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APPLICATION OF INTUITIONISTIC FUZZY GENERALIZED NETS FOR FLOWSHEETING SYSTEM SIMULATION*

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1. Introduction

The Intuitionistic Fuzzy Generalized Nets (IFGN) [1] are an appropriate tool for modeling of real events, phenomenon and complex structures because of their flexibility and universal modeling possibilities. IFGNs allow description of both dynamic and static behavior of complex systems. The main advantage of using the IFGNs is the possibility for fast simulation of various system with complex structure - with sequential, parallel or recycle elements. It makes the IFGNs very suitable tool for mathematical modeling of technological system with large number of units and recycling material and energy streams.

The most of real industrial systems are complex technological systems having grate number of process units, interconnected by many sequential, bypass and recycle streams. Simulation of such complex systems is accomplished by preliminary decomposition of the entire system into a sequence of smaller subsystems. The calculation of these subsystems needs preliminary created computational modules for each process unit. The systems, having at least one recycle stream, require multiply calculations of the computational modules in iteration mode until convergence of so called cut streams is achieved.

Obviously to solve any optimization or control problems of such complex technological system is a time consuming task. Especially, when analytical type of unit models are used, it makes almost impossible to perform the simulation of the overall systems in real time.

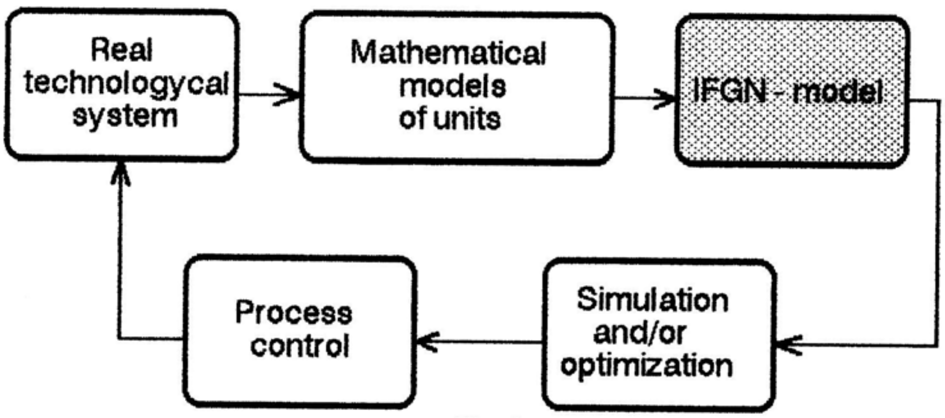

Fig.1

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An application of IFGN for static simulation of complex technological system, known as flowsheeting, is described in this paper.

The general scheme of the IFGN application in chemical technology is presented in Fig.1.

2. Intuitionistic Fuzzy Generalized Nets in Technological Systems.

A GN has static structure, made up of transitions, and dynamic elements - tokens, time component (related to the beginning, duration and elementary time-step of the modeled process), and memory, which accumulates information on the way of the process flow. Each transition has a set of input and a set of output places; pre-set conditions that must be satisfied in order to the token be able to transfer from the input to the output places; conditions of which the transition becomes active; and some other parameters. Tokens enter (or already are in) into IFGN with some initial characteristics and receive new characteristics while moving from place to place.

Up to now the GNs have not been applied for simulation of complex technological systems with recycling streams. Some investigations on use of IFGNs for energy and material balances calculations in refinery industry and for modeling of urea production are published in [2].

