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The Optimal Control System for the Natural Treating Plant Jibissa

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Abstract

The paper presents an optimal control system for the natural gas treating plant Jibissa. The paper has three parts. The first part contains the mathematical model of the absorption – desorption process, developed by using the PRO II software program. Based on this model, the authors have generated the characteristics of the chemical process. The second part is dedicated to absorption control structure analysis. The authors have identified four basic control structure of the absorption process. The third part contains the contribution of the authors to developing an optimal control structure for absorption process Jibissa.

Key words: *natural gas, hydrogen sulfide, modeling, simulation, optimization, control*

Introduction

The natural gases represent an important energetic problem in Europe and Middle Orient. The quantity and quality specified by customer are problems of the control systems. The most important source of natural gases of Syria is the gases field Jibissa. The treating natural gases into Jibissa plant makes the decreasing the carbon dioxide, hydrogen sulfide and water from the natural gases. Theses proceeds are presented in literature [1, 2] and industrial applications too [3, 4].

The actual problem of the chemical plants is represented by the elaboration of the control systems for the reduction of the energetic consumption [5]. The authors have studying the statically characteristics of the absorption process, they have analyzing the control structures presented in literature and they have developed an optimal control system especially for the absorption – desorption plant.

The Statical Characteristics of the Absorption Process

The mathematical model

The authors have developed a mathematically model of the absorption – desorption process. The input-output structure of the proposed model of the absorption subsystem is presented in figure 1. The input variables are the rate flow feed, the feed composition, the DEA rate flow, the specifications of the sweet gas and the specifications of the striping column. The output variables of the model are sweet gas composition and the duty of striping column re-boiler.

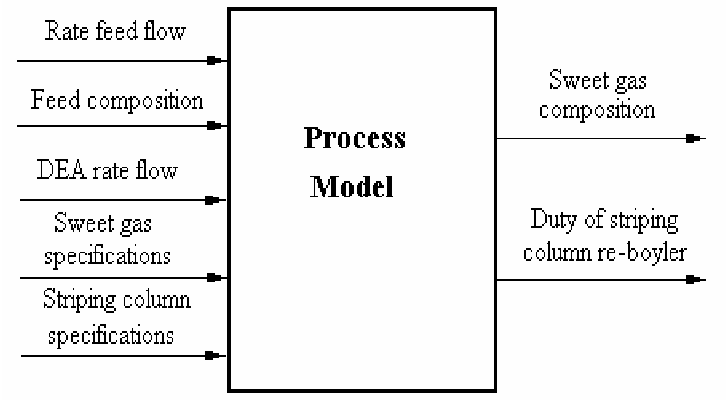

Fig. 1. The absorption – desorption process model structure

The authors have utilized the PRO II simulation program, figure 2. The process model consists in two columns model, an expander vessel model and two exchanger models. For the absorption column model, the authors have utilized the Inside-Out algorithm because the water component of the DEA solution is not vaporized at pressure and temperature column. The operating pressure and operating temperature of the striping column have become established usage of the CHEMDIST algorithm [8].

