarchical control structure of the cracking catalytic unit is structured on three levels. The first level is associated to the base control automation for each unit in the process. Second level is build of multivariable controller subsystem, one multivariable controller subsystem and feed-forward controller fractionator. The three levels are associated to the plant management and the objectives of this level are to the maximize working capacity of plant in order to obtain maximum benefit taking in a count operating technology constraints.

Hierarchical control structure associated to the regenerator is presented in figure 3. This structure contains two subsystems: the multivariable controller and the regenerator subsystem. The set points of multivariable controller on second level associated to the regenerator are:

- differential pressure reactor –regenerator, ΔP ;
- differential temperature by regenerator, ΔT .

The controls used by multivariable controller are:

- air flow regenerator, Q_{ga} ;
- stack gases flow, Q_{aer} ;

Hierarchical control structure associated to the reactor is presented in figure 4. This structure contains two subsystems: multivariable control and regenerator subsystems. The set points of multivariable control on second level associated to the regenerator are reactor temperature, T_r , and catalyst level in reactor, N_r .

The goal of level three is the global optimization of all the units. Increased performance of the control structure is assured by optimizing the function of the plant. The third level is used for energy optimization control for regenerator subsystem, maximization of conversion process into reactor subsystem and optimization of the production for the main fractionator.

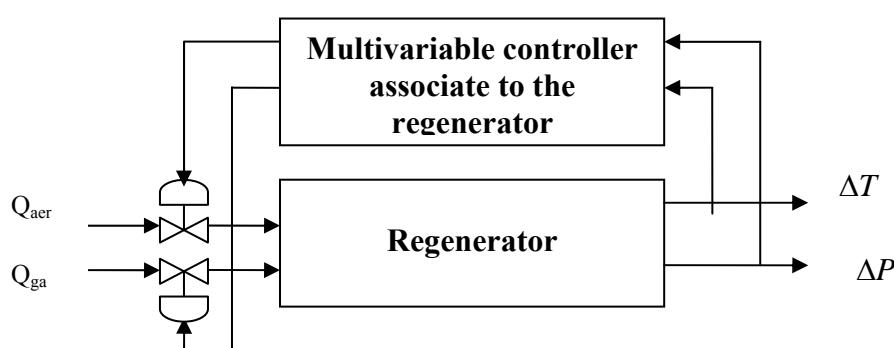


Figure 3. Hierarchical structure from regenerator.

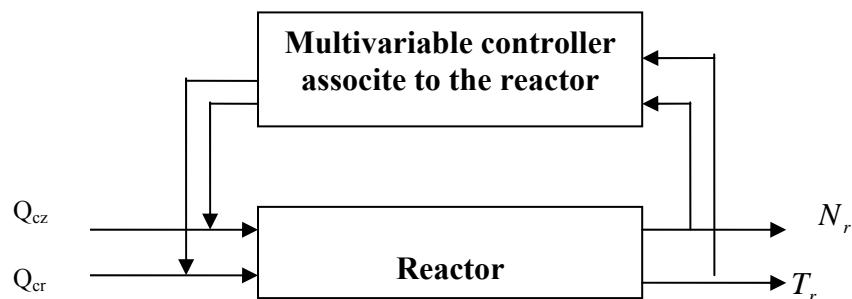


Figure 4. Hierarchical structure from reactor.

4. Conclusion

The purpose of this study is to develop the hierarchical control structures of the catalytic cracking plant, a complex plant that is decisive for a modern fuels refinery. The first part of the paper deals with the main hierarchical concepts for complex technical systems. In the last part of the paper, based on the hierarchical concepts presented in the first part, the authors of this paper to the elaborated hierarchical control structures associate to subsystems regenerator and subsystems reactor.

The main contribution brought by the authors are:

- elaborating structures of the entire catalytic cracking unit;
- development of hierarchical structures of the regenerator subsystem;
- development of hierarchical structures of the regenerator subsystem.

5. References

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