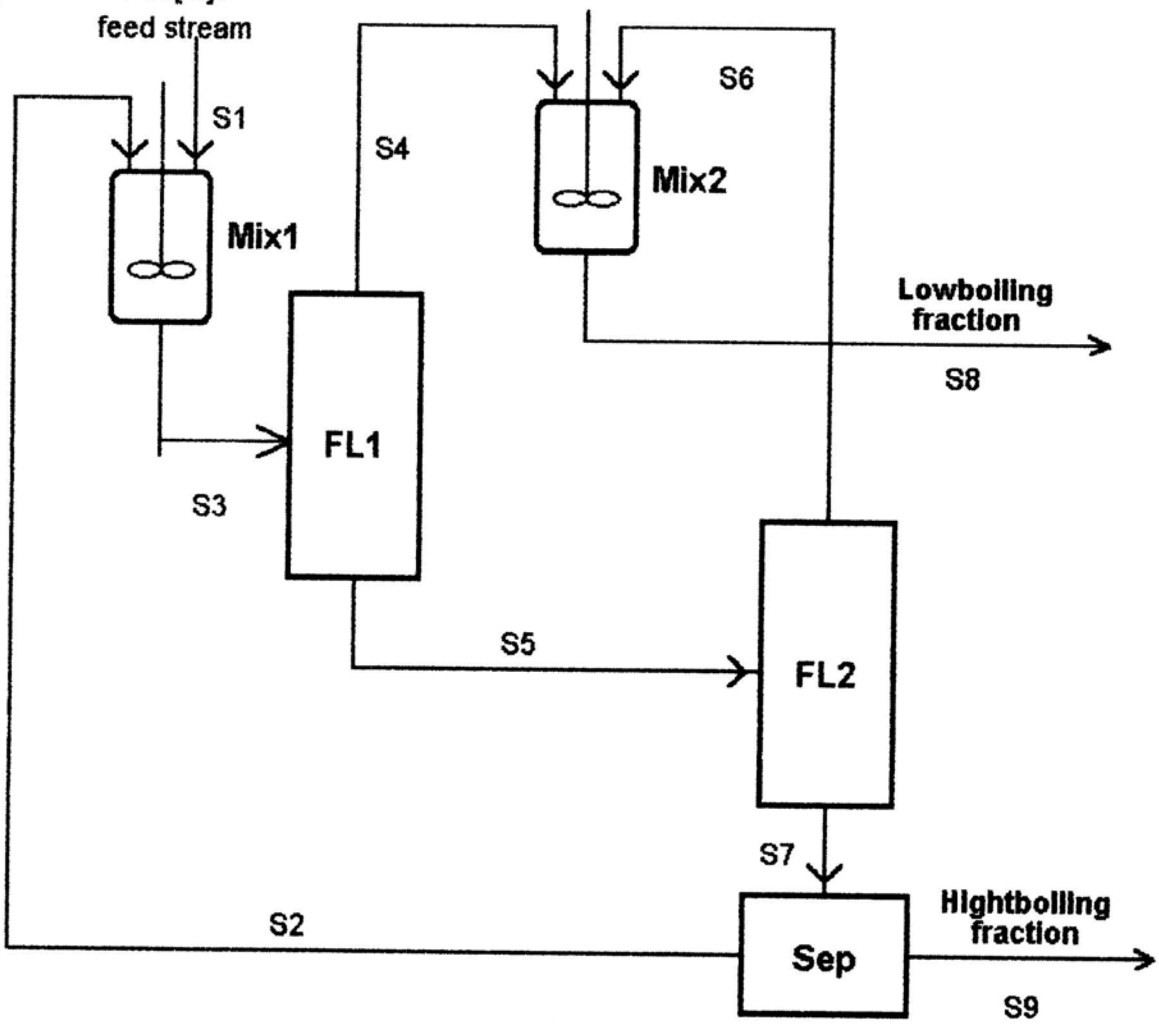

Fig.2

3. Description of the Flowsheeting System

A test continuous flowsheeting system with 9 streams and 5 technological units is presented in Fig.2. A 3-component mixture of butane ($C4H10$), heptane ($C7H16$) and octane ($C8H18$) is mixed in the unit Mix1 (streams **S1** and **S2**) and enters the first flash unit **FL1** (stream **S3**). At boiling temperature, two fractions are separated: the top lowboiling fraction (stream **S4**) and the bottom hightboiling fraction (stream **S5**). The bottom fraction is secondary evaporated in **FL2**. The both top products from **FL1** and **FL2** (streams **S4** and **S6**) are mixed in **Mix2** and leave the system as product stream S8. The bottom product of **FL2** (stream **S7**) enters the separator (**Sep**) where is divided into two streams: stream **S9** as the system heavy product and stream **S2** as a system recycling stream. It is used as a cut stream during the iterative calculations.

Strong analytical models are developed for every unit of the system and are organized as executable program modules.

