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APPLICATION OF INTUITIONISTIC FUZZY GENERALIZED NETS TO PROBLEMS IN SODA ASH PRODUCTION

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Soda ash production [1] is a complex chemical process involving a number of parallel subprocesses. A very suitable method for describing these processes is the method of Generalized Nets (GNs, [2]) and particularly – of Intuitionistic Fuzzy GNs (IFGNs).

In the present paper the authors show how the apparatus of the IFGNs solves some problems in the soda ash production, tangibly problems of the final stage of the production – the process of calcification.

Due to the diversity and the large number of parallelly flowing processes in soda ash production, a second type of IFGN (IFGN2) (see [2,3]) will be used to model them.

The complexity of the processes implies the top-down construction and modelling of an IFGN2-model comprising the following:

Initially, the main IFGN2 of the whole process is modelled. It represents the major steps of soda ash production together with the relations between them.

The next to be constructed is the nets that describe production steps – these are nets corresponding to the places and transitions of the main IFGN2.

The top-down approach helps to build a detailed IFGN2-model of soda ash production with its steps and the parallel processes observed in their completeness and interaction.

The IFGN2-model on Fig.1 represents the main IFGN2 of the process of soda ash production. This IFGN2 includes the eight major stages of the production.

1. Firing the lime
2. Hydratation of the lime
3. Purification of the salt solution
4. Obtaining of ammonified salt solution
5. Carbonization of the ammonified salt solution
6. Filtration of the bicarbonate suspension
7. Regeneration of the ammonia
8. Calcification

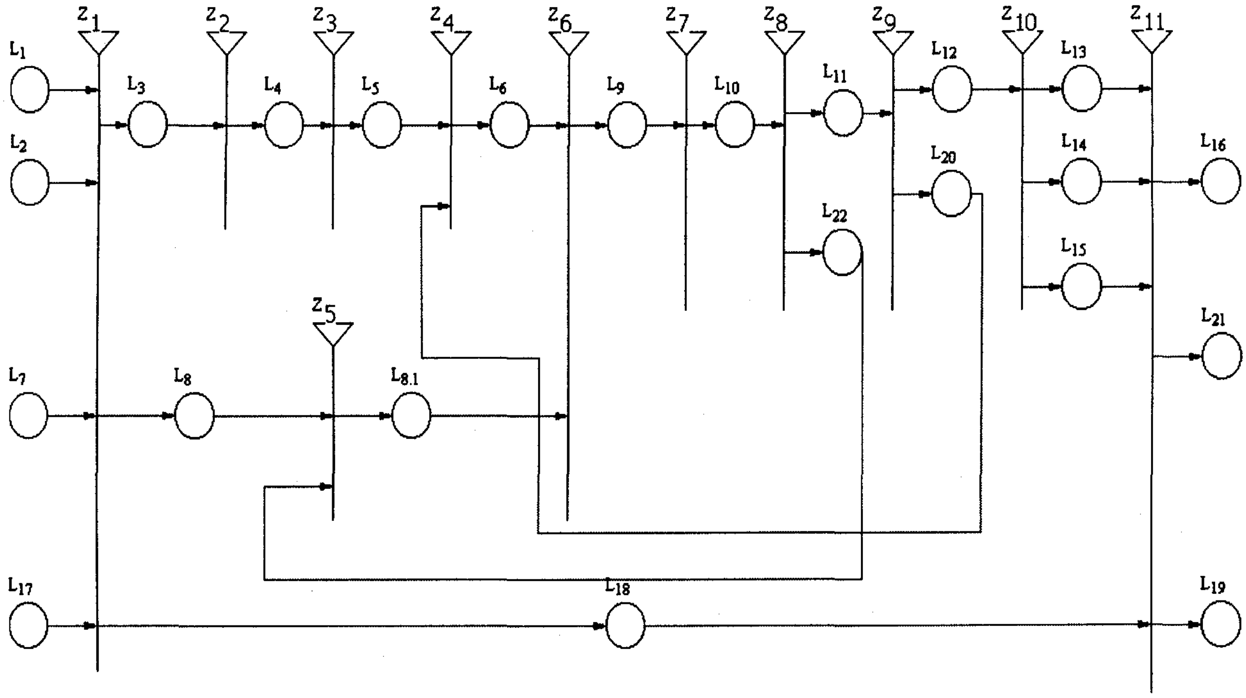

Fig. 1

After constructing the above IFGN2-model, general for the whole process of production, the next step is to bring it to details. The IFGN2 from Fig.1 gives the separate stages of soda ash production. Since they are themselves parallel processes, they can be described as IFGN2s.
The authors trace the details in the last stage of soda ash production – calcification. It is given on Fig. 2. and corresponds to place l_{12} from Fig.1.