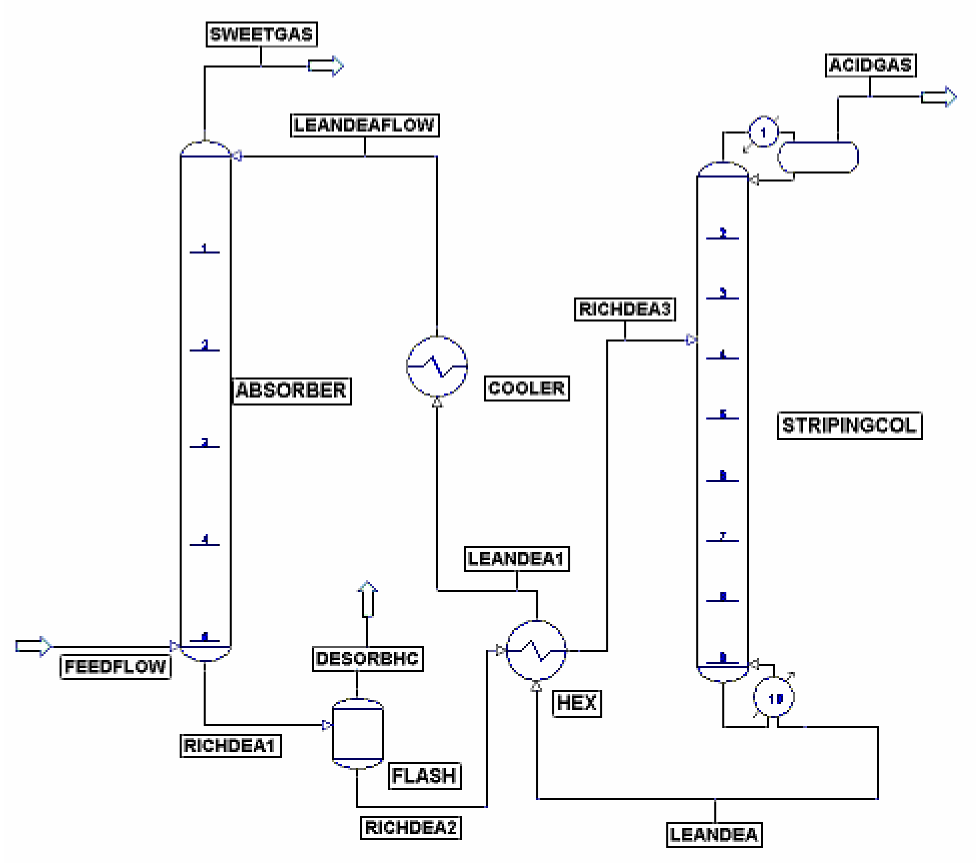

Fig. 2. The PRO II simulating model of absorption – desorption process

The simulation of the process

The simulating of the natural gas treating is necessary to determine the sensibility of process, to calculate the gains of the input-output chains and to make the process control algorithm. The reference operating point is presented in table 1.

Table 1. Reference operating point

Parameter	Unit	Value
Natural gas rate flow	kmol/h	2542
CO_2 in natural gas	% mol	14.56
H_2S in natural gas	% mol	1.82
DEA rate flow	kmol/h	12133
CO_2 in sweet gas	ppm	0.2
H_2S in sweet gas	ppm	0.4
Steam of striping re-boiler	kmol/h	1705

The authors have simulated 40 various operating cases of the absorption subsystem. The statically characteristics of the absorption – desorption process are presented in the figures 3, 4 and 5. The influence of the input variables to the outputs variables are:

- The quality of the sweet gas (CO_2 and H_2S concentration) has a nonlinear variation in rapport to rate flow feed, figure 3. The aspect of this variation of the CO_2 composition is generated by the high DEA rate flow. The absorption subsystem may be operated for a large domain of the rate flow feed with the constant reference DEA flow rate. This situation is possible because the reference DEA rate flow is very high. The consequence of this situation is that the real operating cost is greater than the necessary operating cost.
- The steam flow rate variants versus the feed flow rate because the quantity of CO_2 and H_2S within the feed increases, figure 4. The total increased of steam flow rate is very small (5%) in rapport to variation of the feed flow rate. The conclusion of this dependence is that the operating cost is dependent only in rapport versus DEA flow rate.
- The H_2S concentration of the treated natural gas versus the feed flow rate is a nonlinear function, figure 5. The DEA flow rate, associated the reference operating point, assures the elimination of the hydrogen sulfide correspondent to the feed flow rate increased with 30% in rapport to reference operating point. This operation modality increasing energy lost into striping column up to 30%.