The modules of FL1 and FL2 are identical and describe the flash process at boiling temperature. The mathematical description includes the following relationships [3]:

- equations of component material balances

$$Fx_i - Lx_i^L - Vx_i^L = 0, \qquad (i = 1,\ 2, \dots, N_c); \tag{1}$$

- equations of energy balance

$$Fh_i - Lh_i^L - Vh_i^L = 0, \qquad (i = 1, 2, \dots, N_c); \tag{2}$$

- vapor-liquid equilibrium equations

$$\sum x_i^L K_i - \sum x_i^V = 0, \qquad (i = 1, 2, \dots, N_c) \tag{3}$$

where:

F is flowrate of the feed stream, [kmol/h];
N_C - number of components;
L, V - flowrate of the liquid and vapor phase, [kmol/h];
x_i^L, x_i^V - mole fraction of i-th component in liquid and vapor phase;
K_i - equilibrium constant of i-th component;

The solution of the above set of non-linear equations imposes an inner loop iterative procedure, that creates some computational difficulties in simulation of a complex structure with great number of process units.

The models of the mixers (**Mix1** and **Mix2**) calculate the resulting output streams. The separator model (Sep) works with a specified separation coefficient.

4. Use of Generalized Net for the Flowsheeting System Simulation

The scheme of the GN for the above described Flowsheet simulation is shown in Fig.3. GN model consists of 5 transitions and 9 places. The transitions are marked with **r1**, **r2**, **r3**, **r4**, and, **r5**, as **r1** and **r4** describe **Mix1** and **Mix2**; **r2** and **r3** describe **FL1** and **FL2**; **r5** - separator. Every token has initial or current characteristics in the form of "**f1k**, **f2k**,

f3k' (corresponding to the 1, 2, 3 component flowrate of the **k**-th stream). At every transfer the above characteristics receive current values. At every moment a token enters place **I1** if it is empty, that symbolizes the input feed stream (**S1**). It goes to place **I3** where it unites with the token arrived from **I2**. At initial moment of functioning of the GN the characteristics of the token in place **I2** have approximate values, that symbolizes the recycling stream **S2**. The united token corresponds to stream **S3**. It splits into two tokens: one goes into place **I4** (symbolizing **S4**) and the other - into place **I5** (symbolizing **S5**). The token from place **I5** splits into two tokens - one goes into place **I6** (**S6**) and the other into **I7** (**S7**). The tokens from places **I4** and **I6** are united in place **I8**, that corresponds to output product stream (**S8**).

The token from place **I7** splits into two tokens - one goes into **I9** (symbolizing the output product stream **S9**) and the other comes back into place **I2**. In the end of the process, the final characteristics of the tokens from places **I8** and **I9** are checked up.

The presence of one recycling stream (**S2** at Fig.2) imposes iteration process that continues until the flowrate's parameters of the cut stream converge to the predifined value (about 10 iterations). The GN must function at least 50 takts, assuming that every step in the net is realized in one tact. For simplicity, it can be assumed that every transition is activated at every moment of time and has duration one unit of time. All places, transitions and arcs have equal capacity and priority.