The thermal decomposition of $NaHCo_3$ is the final stage in the soda ash production.
In the plants for soda ash production the Steam Calcificators (steam soda furnaces) with feedback are of widest application.

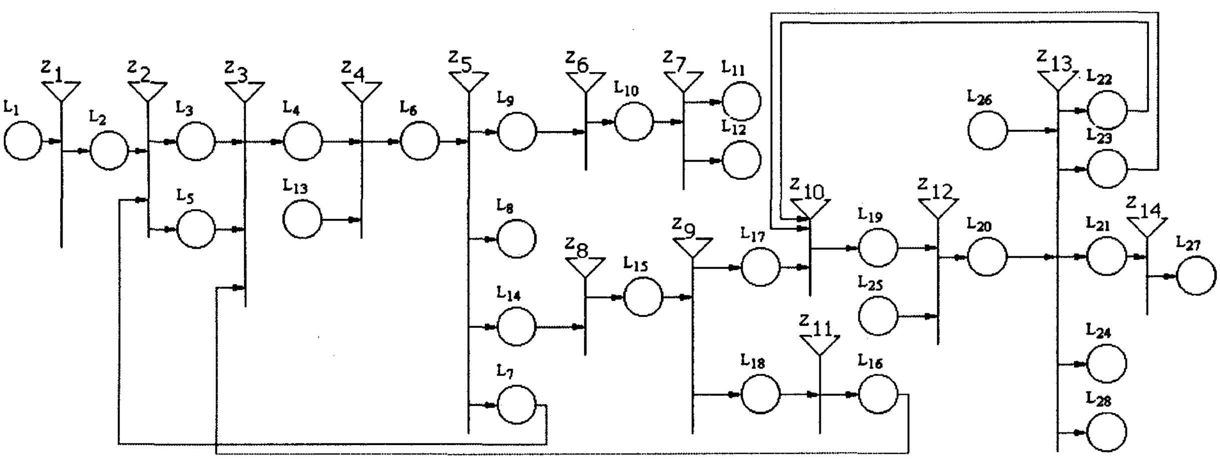

Fig. 2

A system of conveyor aprons transports the $NaHCo_3$ from the vacuum-filter l1 to the calcificators, from where it reaches the feeding apron (bicarbonate apron) l2 equipped with a weighter to account the incoming ammount of bicarbonate. Via a cellular feeding apparatus – l3, the crystal aggregation is transported to the preparative mixer l4. Feedback soda from the transporter is also brought to the mixer – l5. The mixture reaches the stam calcificator – l6 – and because of its rotation it gets poured in concentrically located pipes. There the mixture turns into steam – l13. Via the system of transporting installations l7 and l8, the product obtained is sent for defervescence and packing or in the silos. A part of the stream is deviated for feedback soda – l7. The heat-carrier – overheated water steam – place l13 – enters the pipes of the calcificator – l6, and it rendersheat and evaporates. The condensate flows down the pipes into the condense-assembly – l9. From there it is transported into the expander l10, 25% from which evaporates there. Steam from the expander – l10, is extracted for destilation, l11, and the condensate is brought back to the heating electricity plant – l12. In the stage of calcification of the bicarbonate, in the gas stage, CO2, NH3, water steams and inert fluids are isolated – l14. In order the captivated dust of Na2Co3 and NaHCO3 to be occluded, the gas is passed through the cyclon – l15. The captured particles – place l18 – are returned in the mixer l4 via a transporter. The gas stream l17 passes through the washer l19, where the water steam and the fine dust-like particles having passed are captured. From there it enters the gas refrigerator in the soda ash furnaces – place l20. There it is cooled down to 40^{o}–45^{o}C and then passes through the gas washer in the soda ash furncaes. At the exit – l20 – the gas from l21 is added to the steam. On this place – l22 – it is with concentration of 80-90% CO2. The irrigation in the washer l19 and l20 is accomplished by means of alcaline solution from a reservoir l23. The extra ammount of condensate is poured in an overflow reservoir – l24, and is sent for short Destilation. In the pipes of the refrigerator cooling water is run – l25. The irrigation in l21 is accomplished with water being initially cooled in the heat exchanger – l26. Place l27 represents the gas excreted during calcification, of temperature 30^{o}C and concentration of CO2 90-95%. It is sent to the compressing workshop for obtaining mixed gas and forcing at the first entrance of the carbonizing trunks. Through the ventilator – l28 gas mixture of CO2, NH3 and inert fluids is isolated in the athmosphere.