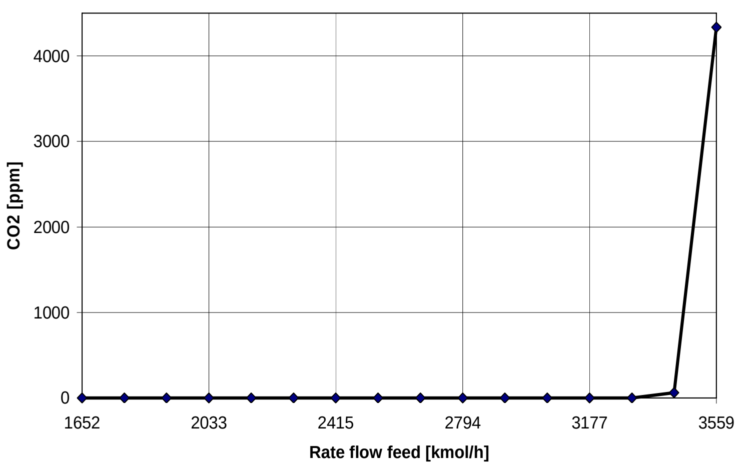

Fig. 3. The dependence of the CO_2 concentration versus the feed flow rate

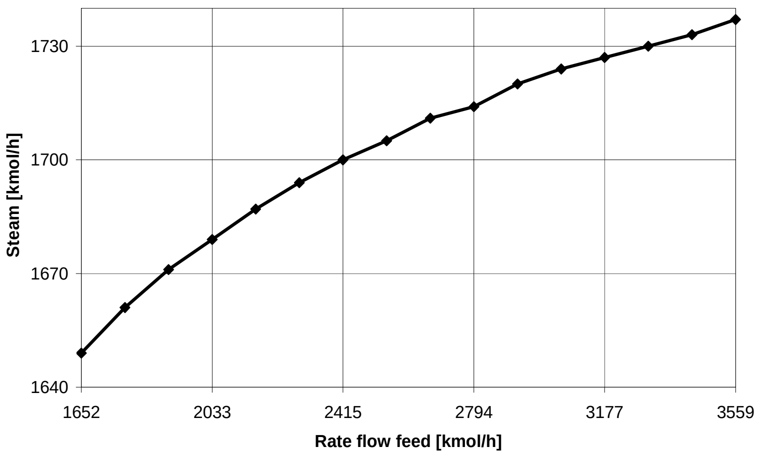

Fig. 4. The dependence of the steam flow rate versus the flow feed rate

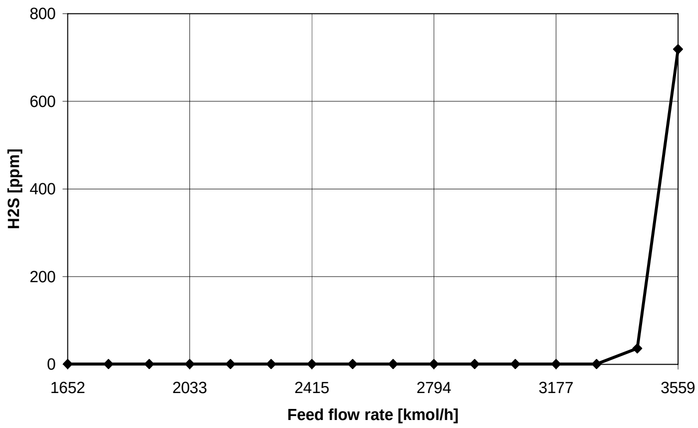

Fig. 5. The dependence of the H_2S concentration versus the feed flow rate

The Analysis of the Absorption Process Control Structures

The classical control structure

The classical control structure is characterized by the following control systems, figure 6 [10]:

a) The flow control system associated to the absorbent flow.
b) The pressure control system.
c) The level control system.

This control structure have an small efficiency because that the gases flow rate is variable and the consequence is that the concentration of the hydrogen sulfide is variable too.

The structure based on the rapport control

The rapport control structure represents a better structure opposite to classically structure. The new structure is characterized by the rapport control system between the feed gases and the absorbent flow, figure 7, [9, 10].

