

THE AUTOMATED FUNCTIONING OF THE PROCESSING CENTRE OF FLAX AND HEMP

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Abstract: One of the viable solutions of applying modern technologies to the melting and drying of flax and hemp is the use of geothermal water for the preparation of the hot water used in the melting tanks or for the preparation of the hot air used for drying. So that the flax and hemp melting centre works independently, with the help of geothermal water, for longer periods – that is 3-4 days, as long as the melting cycle, in this paper we have shown the automation scheme of the entire centre and modeling in Simulink/MATLAB and then the results of the center's performance to solicitations that can show up during a winter day.

1. Introduction

For load variations that show up during one day, the center's functioning can be done non-automatic, by periodical intervention of service operators. Given the variation relatively gentle and regular of thermal losses that should be compensated during one day, the interventions on the operation devices which insure the modification of geothermal water flow (meaning the adjustment of thermal contribution) should be done at relatively high intervals (once or twice an hour), which does not solicit the intervention possibilities limits of a human operator. Still, in order to analyze the possibility of the centre to work independently for longer periods – that is 3-4 days, as long as a melting cycle, we have come with an automation scheme of the entire centre, we have moulded it in Simulink/MATLAB and then we have tested the center's performance to solicitations that can appear during one winter day.

Regarding the technical plants processing centre, so that melting and drying the flax and /or hemp is done in the best conditions, the temperature of the melting tanks should be at the optimum value (36 °C), and the air temperature at the entrance and respectively exit in (or from) each of the tunnel drying cells should have values chosen when it was designed for the respective cell, for the humidity chosen values at the entrance or exit. These values tend to modify during one day, no matter the season, due to the variations of the perturbation values, which, in this case, are atmospheric parametric values: speed of wind, temperature and air humidity. In order to keep these values around the reference values we should operate on some valves or taps and on some pumps, actions that will trigger the flow modification of some fluids in the system's circuit, especially the geothermal water flow, that is the heat flood which supports the processes that take place in the centre.

Besides maintaining the temperatures desired for the water in the melting tanks and the air from the drying tunnel, we also want to maintain some safety levels in the two buffer tanks (or storage) existing in the centre: the one that supplies the drying tunnel (tank 1), respectively the one that supplies the exchangers which prepare the secondary agent for heating the water in the melting tanks (tank 2), which can be achieved physically by operating some pumps and/or some adjustment or closing valves. More precisely, for the design of a centre automation system we will try to do the following:

1. Keeping the temperature from tank t_b in an interval with values close to the optimum value 36 °C. The interval can be ± 0.5 °C or possible ± 1 °C. The temperature tends to modify due to heat flood modification lost in a tank during one day. The adjustment can be done by activating the extraction pump of geothermal water from tank 2, by maneuvering the adjustment valves of flows for the tanks operating simultaneously (mg

adjustment), fact that will trigger the operation of adjustment pumps and valves on the secondary agent circuits to the tanks working simultaneously and finally to activating the mixers from the bottom of the tanks and the obturator blades

2. Keeping the egress air temperature from the air pre-heater in between the interval centered on the design value of 33 °C. In this case the interval accepted for the present value can also be ± 0.5 °C or possible ± 1 °C around reference value. In this case the air flow is constant and we can adjust only the geothermal water flow with low potential (38... 40 °C), water that is taken from the output duct by modifying the opening of an adjustment valve on the pre-heater radiator circuit
3. Keeping the entrance or exit temperature in the tunnel's cell radiators. In the conditions of a constant air flow and some values well defined for humidity at the entrance and exit in and from each cell, keeping the desired temperature can be achieved by adjusting the positions of the 8 adjustment taps, set up on the radiator's supply circuit for each cell (adjustment mg 0...8)
4. Maintaining some safety levels in tanks 1 and 2 according to system's status, season, hour, etc. This adjustment can be achieved by activating the valve from the well's top and the extraction pump for tank 1 (adjustment level 1), by activating the by-pass pump and the extraction one for tank 2 (adjustment level 2). The system should also have protection elements for minimum and maximum level for each tank.

