OPTIMIZING BERRY DRYING USING GEOTHERMAL WATER

Carmen Violeta IANCU[1#], Mariana Florica BEI [1], Manuel Alexandru GITEA[1], Andra Nicoleta LAZĂR[1], Roxana Maria MUREȘAN[2], Romina GABOR [3], Roxana Maria BANFI [4]

[1]University of Oradea, Faculty of Environmental Protection, Oradea City, Maghru 26, 410087, Romania Institution
[2]Student at the Control and Expertise of Food Products specialization, University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048, Oradea, Romania
[3]Student at the Landscaping specialization, University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048, Oradea, Romania

---

Abstract
Geothermal energy is a renewable energy source that can provide heat and power 24 hours a day throughout the year, independently of external factors such as weather and season. This permanent availability makes it an attractive complement to the mixed energy source. In addition, this source of energy is almost inexhaustible and available all over the globe.

The present paper aims to study optimization by regulating the drying of berries using geothermal water. Optimization within the system itself aims to examine which of the methods used in applying geothermal energy to existing technological equipment is more efficient.

Keywords: optimization, geothermal water, regulation, control system
#Corresponding author: ciancu2000@yahoo.com

INTRODUCTION

The possible areas of use of geothermal energy are numerous (Figure 1) [Popovska.'00]. Basically, wherever a relatively low temperature is required (below 150°C), it can be obtained from geothermal water. Depending on the structure of the industrial process, the use of geothermal energy can be independent or in combination with heat energy of other origin (fossil fuel, electricity, bioenergy, etc.)

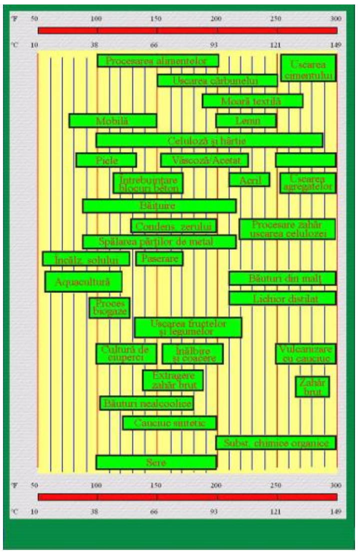

Figure 1**. Use of geothermal energy for industrial and agricultural processes**

BASIC INDUSTRIAL PROCESSES WITH GEOTHERMAL ENERGY APPLICATIONS

In industrial applications, geothermal energy provided by geothermal fluid with a temperature below 150°C is used in basic processes including [Popovska.'00]:

Preheating; laundering; Peeling; evaporation; distillation; sterilization; drying; freezing. (Sanner, 2006, Denis Marcotte et al, 2008, Setel A, 2008).

Specific elements of geothermal technology for industrial applications.

The technological complex for the operation of a geothermal system in industrial applications comprises two main parts. (C. Pantea et al., 2010, Setel, 2008, Zierler, 2008)

The first part includes the general elements of geothermal systems and these are: geothermal well, connector to the geothermal well or a distribution network, fluid transport pipes, equipment for chemical water treatment and a heat exchanger system.

The second part consists of specific elements for industrial applications of geothermal energy; These are:

– steam extraction system;

– geothermal fluid climbing system;

– equipment for modifying the working parameters (pressure, temperature and flow);

– processing devices for the implementation of technological processes.

In order to use geothermal energy as an energy source in industrial processes, due to the physico-chemical properties of the geothermal fluid, materials corresponding to the properties of geothermal water must be provided in the construction of the equipment specific to the respective installations in order to avoid corrosion. (Setel A, 2008, Y. Babi et al, 2008).

Geothermal fluids with high salinity will cause high and uniform and localized corrosion, and will greatly limit the use of carbon steels. The use of "soft" steels in geothermal environments requires precautions: measures must be taken for deaeration, flow, fluctuations, protection of external surfaces. (Setel A, 2008).

If the required precautions are taken, carbon steels can be used for thick-walled installations for most geothermal fluids. Thin-walled installations will be limited due to the danger of the material being affected by corrosion or cracking.