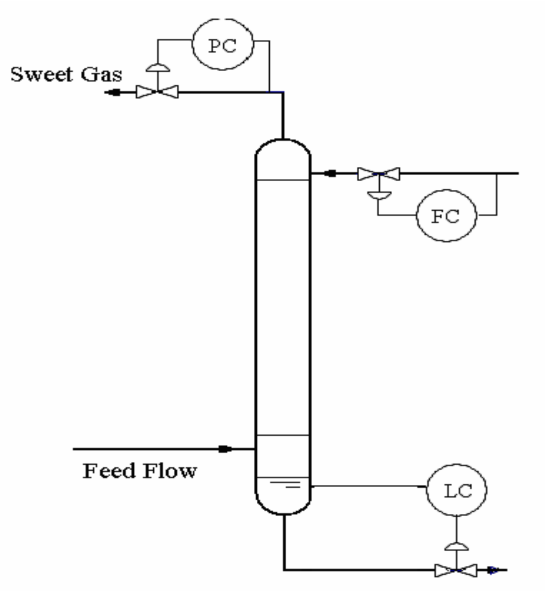

Fig. 6. Classically absorption control system

The advantage of this structure is the maintained the constant concentration of the hydrogen sulfide into treating gas, for various feed flow rate but for invariable feed concentration. The determination of the numerical value of rapport is difficult.

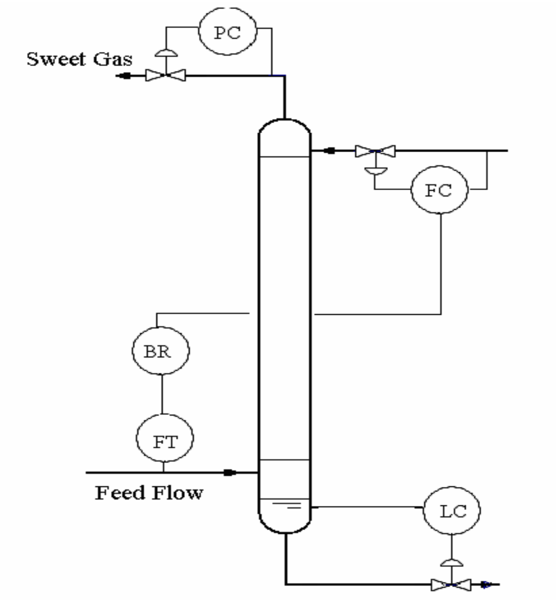

Fig. 7. The structure based on the rapport control

The structure for the column with the external cooling reflux

The absorption process is an exothermic process, but in same time the efficiency of the absorption process is greater at small temperature. For this causal, the absorption column has a thermal exchange for cooling the internal reflux. The control structure for this especially absorption column is presented in figure 8, [12]. This control structure is recommended only for small variations of the feed flow rate and feed composition.

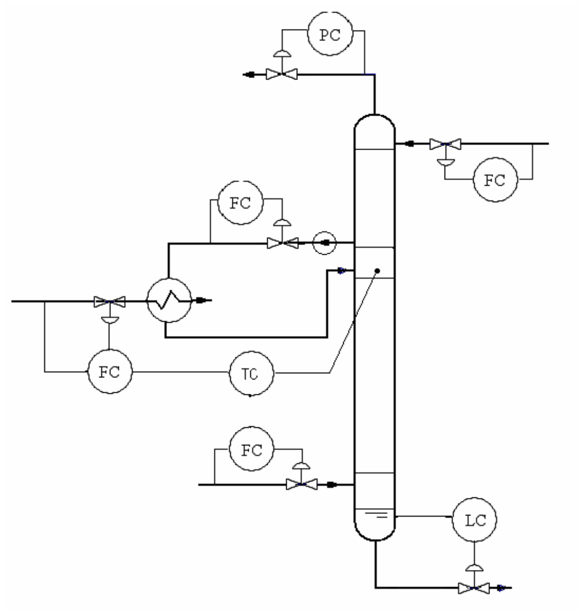

Fig. 8. The control structure for the column with the cooling internal reflux

The acid gas concentration control structure

A modern structure is represented by the hydrogen sulfide concentration control structure. This structure is characterized by the composition transducer, especially hydrogen sulfide transducer, figure 9.

