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# Modeling and Simulation of the Optimal Control System for the Jibissa Natural Gas Treating Plant

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## Abstract

*The paper represents a contribution to the development of an optimal control system for the Jibissa natural gas treating plant. The paper has 2 parts. The first part is dedicated to the modeling of the absorption – desorption process. The second part is dedicated to the development of the optimal control system.*

**Key words:** *gas treating, hydrogen sulfide, absorption modeling, dynamic simulation, optimal controller, control system*

## Introduction

The production and the delivery of natural gases represent an important energetic problem for each country. The most important source of natural gases of Middle Orient is the gases field Jibissa of Syria. The treating natural gases plant decreases the carbon dioxide, hydrogen sulfide and water from the natural gases. The Jibissa plan developed in the year 1985 and the technology was made at the same time. The absorbant solution of the treating Jibissa plant is the diethanol - amine (DEA).

One of the actual problems of the Jibissa plant is represented by the control systems design for the reduction of the energetic consumption [1, 2]. The authors have studied the opportunity for the development of a control system especially for the Jibissa plant [4]. The study has four components:

1. The study of Jibissa treating natural gas plant structure;
2. The modeling of the absorption subsystem;
3. The design of the optimal control system;
4. The validation and the advantage of the optimal control system by using the dynamic simulation.

The study of the structure of the treating natural gas Jibissa and the modeling of the absorption-desorption process are presented in reference [4]. The focus of this paper is on the design and the simulation of the optimal control system.

# The Modeling of the Absorption – Desorption Process

## The steady – state simplified model

The authors have developed a simplified model based on the results obtained by using the rigorous model [4]. Using the feed composition and the rigorous model of the process, they have calculated the output variables (the sweet gas composition $y_{H2S}$ and the duty re - boiler of the desorption column $Q_{steam}$) for the many values of the DEA flow rate $Q_{DEA}$. The domain of the variation of the DEA flow rate is $[13000 \ldots 17900]$ kmol/h. The results represent a discrete function of the steady-state simplified model of the absorption-desorption process.

## The dynamic model

The dynamic model is based on differential equations for each channel between the manipulated variable and the output variable:

$$a_{H2S} \frac{dy_{H2S}}{dt} + y_{H2S} = y_{H2S}^{st}\left(Q_{DEA}\right); \tag{1}$$

$$a_{steam} \frac{dQ_{abur}}{dt} + Q_{steam} = Q_{steam}^{st}\left(Q_{DEA}\right). \tag{2}$$

The constants associated to differential equations (1) and (2) are: $a_{H2S} = 5$ [min], $a_{steam} = 15$ [min]. The values associated to steady – state regime, $y_{H2S}^{st}$ and $Q_{steam}^{st}$, are calculated using the quadratic interpolation into discreet function obtained with the steady-state simplified model.

# Optimal Control System for the Absorption – Desorption Process

## The optimal controller

The authors have elaborated a special structure of the optimal controller. The origin of this structure has been the step- by- step optimal controller [3]. The new structure is characterized by the following input variables: the steam flow rate of the re-boiler of the desorption column and the hydrogen sulfide concentration of the sweet gas. The manipulated variable of the optimal controller is the DEA flow rate, figure 1.

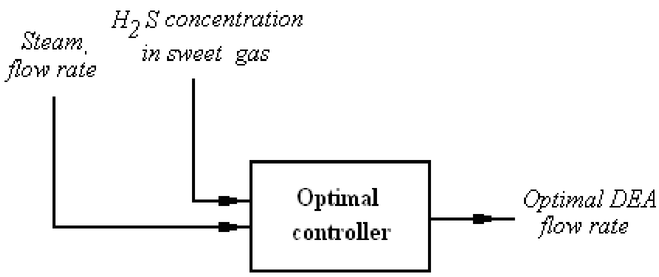


**Fig. 1**. The structure of the optimal controller.

The optimal controller implements the objective function

$$F_{ob}\left(Q_{DEA}\right) = Q_{steam}. \tag{3}$$

The mathematical operation used in the optimal controller is the minimization [5].