Optimization of industrial applications based on geothermal energy

The industrial applications of geothermal energy will follow two directions in development:

1. In the use of existing plants and equipment, and
2. In the construction of new installations and more complex technologies, adapted to the use of this type of energy. (Alejandro H et al, 2006, Setel A, 2008).

In the first case, optimization should be seen as a tool to examine the economic advantages of using geothermal energy compared to classical energy resources. This optimization is determined both temporally and spatially. Optimization within the system itself aims to examine which of the methods used in applying geothermal energy to existing technological equipment is more efficient. There are two methods: (A. Bara, 2001, F. S. Blaga, 2008, Danfoss, 1986, . Setel A, 2008)

– direct use of chemically treated geothermal fluid;

– the use of heat exchangers that use geothermal fluid to heat the secondary circuit.

Efficiency plans must include certain changes in the technological process, in order to allow the use of geothermal energy while ensuring a maximum level of energy. (Ahmed Maidi, et al, 2009, Danfoss, 1986, Setel A, 2008)

In the second case, optimization must include the mathematical analysis of the large number of decisive factors in the development of a particular industrial technology. The most important of these factors are: the parameters of the geothermal fluid; its chemical structure; the quality and price of the installations; the parameters and regime of the technological process itself.

Environmental protection equipment should also be considered (Angel Vidal et al, 2010, Setel A, 2008).

The industrial use of geothermal energy is still in its infancy in Europe. However, the existence of geothermal fields, as well as insufficient conventional energy resources, pose the challenge for future investigations in this field. The quality of geothermal resources available in Europe dictates the use of this type of energy in low-temperature technological processes. These processes are significantly present in different branches of industry, the concern for their diversification being entirely legitimate. (Eui-Jong Kim, et al, 2010, Setel A, 2008).

MATERIAL AND METHOD

However, checking the correct operation of the automation program is only possible when the system is in operation. However, this involves numerous experiments that are costly and time-consuming. For this reason, the simulation program is particularly useful both for the design of the automation program and for its verification.

System management block diagram (fig 2)

– The main objective of the simulation program is to verify the automation program and, in particular, to study the behavior of the installation parameters in the event of disturbing factors. (A. Zavala-Río et al, 2009, Setel A, 2008).

– Another objective is to determine the constants of the PID (Proportional, Integrative, Derivative) regulators. For different values of the PID constants, the response of the system to disturbances will also be different.

By running the simulation program with various values of the PID constants, those values for which the system response is optimal can be retained for implementation in the automation program. (Astrom K. J., 2002, Setel A, 2008).

– A secondary objective in the context of this work, but very important during the operation of the installation, consists in the training and verification of the personnel who serve the pre-drying-drying installation.

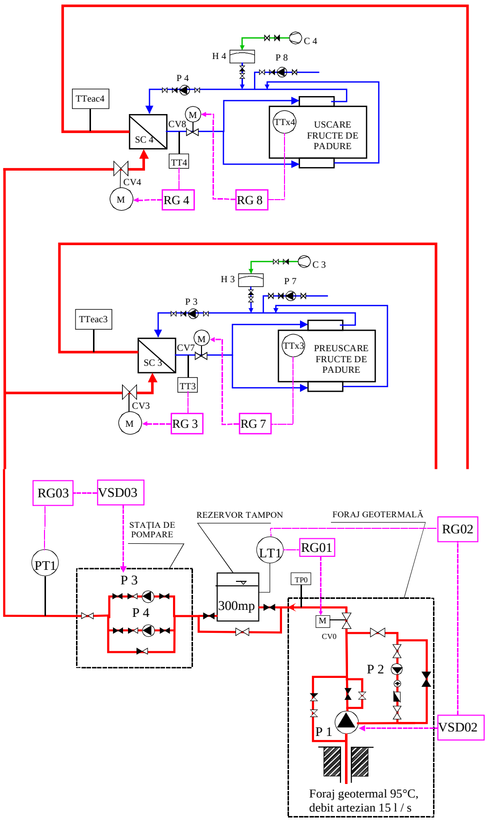

Figure 2 **System Driving Block Diagram**

Thus, thanks to the configuration that will be presented below in figure 3, the trained person can follow the operation of the pre-drying-drying plant on computer 2, on the right side where, through the InTouch graphical interface, the diagram of the plant with the parameters to be followed is displayed. The same image will exist for the plant in operation but, in the case of simulation, the real-time signals are replaced by the mathematical model, written in ACSL-GM on computer 1 on the left side. The examiner, located at computer 1, can simulate any operating scenario, then follow the reaction of the examined person.