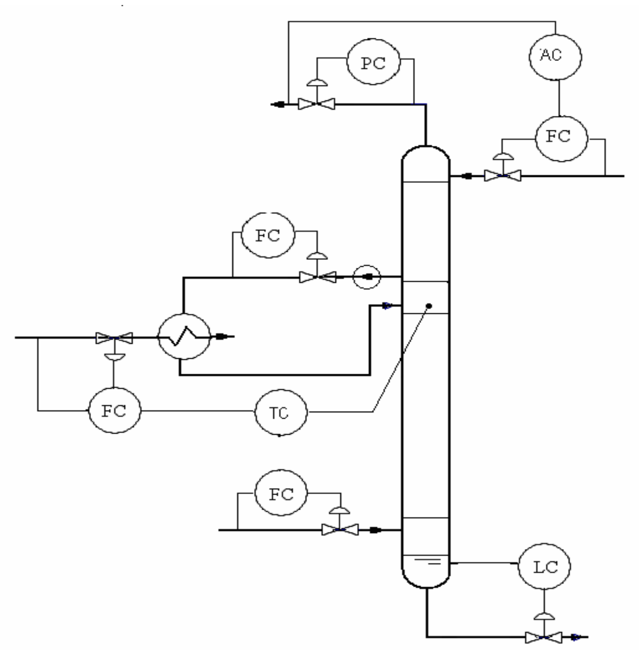

Fig. 9. The acid gas control structure.

For the any variation of the feed composition, the control structure maintains the hydrogen sulfide specified composition on top of the column. The specifically inertial of the transport and mass transfer phenomena causes the errors into hydrogen sulfide composition on top of the column. If the absorption column is equipped with the exchange for cooling the internal reflux, then the control structure will get the specifically elements of the control structure with the cooling internal reflux.

The Optimal Control Structure

The natural gas treating is a controllable process. In this case, the inputs of the process model may be divided into manipulated variables and disturbances. For this reason, the process model structure will have the form presented in figure 10.The specifications of the treated natural gas are presented in table 2.

Table 2. The specifications of the treated natural gas

Description	Unit	Limit
Hydrogen sulfide	ppm	4
Carbon dioxide	%	0.5

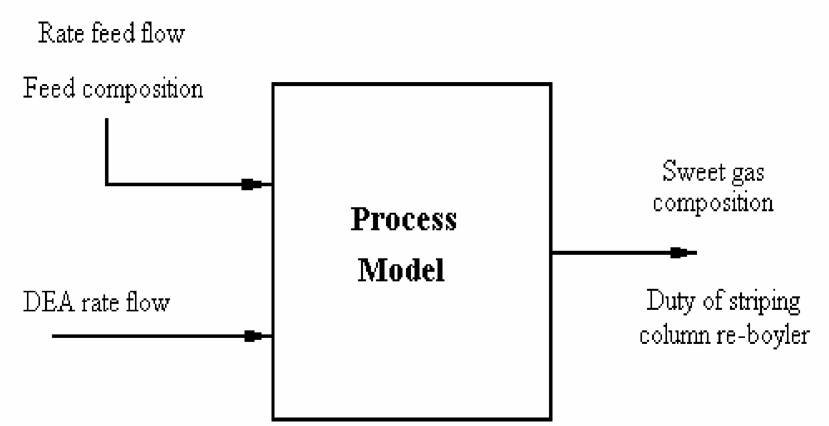

Fig. 10. The model structure of the controllable process

The extremely characteristic of the controllable process

The most important manipulated variable of the process is the DEA flow rate. The authors have studying the controllable process sensibility by simulated the absorption-stripping process for the various DEA flow rate. The conclusions of the study of the controllable process are:

- For the feed flow rate correspondent to the reference operating point, the concentration of the carbon dioxide and hydrogen sulfide into treating gas is not influenced by the DEA flow rate greater than 9100 kmol/h, figure 11 and figure 12. In rapport to reference operating point, characterized by 12133 kmol/h DEA flow rate, the process is operated by 25% excess DEA flow rate, respectively 3033 kmol/h excess.
- The steam flow rate have a linear variation in rapport with DEA flow rate, figure 13. This characteristic indicates that the DEA flow rate is the most important factor of the operating cost.

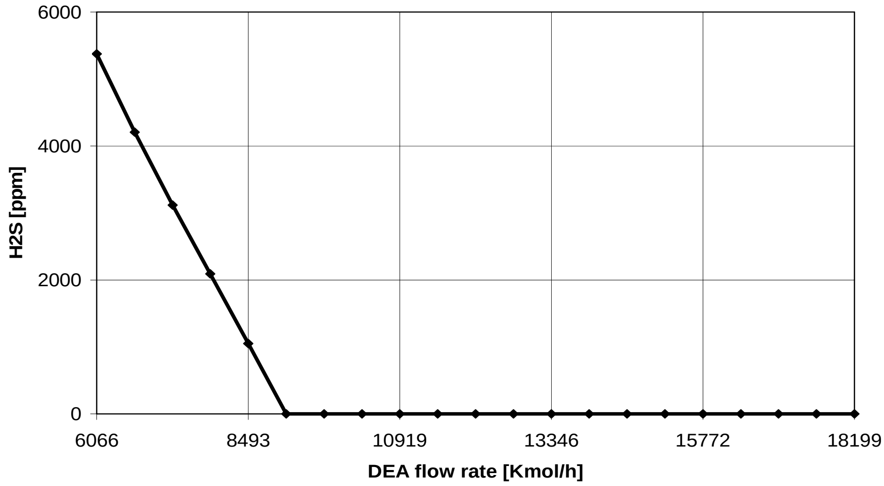

Fig. 11. The dependence of the H_2S concentration versus the DEA flow rate

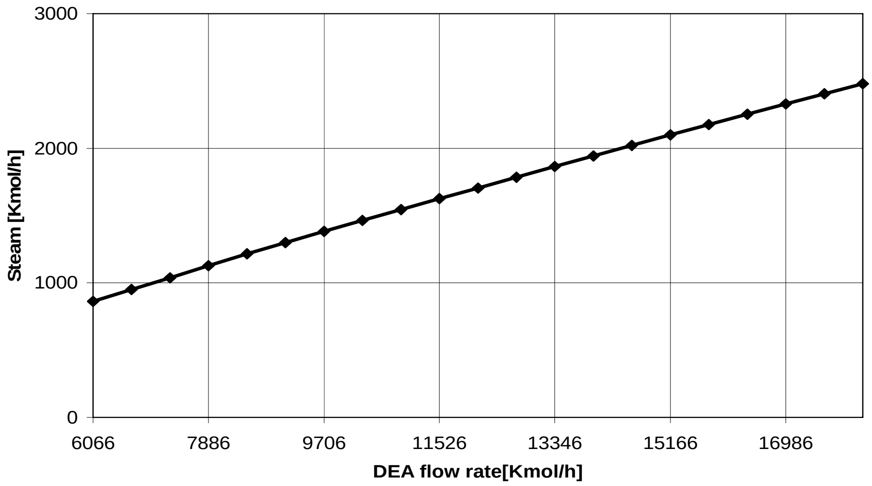

Fig. 12. The dependence of the H_2S concentration versus the DEA flow rate

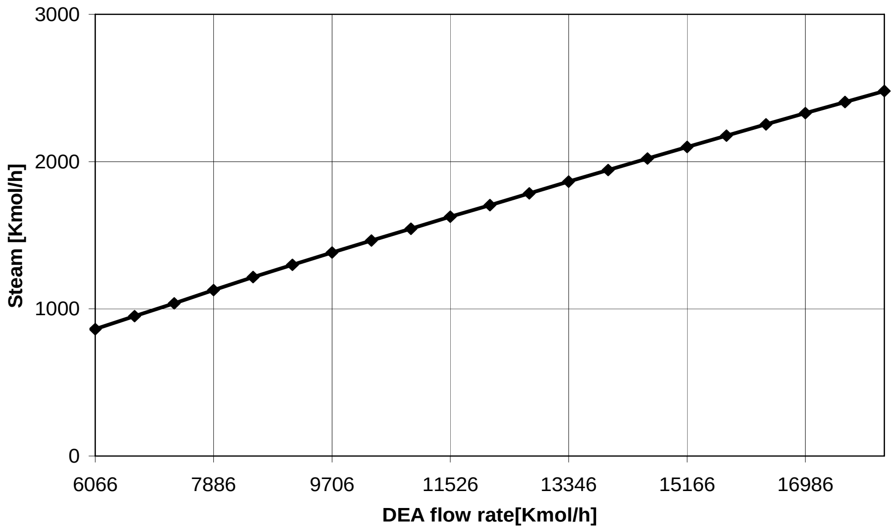

Fig. 13. The relation between the striping steam flow rate and the DEA flow rate

The design of the optimal control system

The optimal control system is characterized by the objective function of the stationary state, the restrictions associate to objective function,

$$\Phi(DEA) = DEA\,, \tag{1}$$

where *DEA* represents the DEA flow rate.

The restriction system is defined by the accomplishing the natural gas specifications:

$$\begin{cases} y_{H2S} \le 4; & [\text{ppm}] \\ y_{CO2} \le 0.5; & [\%\,\text{mol}] \end{cases}. \tag{2}$$

An another restriction is defined by the mathematical model of the absorption subsystem

$$[y_{H2S}, y_{CO2}] = H(F, y_F, DEA), \tag{3}$$

where y_{H2S} and y_{CO2} represent the hydrogen sulfide and carbon dioxide concentration of the treating natural gas; *H* – mathematical model of the absorption subsystem; *F* – feed flow rate; y_F – the vector of the feed composition.