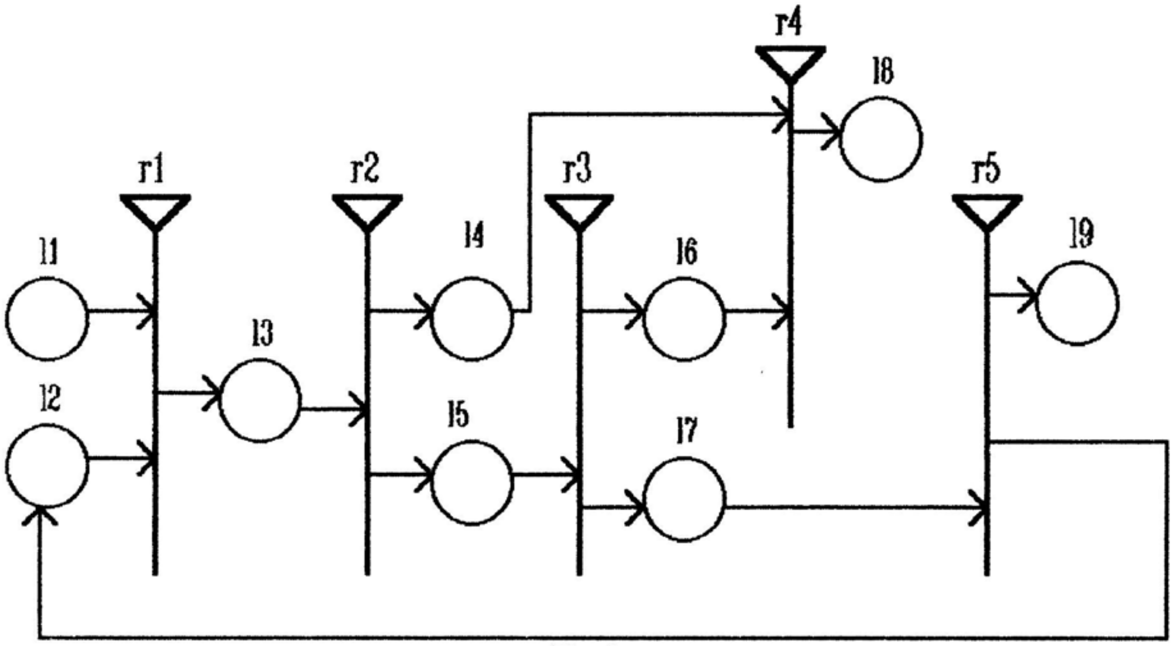

Fig.3

There are specifics in real processes that we most consider in our model. This is usually a very hard problem to solve. The use of IFGN is extremely suitable for such cases.

Let the token that enters place I1 has as initial characteristic the pairs $\langle\langle\mu_{x1,s1},\nu_{x1,s1}\rangle$, $\langle\mu_{x2,s1}, \nu_{x2,s1}\rangle$, $\langle\mu_{x3,s1}, \nu_{x3,s1}\rangle, d_{s1}\rangle$ where $\mu_{xi,s1}$, $\nu_{xi,s1}$, (i=1, 2, 3), $\mu_{xi,s1}+\nu_{xi,s1}\leq 1$ and $\mu_{xi,s1}$ represents the minimal mass percent of component **i** in the entering stream **S1** for which we can guarantee, that it will enter the IFGN, $\nu_{xi,s1}$ represents the maximal mass percent of component **i** in the entering stream **S1** for which we can give the same guarantees and $\mathbf{d_{s1}}$ is debit of the stream **S1**.

The token that enters place **l2** has as initial characteristic the pairs $<<\mu_{x1,s2}, \nu_{x1,s2}>$, $<\mu_{x2,s2},\nu_{,s2}>$, $<\mu_{x3,s2},\nu_{x3,s2}>$, $d_{s2}>$ where $\mu_{xi,s2}$, $\nu_{xi,s2}$, (i=1, 2, 3), $\mu_{xi,s1}+\nu_{xi,s1}\leq 1$ and $\mu_{,s2}$ represents the minimal mass percent of component **i** in the is carried by stream **S2** for which we can guarantee, that it will be obtained by previous cycle of functioning of the IFGN, $\boldsymbol{\nu_{xi,s1}}$ represents the maximal mass percent of component **i** in the entering stream **S2** for which we can give the same guarantees and d_{s1} is debit of the stream **S2**. We must note that only the initial values of $\boldsymbol{\mu_{xi,s2}}$ and $\boldsymbol{\nu_{xi,s2}}$ (i=1,2,3) are gained this way, all subsequent values are calculated in the process of functioning of the IFGN.

Two entry streams are mixed together in **Mix1** that is represented by transition **r1**. The result is obtained in place **l3**. Its characteristics are determined by the characteristic function of the IFGN and they are of the following type

$\mu_{xi,s3}=F_{s3}(\mu_{xi,s1},d_{s1}, \mu_{xi,s2},d_{s2})$,

$\nu_{xi,s3}=G_{s3}(\nu_{,s1},d_{s1}, \nu_{xi,s2},d_{s2})$, where $\mu_{xi,s3}+\nu_{xi,s3}\leq 1$, (I=1,2,3),

$d_{s3}=d_{s1}+d_{s2}$..