The so modelled detailization is interesting because the IFGN from Fig.2 and its GN-based "demo-version" help solving some problems having arisen during the process of calcification, namely:

1. For regulation of the regimen in the calcification workshop, several major rules need to be observed:
   - The influx of heat carrier (steam or fuel) shall be regulated in order to maintain its normal proportion with the ammount and the dampness of the entering bicarbonate: the steam quanity is self-regulating, but the temperature and the pressure of the incoming heat carrier are subject to regulation.
   - It is of great significance to have the feedback soda correctly regulated in accordance with the dampness of the bicarbonate in the filtres.

   The lower the quality of the soda crystals (because of broken regimen of the carbonizing trunks), the damper gets the bicarbonate in the filters. It means that the ammount of feedback soda shall be increased. In the opposite case there is danger for the calcinating trunks to get layered with bicarbonate, leading in this way to rapid backset in the heat exchange.

   The IFGN from Fig.2 not only tracks for keeping the main requirements of the technological regimen, but it also regulates the process in each moment of time as tracing the proportion bicarbonate dampness to ammount of feedback soda. The undesirable occurrences are thus prevented.

The "demo-version" of the flowing processes of calcification and the occurring conflict situations is based on the IFGN from Fig.2. and is being developed by a team together with Prof. Krassimir Atanassov, Peter Georgiev and others. It discovers the possibilities for solving the problems described above (determining the dampness of the raw bicarbonate and the necessary ammount of feedback soda) by means of the GN apparatus.

2. The second problem that implies the need of detail description of Fig.2 is the problem with ecological pollution of the environment.
   In this sense, when regulating the process flow in the calcination workshop, high and steady concentration of $CO2$ should be maintained. It means that in the calcination barrel good airtight condition shall be provided. In the opposite case $CO2$ and $NH3$ are isolated in the athmosphere, thus polluting it. For this reason a GN-model from Fig.2 was developed since the first version of the model did not involve the block for tracing the gas stage. This additional block includes transitions Z8, Z9, Z10, Z11, Z12 and Z13.
   In this relation, the authors are now developing a new GN-model of the ecological pollution of the environment while producing soda ash [4]. At principle level in this model are reflected the interconnections between atmosphere, hydrosphere, lithosphere, the soda ash production and the human factor. As a result of future simulations, evaluation of the ecological pollution over the environment, because of soda ash production, will become possible.

Finally, we shall note that the so discussed chemical process has a lot of elements that can be interpreted as a Flexible Manufacturing system (FMS). Here we shall comment on this possibility and the benefit of this.

Shortly, FMSs contain some types of elements – statical elements that realize some (fixed for each individual element) procedures; dynamical elements that are objects of processing by the static elements; and transportation units. We can easily see that similar components are involved in the above chemical process.

Now, the static elements are the already described machines, and the dynamic elements are the chemical raw materials the machines process and produce. The transportational units are suitable for the process. Therefore, the researches devoted to FMSs can be transformed for the soda ash processes, too. These processes are already represented by IFGNs and their interpretation lies ahead.
Therefore, we can extend the constructed GN-models with optimization components and with components for decision making basing on expert systems, as it has been made for FMSs (cf. [5]). As it was shown above, the present processes are continuous and therefore the GN-models of the new components must be represented by first type of IFGNs (IFGS1; see [2,3]). In the frameworks of these new (extended) IFGNs conflict (troubles, blockages, etc.) and transportational situations generated in the soda ash plants can be solved.

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