The objective function is accompanied with the restriction system associated to the quality specifications of the sweet gas

$$\begin{cases} y_{H2S} \le 4, & [\text{ppm}] \\ y_{CO2} \le 5000, & [\text{ppm}] \end{cases}. \tag{4}$$

The optimal controller is based on the following relations:

$$Q_{DEA}(k) = Q_{DEA}(k-1) + r(k)\,\Delta Q_{DEA}; \tag{5}$$

$$r(k) = \begin{cases} r(k-1); & Q_{steam}(k) \le Q_{steam}(k-1) \\ -r(k-1); & Q_{steam}(k) > Q_{steam}(k-1) \end{cases}, \tag{6}$$

with the initial conditions

$$\begin{cases} r(1) = -1 \\ Q_{DEA}(1) = 17000. \\ \Delta Q_{DEA} = 500 \end{cases} \tag{7}$$

The significance of the previous relations are: $k$ - the current iteration of the exploration algorithm; $Q_{DEA}$ - the variable of the objective function (3) and the manipulated variable of the optimal controller; $\Delta Q_{DEA}$ - the incremental value of the exploration algorithm; $Q_{steam}$ - the value of the objective function; $r$ – variable that defines the exploration sense

$$r = \begin{cases} 1, & \text{incr} \\ -1, & \text{decr} \end{cases}. \tag{8}$$

Supplementary, the algorithm of the optimal controller verifies the hydrogen sulfide concentration of the sweet gas, at each step time. If this concentration is less than the specified limit, then the output controller is calculated by using the (5) – (6) relations. If the hydrogen sulfide concentration is greater than or equal to limit (4), then the optimal control algorithm will calculate the output of the optimal controller by using the following equation

$$r(k) = \begin{cases} r(k-1); & y_{H2S}(k) \le y_{H2S}^{lim} \\ -r(k-1); & y_{H2S}(k) > y_{H2S}^{lim} \end{cases}. \tag{9}$$

## The simulation of the optimal control system

The authors have elaborated a special program destined to dynamic simulation of optimal control system. The structure of the optimal control system is presented in figure 2. This program resolves the differential equations system of the process model and algebraic equations associated to the optimal controller algorithm.

The results of the dynamic simulation program are transposed into the following pictures: the dynamics of the output of the optimal controller, the dynamics of the objective function value and the dynamics of the hydrogen sulfide concentration into sweet gas.

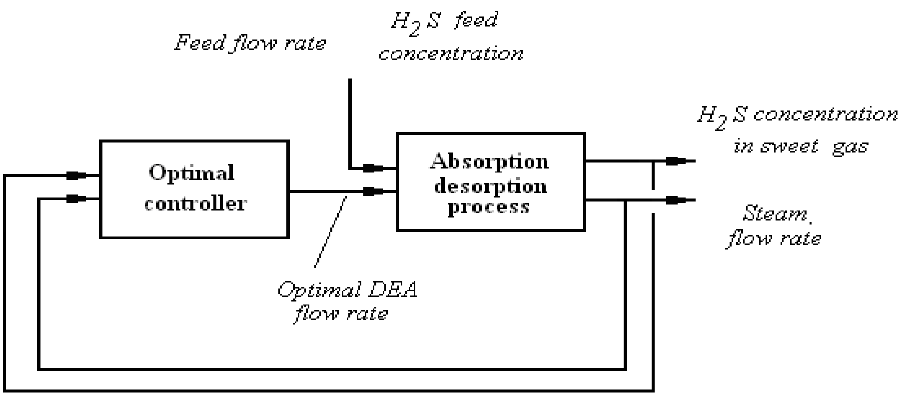


**Fig. 2**. The structure of the optimal control system.

The dynamic of the output of the optimal controller has a multi – step variation type, figure 3. Because the initial DEA flow rate is bigger, the way of decreasing the objective function is that to decreasing the DEA flow rate. After each 80 min, the optimal controller will decrease the DEA flow rate with $\Delta Q_{DEA} = 500$ kmol/h.