For conceiving the automated system model for the processing centre, we have taken into consideration the following aspects:

a) High inertia for the adjusted values, which are temperatures of some high amounts of water, meaning that it is sufficient if the adjustment is proportional with the difference between the present value and the order one (regulator type P). For the systems with low inertia for example, for air pre-heater, PD type regulators (proportional-differential) should be used, where it is taken into consideration both air mass inertia and also an activation anticipation by adding a component which takes into consideration the temperature variation speed. For the systems that we don't know the influence of the variation method of adjusted value, PID type regulators (proportional – integral – differential) are used.

b) For the whole system we will use the simplest possible type of activating elements: we will use taps with linear features between output and valve's run [2], and for pumps we will use pumps having quadratic features (output proportional to revolution quadratic root [5]. For simplifying the system we didn't take into consideration either the whole complexity of the hydraulic system or the link between different hydraulic resistances and circuit pressure. We haven't described the real functioning of the pump system, circuit, valves, ramifications, exchangers, etc., because we want to make a study of the canter's automated performance from the point of view of the exact description of thermal values evolution and not the hydraulic values. For our model we have considered that the pumps repress at a constant pressure no matter of the network pumping height (revolution proportional to output's square), and the valves adjust the output only according to the valve's run (linear feature), not considering the pressures from before and after the tap.

c) The elements and schema of the adjustment system were chosen in the case of normal perturbations that show up during one day, both for the tank and the drying tunnel. From previous simulations (those without automation, with instantaneous correlation) we have established that the perturbations during one day have a sinusoidal aspect, aspect that we will keep in the case of simulating the automated performance. In this case, due to gentle variations of perturbations values, the adjustment is a *tracing adjustment* and we don't need complex elements to respond to some perturbations of scale type, which is plausible, considering the fact that neither wind speed nor temperature or air humidity represent sudden steps to values a lot more different than the real daily evolution. Even so, the

automation elements should establish the new values system, even if response time is not that important. The parameters of adjustment loops elements should be chosen so that the electro-hydro-mechanical elements should not be used too often, for example not more than 10 times per hour, in order to keep these elements running for a longer period of time. On the other hand, the electrical and electronic values can vary a lot faster, for example the frequency for the frequency converter of the variable revolution pumps.

2. Designing the equipment for the melting and drying of flax and hemp using geothermal water

The constructive variant of the flax and hemp processing centre will look according to the diagram in Figure 1. For drying, the solution enforced by the technological process' features is a multicellular drying tunnel, in each cell a fraction of the total humidity will be eliminated; heating the drying air is achieved best with the help of heat exchangers with extended surfaces (radiators), one for each cell. We have nine drying cells, and a last cell, the tenth will be a conditioning cell in which the material (stalks) are sprinkled with a fine fog if they were dried more than needed, so if their humidity is less than 12%.

As far as the melting process is concerned, the number of tanks which can work simultaneously differs from one season to another: 4 in winter, 5 in spring and in autumn, and 6 in summer, the average total geothermal water consumption per day being approximately the same during the melting process.

A melting cycle lasts four days from filling the tanks up to finishing the melting process. In between melting two lots we need one whole day for emptying the tanks, cleaning and refilling them, after which the process can be resumed with a new lot. In parallel, this period of time can be used to accomplish the maintenance works at the drying tunnel (cleaning, dusting the filters, lubricating the bearings, etc).

This means that once every four days, in the fifth day, the water from the well is not necessary and the output can be reduced to minimum (zero).

On the other hand, the well can be left working in the fifth day too, at full capacity, and the water produced can be stored in a storage tank and it can be used later when the need of thermal power exceeds the well's possibilities, offering an extra output according to necessities. For designing the structure and the component elements we started from the available quantity of geothermal water that is an output of 30 l/s, which can reach 37.5 l/s when using a storage tank which is filled up during the cleaning period of the tanks between the two melting cycles and it is emptied during the melting-drying cycle.

In order to insure a higher degree of flexibility between the instant charge values of the two productive processes (melting-drying) a second storage tank (buffer) should be designed for gathering the geothermal water coming from the drying process, before using it in the melting process.