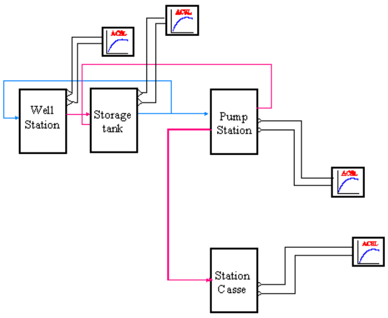

Figure 3 **Block scheme corresponding to the pre-drying-drying complex**

The required flow rate is ensured by the commands given by the RG03, RG02, RG01 regulators, depending on the pressure in the system, measured by the PT1 pressure transducer.

It is noted that the management strategy is unitary, consisting of seven regulators that function unitarily, integrated for the proper functioning of the system. The establishment of the PID constants of the 7 regulators as well as their connection will continue to be carried out.

1. The regulation scheme for obtaining the hot air preparation agent, necessary for the technological process of drying berries

The block diagram with the automation loops of the system for obtaining the hot air preparation agent, necessary for the technological process of pre-drying berries is shown in figure 4.

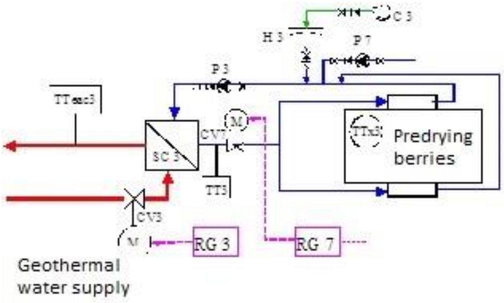

Figure 4 **Conduction block scheme for obtaining the hot air preparation agent, necessary for the technological process of pre-drying berries**

2. Diagram of the driving block for obtaining the hot air preparation agent, necessary for the technological process of drying berries (Fig.5.)

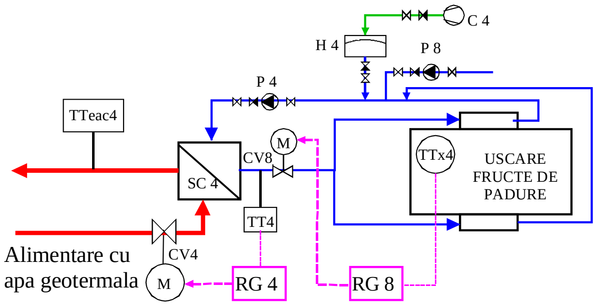

Figure 5 Driving block scheme for obtaining the hot air preparation agent, necessary for the technological process of drying berries

The hot air inlet temperature tx3 is measured by the TTx3 temperature transducer. Due to various disturbing causes, the temperature tx3 may change from its nominal value (50±2°C), which requires it to be brought back within the limits allowed by the control given by the RG7 controller to the CV7 electrically operated valve. (C. Popescu et al, 2001, Setel A, 2008).

The inlet temperature of the secondary agent into the berry drying plant t3 is measured by the TT3 temperature transducer. Due to various disturbing causes, the temperature t3 may change compared to its nominal value (55 ±2°C), which requires it to be brought back within the limits allowed by the command given by the RG3 regulator to the CV3 electrically operated valve (the geothermal water supply flow is modified). (Z. Liao et al, 2005Setel A, 2008).