The minimization of the objective function (1), using the restriction system (2), has generated the numerical solution

$$DEA^{opt} = 9050. \quad [\text{kmol/h}]$$

The design of the optimal control system begins with the actual control structure of the absorption subsystem of the Jibissa plant. This control structure contains one hierarchical level based by the measurement system and the classical control loop. The actual hierarchical level is named basic level. The optimal control system structure has two hierarchical levels: the basic level (low level) and the optimal control level (high level). The optimal control level contains an optimal controller, figure 14. The inputs of the optimal controller are: the values of the dioxide carbon and the hydrogen sulfide concentration transducers of the feed; the flow rate of the fresh DEA solution and the condensate water flow rate form the striping re-boiler. The output of the optimal controller is represented by the fresh DEA solution flow rate.

The optimal controller has two components [6, 7]. The first component is represented by the steady state algorithm for the optimal fresh DEA flow rate calculus.

The numerical algorithm selected is the gold section. To implementation the function $H(F, y_F, DEA)$ in real time is necessary to convert the PROII program into new program, accepted by the real time system.

The second component of the optimal controller belongs to dynamic state. Because the numerical solution of the optimal algorithm is a stationary operating point, it is necessary to accomplish the steady state algorithm with the dynamic model for the DEA solution flow rate

$$a\frac{dDEA}{dt} + DEA = DEA^{opt}\,(t - \tau_d) \tag{4}$$

where *a* represents the time constant and τ_d - the dead time.