In this way, the geothermal water coming from the drying tunnel which reaches the shell and tube heat exchangers, where it heats this secondary agent (water supply). The secondary agent is then sent back to the grid exchangers on the bottom of the melting tanks, where it heats the melting water, keeping an average temperature of 36°C and compensating the heat losses that show up during the processes mentioned before.

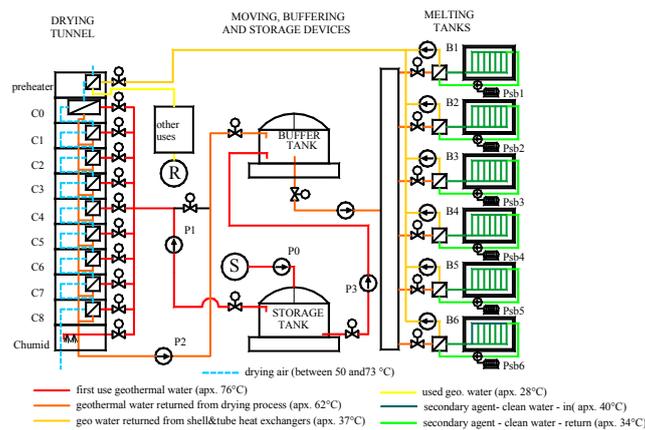


Fig. 1. Functioning diagram of the flax and hemp processing centre

We designed four pumps (P0 – direct link from the well to the collector if the artesian output is too small and we want to increase it, P1 – which extract the geothermal water from the storage tank and sends it to the drying cells’ radiators, P2 – on the return from the drying tunnel’s collector to the buffer tank (geothermal water collector for melting) and P3 – pump for by-passing the drying tunnel, from the storage tank to the buffer tank), in order to obtain the same pressure at the entrance of the three geothermal water outputs to the collector. If there is a high enough pressure in the collector, then pumps Pb1 ... Pb6 are not necessary, only those for circulating the secondary agent Psb1 ... Psb6 being compulsory [4].

3. The description of the automated model

Simulink model which describes the automated functioning of the processing centre of technical plants bears the name *automatizare.mdl*, and the main graphical image is presented in Figure 2. We notice two sub-models which simulate the automated behaviour of the melting tanks, respectively the drying tunnel (*Automation melting* and *Automation drying*), the two block which adjust the geothermal water level of high potential, in tank 1, respectively of medium potential in tank 2 and also a block which describes the pumps’ station.

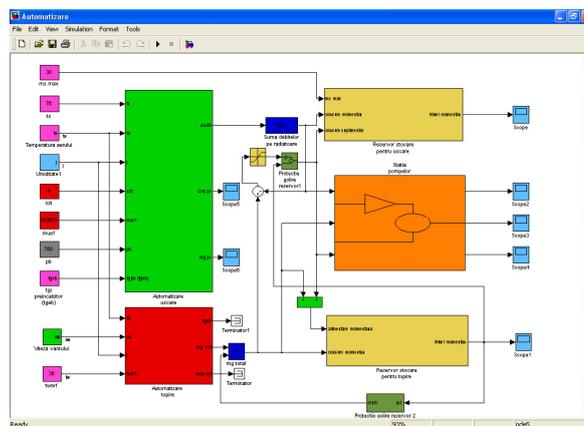


Figure 2: General model for simulating the automated functioning of the centre

Automation drying block has some source blocks for the specific constant values and computes the output for all the tanks; the rest of the calculations are done by the sub-model *Tunnel’s balance sheet* and a block which undertakes the values of computed outputs, meaning those currently necessary and, with the help of an automation block it

orders the opening of the taps from cells' radiators.

In Figure 3 we notice these blocks, one for each tap, from each radiator to the cells 0...8. In the top-right figure is shown the decisional block structure which orders the activation of the taps to differences bigger than 1kg/s between the needed output and the real one. For cells 0...8 there is not need for a complex automation as the cells are not sensitive to environment factors (oscillations in output during one day represent grams per second). The factors to which the output of these cells could be sensitive are the humidity at the entrance, respectively at the exit, but for our model these were imposed, and the fluctuations of the environment factors were taken over by the pre-heater.