Where $\mathbf{F_{s3}}$ is a function that calculates the current value of minimal guaranteed amount of all components (x_1,x_2,x_3) in stream **S3** on the base of input characteristics of these components in the streams **S1** and **S2** and current technological conditions, and $\mathbf{G_{s3}}$ is a function that calculates the current value of maximal guaranteed amount of all components (x_1,x_2,x_3) in stream **S3** on the same base.

On the next step the token enters place **l4**, passing trough the transition **r2** which represents first flash unit **Fl1**. Here the input substance is divided on two and the new characteristics are determined in the following way:

$\mu_{xi,s4}=F_{s4}(\mu_{xi,s3},ds3)$,

$\nu_{xi,s4}=G_{s4}(\nu_{xi,s3},ds3)$, where $\mu_{xi,s4}+\nu_{xi,s4}\leq 1$,

$d_{s4}=h_{s3}*d_{s3,}$

$\mu_{xi,s5}=F_{s5}(\mu_{,s3},d_{s3})$,

$\nu_{xi,s5}=G_{s4}(\nu_{,s3},d_{s3})$, where $\mu_{xi,s5}+\nu_{xi,s5}\leq 1$, (i=1,2,3),

$d_{s5}=(1-h_{s3})*d_{s3}$.

Where $\mathbf{F_{s4}}$ and $\mathbf{G_{s4}}$ are analogous to $\mathbf{F_{s3}}$ and $\mathbf{G_{s3}}$, but they are calculated only on the base of characteristics of the input stream **S3** and current technological conditions at that moment and $\mathbf{h_{s3}}$ is a coefficient of division of the stream **S3**.

By analogy we proceed further on the IFGN, transition by transition and on every step we calculate the new values on the base of the input characteristics. The above describes transitions are basic for this IFGN. We can use similar functions for all transitions of these types.

If the transition is from type 1 (two input places and one output place) the general form of the functions, which determine the characteristics of the token in the output place is:

$\mu_{xi,sj}=F_{sj}(\mu_{xi,sj-1},d_{sj-1},\mu_{,sj-2},d_{sj-2})$,

$\nu_{xi,sj}=G_{sj}(\nu_{xi,sj-1},d_{sj-1},\nu_{xi,sj-2,},d_{sj-2})$, where $\mu_{xi,sj}+\nu_{xi,sj}\leq 1$, (i=1,2,3),

$d_{sj}=d_{sj-1}+d_{sj-2}$,

Or in other words, the characteristics in the output place depend on the characteristics of the input streams S_{j-1} and S_{j-2} and the current technological conditions.

If the transition is from type 2 (one input place and two output places) the general form of the functions, which determine the characteristics of the token in the output places is:

$\mu_{xi,sj-1}=F_{sj-1}(\mu_{,sj},d_{sj})$,

$\nu_{,sj-1}=G_{sj-1}(\nu_{xi,sj},d_{sj})$, where $\mu_{xi,sj-1}+\nu_{xi,sj-1}\leq 1$, $(i=1,2,3)$,

$d_{sj-1}=h_{sj}*d_{sj}$,

$\mu_{,sj-2}=F_{sj-2}(\mu_{,sj},d_{sj})$,

$\nu_{xi,sj-2}=G_{sj-2}(\nu_{,sj},d_{sj})$, where $\mu_{xi,sj-2}+\nu_{xi,sj-2}\leq 1$, $(i=1,2,3)$,

$d_{sj-1}=(1-h_{sj})*d_{sj}$.

Or in other words, the characteristics in the output places depend on the characteristics of the input stream s_j and the current technological conditions.

The result is that in places l8 and l9 we obtain tokens with calculated characteristics, that show the limits in which each component will be represented in the output stream and on the base of this knowledge we can make conclusions about the influence of the technological conditions and in some extend predict and control the real process.

5. Conclusions

In this paper a method for simulation of complex technological systems by use of GNs is proposed, because of the flexible properties of the IFGN. The results show a very good possibility of the IFGN to simulate various technological systems with recycling structure.

References

1.Atanassov, K., Generalized Nets, World Scientific, Singapore, 1991.

2.Atanassov, K., (Ed.) Applications of Generalized Nets, World Scientific, Singapore, 1993.

3.Gani, R., G.Toneva, Simultaneous Steady-state and Dynamic Simulation of Chemical Processes, ffComp. Chem. Eng., V.13, No 415, pp. 563-570, 1989.

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