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Monitoring and Optimization of Crude Oil Distillation Plant by Intuitionistic Fuzzy Generalized Nets

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Introduction

Processes in chemical and petrochemical industry exhibit a great diversity of production and substantial degree of complexity. These have in common the feature of requiring a relatively large number of functionally different processing stages which need various kinds of energy, auxiliary substances and information.

The processes vary with respect to the range of products produced from a given raw material, ways to obtain the same product etc. They are both strongly related with each other and with other branches of the economy. These relationships are determined by the raw materials, final products, various kinds of energy, transport communications and information.

Optimal process control is a problem of principal significance to the modern technologies. It requires the solutions of a number of new process control tasks, related to plant start/stop, self–diagnostics, automatic protection, technological and economic optimization etc.

In actual Chemical Technological Systems, the production situation changes frequently for various reasons, which is a great complication to the task of building a system for process control and on-line optimization.

To that end, applications of the theory of Petri nets have proved expedient for the needs of construction of reliable systems for monitoring and control optimisation. A main advantage of the net models is their parallelism as well as the ability of adequate rendering of the triple relationship "process–control–operator".

Since the origination of Petri nets in 1962, a large number of publications have appeared, both theoretical and applied. Petri nets theory has been applied successfully to the tasks of modelling logical systems in various areas of human knowledge, like: discrete systems, software engineering, as well in systems for monitoring and control optimization.

In such applications, the developed nets are tailored for the practical implementation, taking into account the specificity of the particular system as well as the goal to be achieved, due to which most of the existing net models lack theoretical completeness and their application is limited.

In the present work, the theory of Generalized Nets [1,2] is employed to build a system for monitoring and control optimization of crude oil distillation plants. Generalized Nets (GNs) unite the features of all types of Petri nets, having many advantages over them – they are universal and more powerful (all other types of Petri nets can be modelled by GNs).

The Intuitionistic Fuzzy GNs (of the first type) (IFGN) are extensions of the ordinary GNs (see [1,2]). On the other hand, they have equal modelling power compared to the ordinary GNs, i.e., both types of nets are equivalent.

1 The System for Monitoring and Optimization

1.1 Technological Description

The column block consists of 5 rectification columns connected sequentially. The crude oil heated up to 180–200°C enters the reduced crude oil column *K101.* The main units of the plant are: the column *K102* and the stripping column *K103,* where 4 fractions are obtained: Light Gas Oil (LGO, 180–240°C), Middle Gas Oil (MGO, 200–300°C), and Residual Oil (RO, Mazout). The unstable benzine exiting from the top of *K*101 and *K*102 goes for further rectification to the so-called ***stabilization column** K104* and after that, to the ***secondary distillation column** K105.* The last two columns separate the following light benzine fractions: 62°C (45°C), 62–85°C, and 85–180°C.

1.2 Function and Structure of the Computer System

The computerized system for monitoring and optimization of crude oil distillation plants has been developed on the basis of the popular microprocessor distributed system of the type MIC–2000C, produced in Bulgaria.

The system is designed to operate in two modes: Monitoring mode and Optimization mode. In Monitoring mode, the system displays the current state of the plant as well as the qualitative parameters of the obtained fractions.

The Optimization mode provides means for solving various types of optimization tasks, depending on the changing production demands. These tasks differ mainly in the number and boundaries of inequality constraints; there are also cases when the optimization criterion may vary as well.

From a structural point of view the system consists of the following main program modules:

- Identification and Crude Oil Recognition
- Data pre-processing
- Process' Internal Mathematical Models
- Quality Models
- Material and Heat Balance of the Columns
- Solution of the Optimization Task (in two steps)
- Calculation of the Optimal Setpoints of the Controllers.

The connection between the two parts of the system, as well as the formulation of the optimization task and the relation between the system and the lower level of control and the operator are implemented using an IFGN model.

2 An IFGN for Monitoring and Optimization of Crude Oil Distillation Plant

The IFGN for monitoring and optimization is shown on Fig. 1 and can be described formally as

$$E = \langle\langle A, \Pi_A, \Pi_L\rangle, \langle K\rangle, \langle T, t^*\rangle, \langle X, \Phi\rangle\rangle \quad (1)$$

where
A is the set of transitions
Π_A is the function giving the transitions' priorities
Π_L is the function giving the places' priorities
K is the set of tokens
T is the time-moment in which the IGFN1 starts functioning
t^* is the duration of the active status of the net
Φ is the characteristic function, which gives the characteristics of the places.