The block which takes over the exit from Sub System is mg block (current output of geothermal water). This block is introduced as an entrance dimension in the block for **Current flux supplied while melting** and thus the adjustment loop from the pre-heater is closed.

At the bottom we notice the adjustment loop newly introduced: the heat flux needed for heating the air is compared to the one supplied by the pre-heater and the flux difference should be covered by modifying the geothermal water output at the pre-heater.

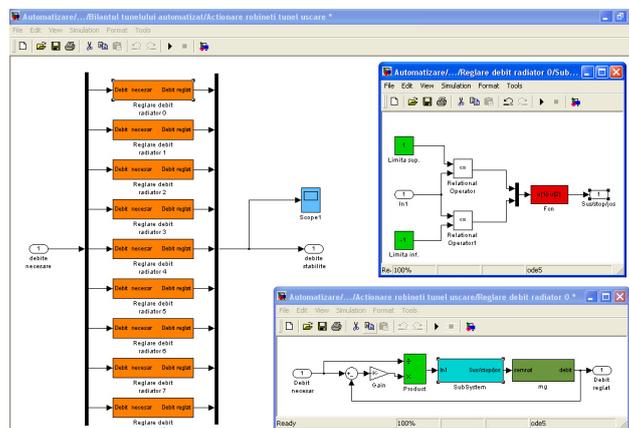


Figure 3: Adjustment model of geothermal water outputs at radiators 0...8

$Dt[^\circ\text{C}/\text{s}]$ block is actually an adjustment element of type PD – see structure in Figure 4 – which takes into consideration both the influence of air mass from the tunnel (as the product between the volume of one cell and the number of cells and air density) and also the influence of the speed of variation in the required heat flux (dictated by weather conditions). The exit value of the block is the speed of variation in the temperature of the air on exit, which by integration leads to the range of instant temperature variation, **Delta t**, which, when added to the reference temperature, gives the instant value of the temperature at the pre-heater's radiator exit. **Delta t** is an entry value in the decision block for the action signal (*SubSystem* – The figure in the previous slide, top-right) which turn on, halts, or turns off the adjustment valve if the momentary value is outside the acceptable variation range.

The block that follows after the *SubSystem* exit is the *mg* block (The instant geothermal water output), consisting of 3 blocks in series as shown in Figure 5. The **start / halt / start in reverse** signal controls the booster, which starts to spin the screw of the spigot rod at 60 rot./min (or 1 rot./sec). We chose spigots with smooth-stepped rods, that climb or drop 1mm for 12 rotations, and the exit of the *Booster Cycle* block is actually the value of its instant cycle, and the exit of the next block is the instant (adjusted) geothermal water output to the pre-heater's radiator. This output is entered in the calculation block *Calc Q of kSdtm* as entrance value and thus the adjustment loop for the pre-heater's radiator is closed.

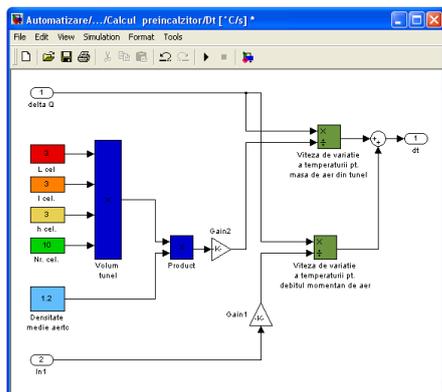


Figure 4: Calculation block for air temperature variation speed at the radiator exit

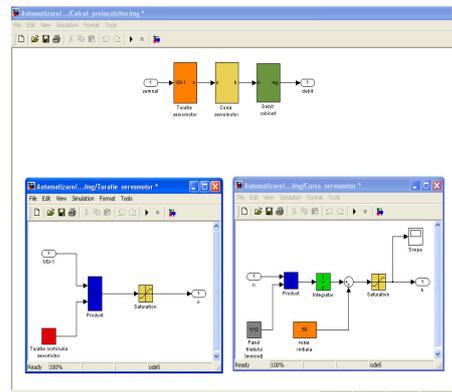


Figure 5: Mg block structure and two of its submodels: revolution and booster cycle