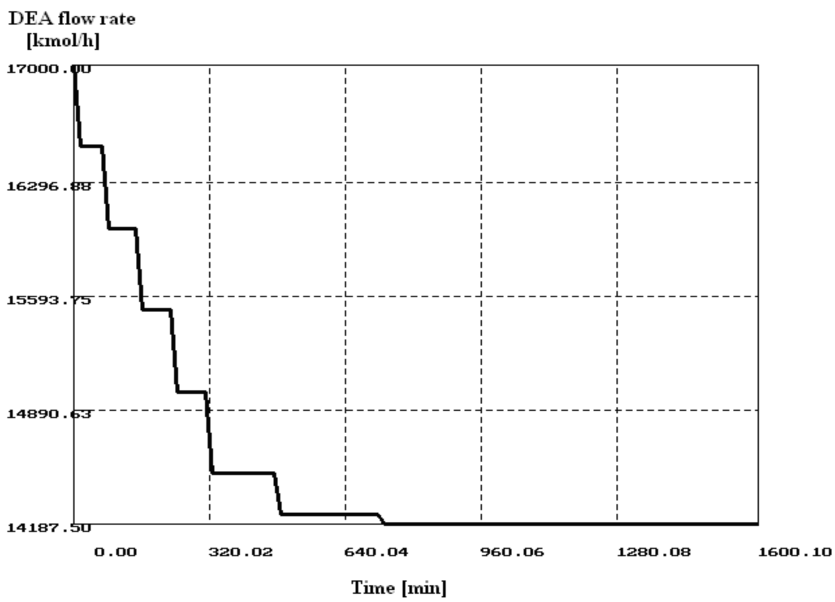


**Fig. 3**. The dynamic of the DEA flow rate

The decreasing of the output optimal controller continues up to time $t = 400$ min with $\Delta Q_{DEA} = 500$ kmol/h. The effect of this operation is measured after each 80 min and the new value of the objective function decreases, figure 4. At the time $t = 400.1$ min, the output value of the optimal controller does not assure the separation of the hydrogen sulfide. For this time and for this operation point, the hydrogen sulfide concentration increases up to 5.34 ppm, the value that is greater than the admissible limit, 4 ppm, figure 5. After this moment, the optimal controller will action to satisfy the restriction equation system and will ignore the minimization of the objective function.

The new output value of the optimal controller, for the time between 400.1 and 480 min, will be $Q_{DEA} = 14500$ kmol/h. With this DEA flow rate, the hydrogen sulfide concentration decreases up to 0.4 ppm. The optimal algorithm will continue with the decrease exploration step, $\Delta Q_{DEA} = 250$ kmol/h, and the relations (5) – (6).

The way of the modifier of the optimal controller output will continue by using the minimization of the objective function. At the moment of $t = 560.1$ min, the hydrogen sulfide concentration is 5.34 ppm, corresponding to $Q_{DEA} = 14250$ kmol/h. The subsection based on the relation (9) will be active and the output of the optimal controller will decrease up to $Q_{DEA} = 14187$ kmol/h. After the moment $t = 880$ min, the optimal control system will operate with this value that will be considered the optimal operating point.