Conclusion

In this paper the authors have been analyzing the natural gas treating plant Jibissa. In the first part the authors have developed the mathematical model of the absorption – desorption process, using the PRO II software program. Based on this model, the authors have generate the statically characteristics of the chemical process. These characteristics have an optimal operating point. The second part contains the absorption control structure analysis.

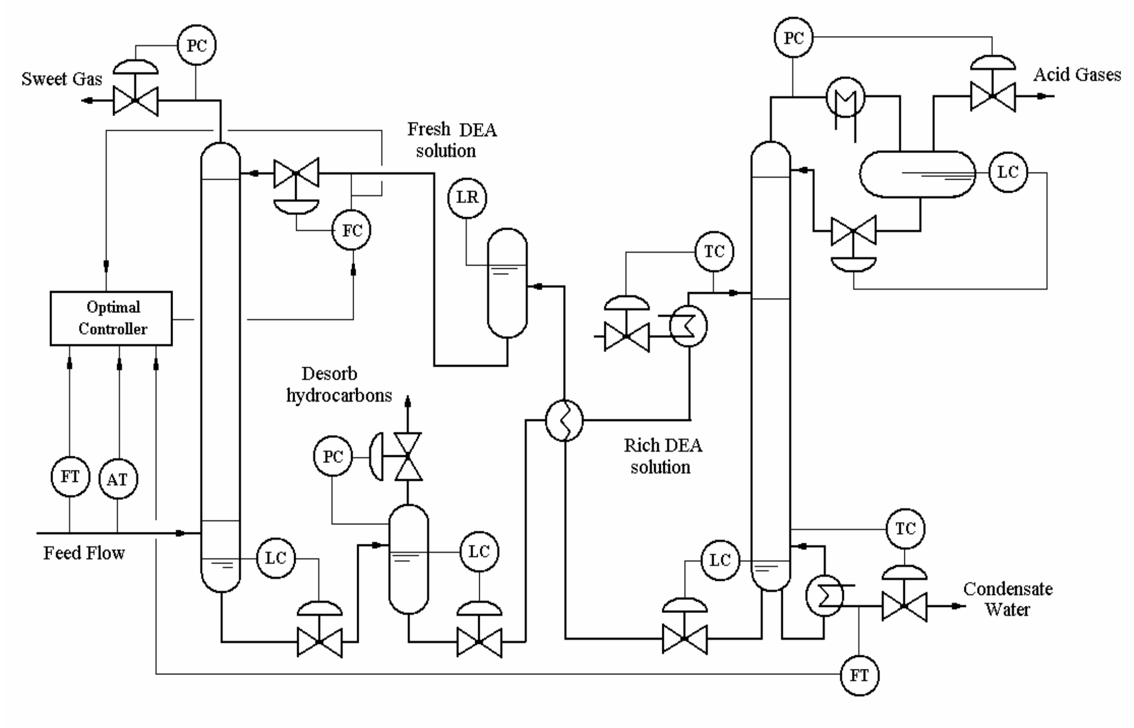

Fig. 14. The optimal control structure

The authors have identified four basic control structure of the absorption process. The third part contains the contribution of the authors to developing an optimal control structure for absorption process Jibissa.

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Sistem de reglare optimală a procesului de tratare a gazelor naturale de pe platforma Jibissa

Rezumat

Lucrarea prezintă un sistem de reglare optimală a procesului de tratare a gazelor naturale de pe platforma Jibissa din Siria. Lucrarea are trei părți. Prima parte conține modelul matematic al procesului de absorbție-desorbție, model dezvoltat cu ajutorul sistemului de programe PRO II. Utilizând acest model, autorii au generat caracteristicile statice ale procesului. Partea a doua este dedicată analizei structurilor de reglare ale procesului de absorbție. Autorii au identificat patru structuri fundamentale destinate reglării procesului de absorbție. Partea a treia conține contribuția autorilor la dezvoltarea unui sistem de conducere optimală a procesului de absorbție de pe platforma Jibissa.