As for the melting tank temperature adjustment block (*Melting automation*), it is illustrated in Figure 6. There is an adjustment loop similar to the one used for the pre-heater. Here also we have a **calculation block for instant flux fed to melter Q_{calc} of $kSDtm$** , with the instant geothermal water output (*mg*) as entrance value. The exit value is the output **Q_{calc}** calculated - for heat exchange reasons - at the exchanger with coated pipes, which is then compared to the lost instant tank flux, derived based on weather conditions and heat exchange with the environment. The next block ($Dt[^\circ C/s]$) takes over this difference and sends an exit signal proportional to the entry (type P element). The temperature variation speed of the water in the melting tanks is directly proportional to the difference between the lost flux and the flux fed to the exchanger and inversely proportional to the mass of water and stalks in the tank. By integrating the variation speed the **Delta t** instant speed variation is obtained, and by adding the reference temperature, the instant temperature is found. The *SubSystem* decision block follows, similar to the adjustment loop for the pre-heater.

The exit from the decision block controls two output adjustment blocks, for geothermal water as well as for the secondary agent which links the exchanger with coated pipes to the grates on the bottom of the tanks. Because it is directly determined by the value of the required *mac* instant secondary agent output, the position of the obturator blades is determined directly, based on the value of the secondary agent output. The delivered outputs are then entered into the delivered heat flux calculation block and thus the adjustment loop for the melting tanks is closed.

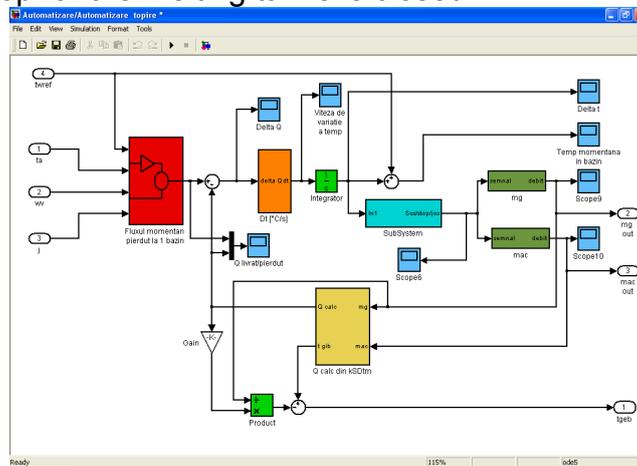


Figure 6: Structure of Automation melting

4. Experimental results of the simulation of automated operation for a winter day, biological phase

The simulation of automated operation of the centre was based on a winter day. The time interval was 24h, meaning 86400s. The chosen solver had a 1s fixed-step, all the system values being calculated 86400 times with the ODE 45 algorithm Dormand-Price variant (the solver was chosen for numeric integration of ordinary differential equations) used for solving differential equation systems. The progress of different parameters of interest can be followed with the help of SCOPE type blocks.

Figure 7 shows the heat flux required in order to maintain the air temperature at 33 °C at the radiator exit (in purple) and the geothermal flux (with a low potential of 38...40 °C) delivered to this radiator (in yellow). One can see that the adjustment system insures a good follow up adjustment, the delivered flux being very close to the required value in any moment of the day.



Figure 7: Required heat flux and the one supplied by geothermal water to the pre-heater

Figure 8 shows the instant air temperature variation on exiting the pre-heater. We have set the accepted limits for temperature variation on exit to the planned value of 33 °C ± 1 °C. One can see that the adjustment system insures a constant instant temperature inside this interval.

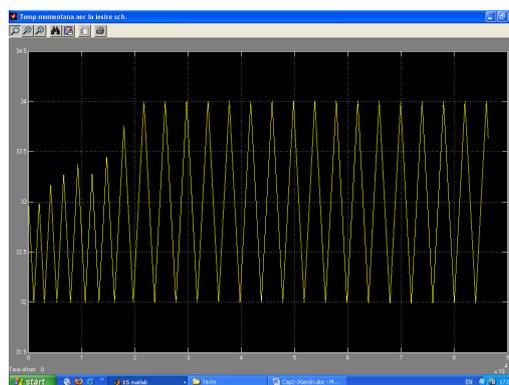


Figure 8: Air temperature variation at the exit from the pre-heater

Of course a tighter limit can be set, ± 0,5 °C for example. But in this case, the number of interventions of the adjustment system will double. For the current simulation we have 49 system interventions in 24 hours, so one operation of the adjustment tap at around 30 minutes. When the accepted temperature variation range is reduced, the time between two operations of the valve will also drop, to a value of approximatively 15 minutes, which in fact is reasonable and does not overwork the operation organs.