The IFGN contains 13 transitions $Z_1, ..., Z_{13}$ which have the following forms:

$Z_1 = \langle\{l_2, l_{28}\}, \{l_3\}, r_1\rangle,$
$Z_2 = \langle\{l_1, l_3\}, \{l_4, l_5\}, r_2\rangle,$
$Z_3 = \langle\{l_4, l_{30}\}, \{l_6, l_7, l_8, l_9\}, r_3\rangle,$
$Z_4 = \langle\{l_6, l_7, l_8, l_9\}, \{l_{10}, l_{11}\}, r_4\rangle,$
$Z_5 = \langle\{l_{10}, l_{11}\}, \{l_{12}, l_{13}, l_{14}\}, r_5\rangle,$
$Z_6 = \langle\{l_{12}, l_{13}, l_{14}\}, \{l_{15}, l_{16}\}, r_6\rangle,$
$Z_7 = \langle\{l_{15}, l_{16}\}, \{l_{17}, l_{18}\}, r_7\rangle,$
$Z_8 = \langle\{l_{17}, l_{18}\}, \{l_{19}, l_{20}\}, r_8\rangle,$
$Z_9 = \langle\{l_{19}, l_{20}\}, \{l_{21}, l_{22}\}, r_9\rangle,$
$Z_{10} = \langle\{l_{21}, l_{22}\}, \{l_{23}\}, r_{10}\rangle,$
$Z_{11} = \langle\{l_{23}, l_5\}, \{l_{24}, l_{25}, l_{26}, l_{27}\}, r_{11}\rangle,$
$Z_{12} = \langle\{l_{24}, l_{25}, l_{26}, l_{27}\}, \{l_{28}, l_{29}\}, r_{12}\rangle,$
$Z_{13} = \langle\{l_{29}\}, \{l_{30}, l_{31}\}, r_{13}\rangle.$

All these transitions have a conjunctive type.

In the input place l_1 of the IFGN enter 83 "quantities" (the analogues of the tokens in a standard GN) which represent the status of the athmospheric distillation plant *AD-5* with respect to measured abnormal states of the process.

In the input place l_2 of the IFGN enter 37 standard GN tokens with initial characteristics determining the current status of the control parameters.

As a result of the functioning of the IFGN, the 37 tokens with the results of the optimization are collected in place l_{28}.

Reference

[1] Atanassov, K., Generalized Nets, World Scientific, Singapore, New Jersey, London, 1991, 377 p.

[2] Atanassov, K., Generalized Nets, Burgas, Pontica Print, 1992, 168 p. (in Bulgarian).

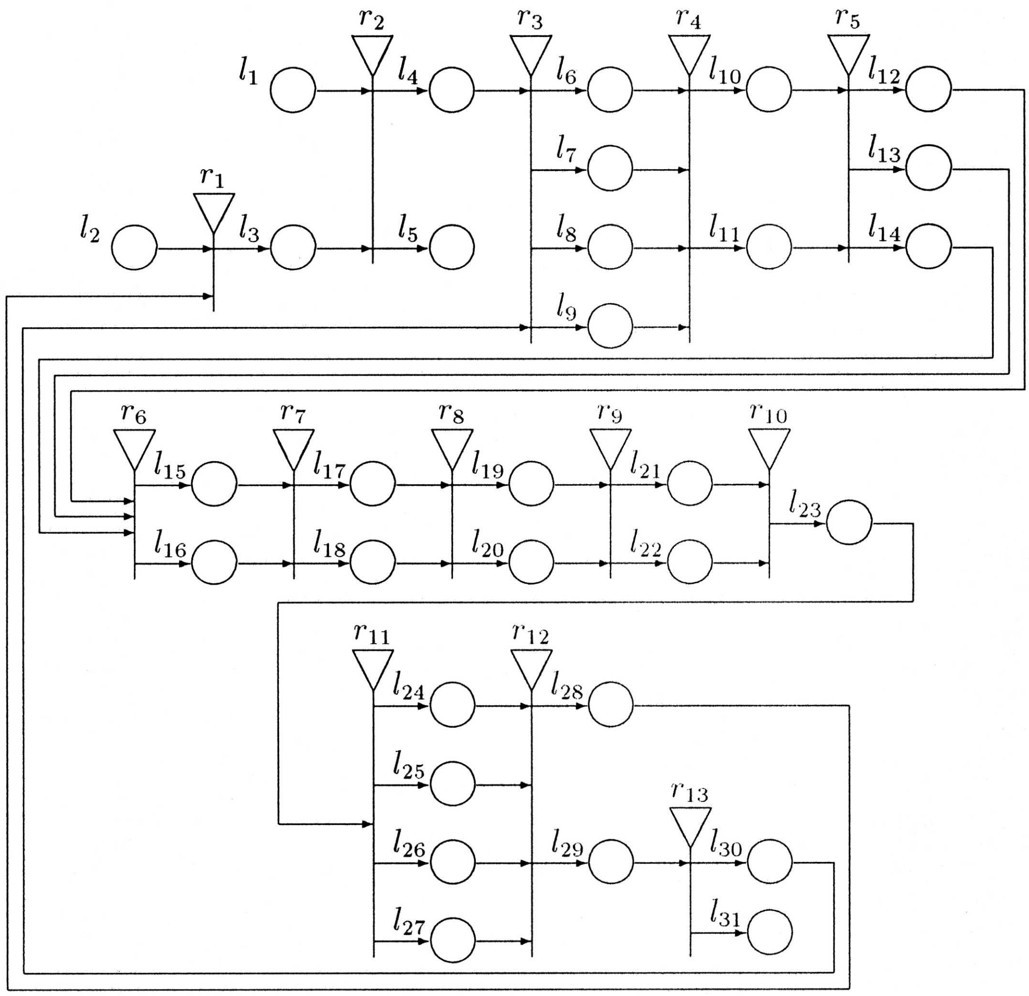

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Fig. 1.