The differential equations that define the process are written, successively determining the opening of the tap CV3 (h), the flow of geothermal water passing through the tap and, finally, the inlet temperature of the secondary agent in the berry drying plant (t3), respectively the outflow temperature of the geothermal water teac3 measured by the temperature transducer TTeac3. The calculation is performed for each moment of the process until it is stabilized, and the simulation program allows the plot of the evolution of the monitored parameters to be traced in real time. (Crispin Allen, 1990, Setel A, 2008).

RESULTS AND DISCUSSIONS

After the implementation of the program for simulating the operation of the berry pre-drying-drying plant, it was run, in order to achieve the proposed objectives (verification of the proposed management system and granting of PID regulators). As a result of the simulation, taking into account different simulation scenarios and matching the data obtained with the data resulting from the analysis of the operation of the experimented subsystems, it was possible to grant the PID regulators. Some scenarios that were taken into account in the study are presented below. (Y. Babi, et al, 2007Setel A, 2008).

Through the simulation program, it was determined how to get to steady mode at the start-up of the berry pre-drying-drying plant, after which the parameters corresponding to the RG1, RG2, RG3, RG4 regulators were modified so that the time needed to reach the stationary regime would be in accordance with the functional parameters resulting from the practice. (Curtis D.J. 1988, Setel A, 2008).

1. Transitional regime for the berry drying plant

Figure 6 shows the evolution of the main parameters, until the steady state is reached, namely the temperature t3 (measured by TT3) of the outlet of the secondary agent from the heat exchanger (IPUFPTT3), the temperature teac3 (measured by TTeac3) of the outlet of the geothermal water from the heat exchanger (IPUFPTTEAC3), given that the temperature in the drying chamber tx3 (measured by TTx3) is 50°C (IPUFPTTX3).

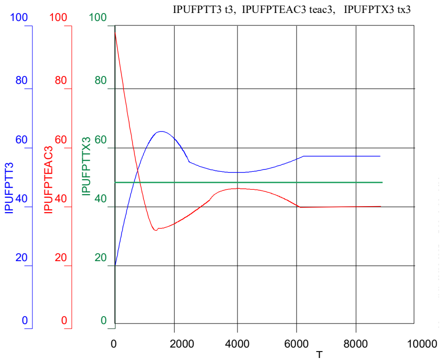

Figure 6 Evolution of the output temperatures of the primary and secondary agents for Berry drying plant until steady state is reached (at start-up)

It is found that the regime stabilizes after approximately 6,200 seconds (105 minutes), which corresponds to the data provided by practice. In this case, the parameters at which the regime is stabilized are 55°C for the secondary agent and 40°C for geothermal water.

2. Transitional regime for the berry drying plant

Figure 7 shows the evolution of the main parameters, until the steady state is reached, namely the temperature t4 (measured by TT4) of the outlet of the secondary agent from the heat exchanger (IUFPTT4), the temperature teac4 (measured by TTeac4) of the outlet of the geothermal water from the heat exchanger (IUFPTTEAC4), given that the temperature in the drying chamber tx4 (measured by TTx4) is 70°C (IPUFPTTX4).

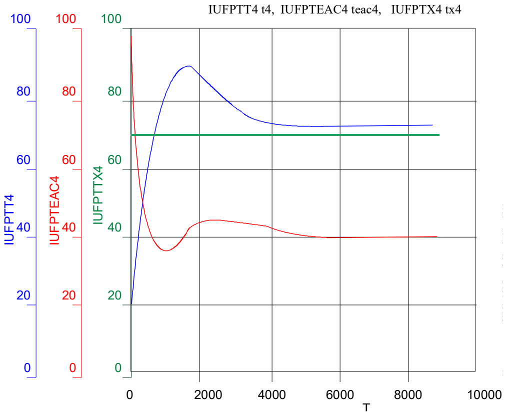

Figure 7 Evolution of the output temperatures of the primary and secondary agents for Berry drying plant until steady state (start-up)

Transitional regime in the event of disturbances for the pre-drying plant

Berries

It is considered the situation in which the temperature in the berry drying room drops from 50°C to 45°C, due to accidental opening of the door. In this situation, the TTx3 temperature transducer, which measures the temperature in the drying chamber, transmits the signal to the RG7 controller, which commands the opening of the CV7 valve, increasing the flow of secondary agent and, consequently, the temperature t3 decreases. The TT3 temperature transducer transmits the signal to the RG3 controller which commands the unplugging of the CV3 tap, increasing the flow of geothermal water. The control process (control of the CV3 and CV7 valves by the RG3 and RG7 controllers) is carried out until the temperature in the room stabilizes at 50°C.