Figure 9 shows the moments when the geothermal water tap on the pre-heater radiator is operated. One can see, as was expected, that the average values follow the sinusoidal required variation, and the values of the instant variation amplitudes of the value adjusted to the average value are not too high (slightly higher towards the end of the consumption curve, where system stabilization is more difficult).

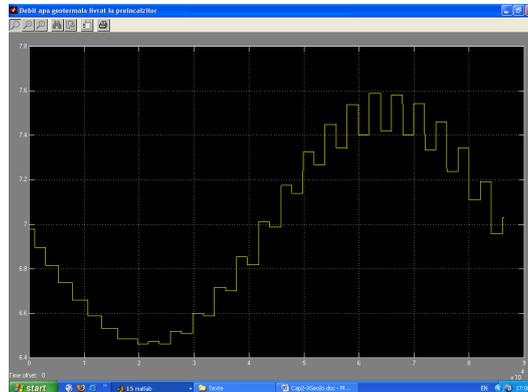


Figure 9: Geothermal water output supplied at the pre-heater

Regarding the melting process, Figure 10 shows the yellow curve which is the required heat flux for a tank, on top of which the is the curve representing the flux delivered by operating the adjustment tap (in purple). One can see that the adjustment system is handling the task of tracking the fluctuations in the required consumption very well, and the variations from the instant required value are very small.

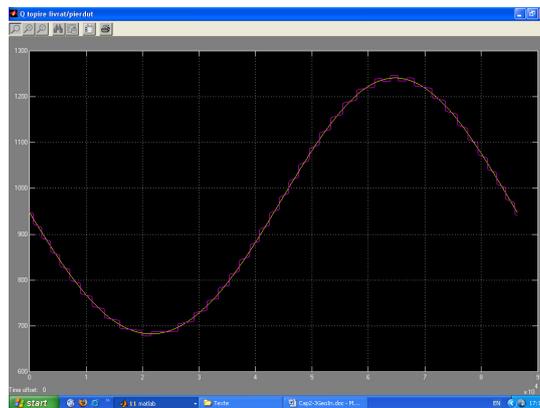


Figure 10: Required heat flux and the one supplied by geothermal water to a melting tank

Figure 11 shows the variation of instant temperature in a melting tank. To an optimal value of 36 °C we set as accepted variation limit a range of $\pm 0,5$ °C. One can see that the adjustment system maintains the temperature between 35,5 and 36,5 °C, but more interventions are required compared to the adjustment system for drying, around 80 in 24 hours, so an intervention every 18 minutes.

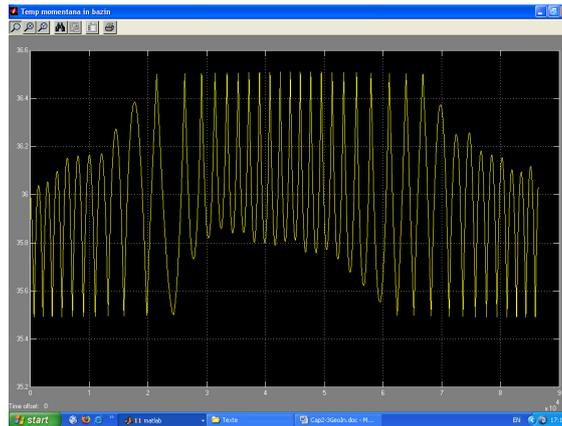


Figure 11: Temperature variation in the tank during one day

Figure 12 shows the Output of used geothermal water. One can see that in this case the adjustment system makes a correct tracking adjustment and does not overwork the operation organ, meaning the booster of the tap and the tap itself. The secondary agent output has the same variation aspect, since it is controlled by the same signal (parallel adjustment), only the absolute values are different.