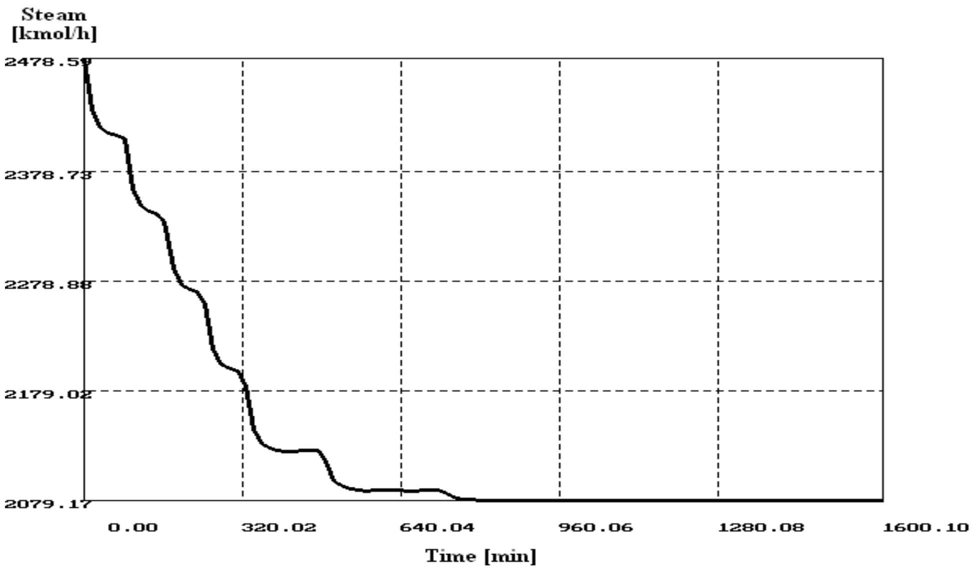


**Fig. 4**. The dynamics of the objective function.

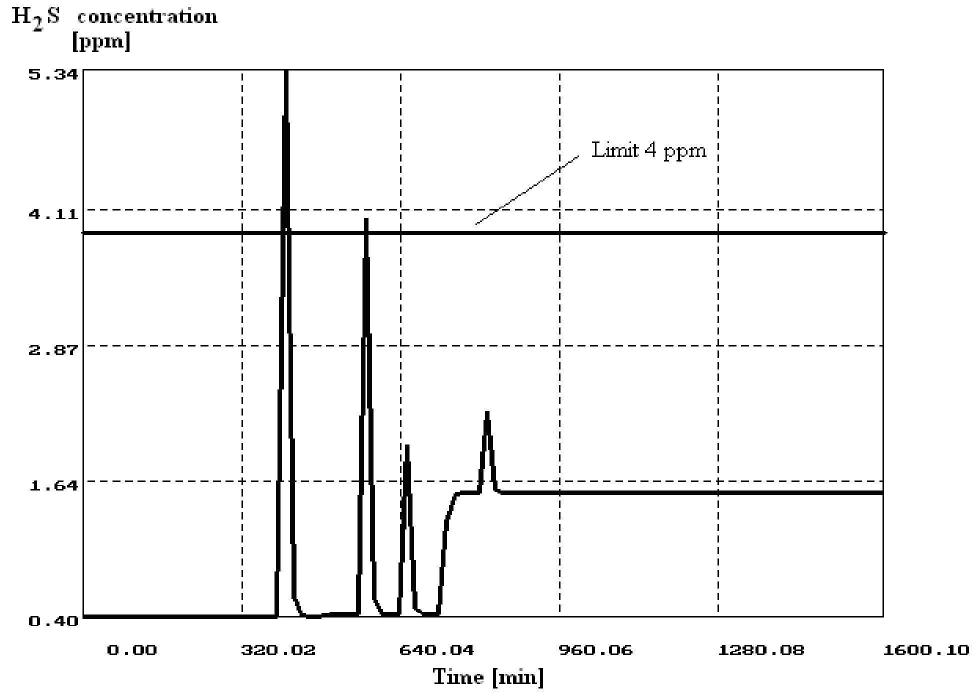


**Fig. 5**. The dynamics of the $H_2S$ concentration.

## Conclusions

The paper represents a contribution to the development of an optimal control system for the Jibissa natural gas treating plant. The paper has 2 parts. The first part is dedicated to modeling of the absorption – desorption process. The second part contains the development of the optimal control system.

## References

1. Kohl, A., Nielsen R. – *Gas Purification*. Gulf Publishing, 1997.
2. Tofik, K. – *Superior Gas Sweetening*. Hydrocarbon Engineering, Dec. 2003.
3. Patrăşcioiu, C., Marinoiu, V. – *Modeling and Optimal Control of an Industrial Furnace*. 5th IFAC Symposium on Dynamics and Control of Process Systems, 1998.
4. Patrăşcioiu, C., Petre, M., Rabahi, I. – *Modeling, Simulation and Optimal Control of Jibissa Natural Gas Plant*. Proceedings of the 8th WSEAS International Conference on Simulation, Modelling and Optimization, ISBN 978-960-474-007-9, ISSN 1790-2769, 2008.
5. Rabahi, I., Patrăşcioiu, C., Dumitrescu, S., Petre, M. – *The Optimal Control System for Jibissa Natural Treating Plant*, Petroleum Gas University of Ploiesti Bulletin, Technical Series, Vol XL, No. 3B/2008.

# Modelarea şi simularea sistemului de reglare optimală a instalaţiei de tratare a gazelor naturale Jibissa

## Rezumat

*Lucrarea reprezintă o contribuţie la dezvoltarea unui sistem de reglare optimală a instalaţiei de absorbţie-desorbţie de pe platforma de tratare a gazelor naturale Jibissa. Cercetările autorilor au fost reflectate în lucrare în cadrul a două părţi. Prima parte este dedicată modelării în regim staţionar şi dinamic a procesului de absorbţie-desorbţie. Partea a doua prezintă cercetările autorilor privind modelarea şi simularea unui sistem de reglare optimală a procesului de absorbţie-desorbţie.*