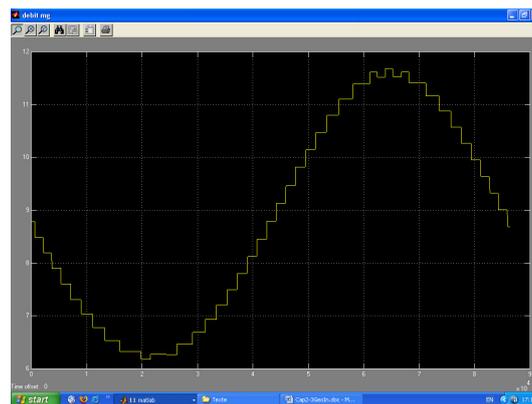


Figure 12: Geothermal water output used at the pipes exchanger from the melting tank

5. Conclusion

The automation model allows the modification of some parameters and performing the simulations in different conditions which will definitely lead to different results, allowing in this way to choose optimum parameters for the automation system. We can also opt for structural changes according to the complexity of the real automation system chosen for building the centre.

The *Automatizare.mdl* automation model simplifies some problems regarding the automated adjustment of technical plants processing centre. Thus, the model starts from the current need of energy for each heat exchanger, then it establishes and orders the activation of the adjustment taps and the extraction pumps, using features of some real circuit elements, as well as inertia elements characteristic to these elements. The outputs resulted from the taps' rods and the modification of extracting pumps rotations are introduced in the thermodynamic calculus of exchangers; in this model they are considered entrance values.

Running different scenarios confirms the model's correct conception in general and of each block in part. Regarding the adjustment system, the simulations show that the system can insure a corresponding tracing adjustment, tracing the disturbing factors fluctuations during one day, without activating too often the execution elements from the

adjustment loops composition, from 5-6 times to two times per hour. The simulation scenarios can confirm the system's immediate answer to variation scale type of one of the parameters (wind speed, or temperature or respectively air humidity). Physically, the adjustment system can be achieved with the help of some elements (adjustment taps, boosters, and available pressure and temperature sensors, rotation speed variation device) which are currently on the market, without the need of special constructions.

The simulations show the viability of the solution with two storage tanks, one between the well and the drying tunnel, the other between the drying tunnel and the melting tanks, as well as the need of a period of accumulation in order to supply an extra output during the four days production cycle. The period necessary for the accumulation is one day for a well's maximum output, which would be necessary anyway for replacing the lots and cleaning the tanks. The simulations also show the necessity of starting a productive cycle with a minimum level of water in the two tanks (minimum 3.5 m out of maximum level of 4.9 m) to be able to cover the top charges during maximum consumption, during the night; the level is restored during the day, when the consumption decreases under the average level.

The automated system has a double mechanism for noticing the critical levels in the tank of water meant for preparing the melting agent, it is activated first when the level in the tanks drops under one meter, by extracting an extra output from the first tank and filling the critical tank, respectively by removing one tank from the melting technological process, when the level drops under 10 cm. The effect on the tank temporary disconnected from the energy source is that of prolonging the melting period, the temperature not being the optimal one. For the first tank we don't have such a system as there is no other source of geothermal water but the well. If needed, the activity of the drying tunnel can be temporarily interrupted.

References

1. Indrie, L., Gherghel, S., Almășan, I.: *Designing the equipment for the melting and drying of flax and hemp using geothermal water*, University of Oradea Annals, Fascicle of Management and Technological Engineering, Volume V (XV), Oradea, 2006.
2. Marinoiu V., Poșchină I., Stoica M.: *Robinete de reglare (Adjustment taps) (ed. a II-a)*, Technical Publishing House, București, 1980.
3. Ștefănescu, D., Leca, A.: *Transfer de căldură și masă. Teorie și aplicații (Heat and Mass Transfer. Theory and Applications)*, Didactical and Pedagogical Publishing House, Bucuresti, 1983.
4. ***: *Curs general de mașini și instalații (General course on machines and installations)*, Didactical and Pedagogical Publishing House, București, 1963.