Figure 8 shows the evolution of the main parameters, up to the steady state, namely the temperature t3 (measured by TT3) of the outlet of the secondary agent from the heat exchanger (IPUFPTT3), the temperature teac3 (measured by TTeac3) of the outlet of the geothermal water from the heat exchanger (IPUFPTTEAC3), the temperature tx3 (measured by TTx3) from the drying chamber (IPUFPTTX3)

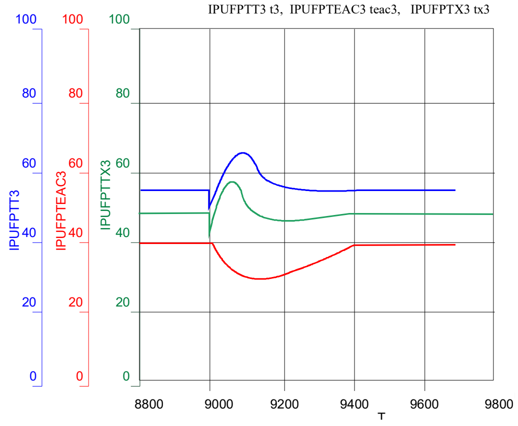

Figure 8 Evolution of the output temperatures of the primary and secondary agents for the berry drying plant until the steady state is reached (when disturbances occur

It is found that the regimen stabilizes after about 500 seconds (8.3 minutes), which corresponds to the data provided by practice. In this case, the parameters at which the regime is stabilized are: 50°C for the temperature in the enclosure, 55°C for the secondary agent and 40°C for geothermal water.

Transitional regime in the event of disturbances for the berry drying plant

Figure 9 shows the evolution of the main parameters, until the steady state is reached, namely the temperature t4 (measured by TT4) of the outlet of the secondary agent from the heat exchanger (IUFPTT4), the temperature teac4 (measured by TTeac4) of the outlet of the geothermal water from the heat exchanger (IUFPTTEAC4), the temperature tx4 (measured by TTx4) from the drying chamber (IUFPTTX4).

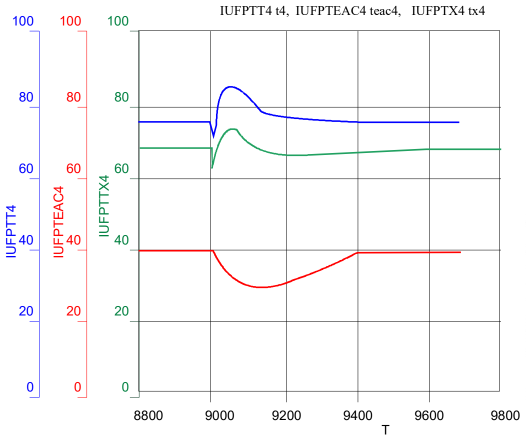

Figure 9 Evolution of the output temperatures of the primary and secondary agents for the plant drying of the berries until the steady state is reached (when disturbances occur)

CONCLUSIONS

Regarding the operation of the "berry drying" module, it is noted:

– at start-up, the system stabilizes in one hour and 48 minutes. The regulators that control the operation of the module are RG3 and RG7, the RG7 regulator ensures the control over the necessary flow of secondary agent (by the command given to the CV7 electrically operated valve) for the constant maintenance of the temperature in the drying chamber (the temperature value in the drying chamber is obtained from the ttx3 temperature transducer). The values at which the system stabilizes are:
TTX3=50,2˚C; TT3=54,8˚C; TTac=44˚C .

– in the event of a disturbance where the temperature in the pre-drying room decreases by 5°C (from 50.2°C to 45°C, possibly caused by accidentally opening the door of the pre-drying system), the system stabilises relatively quickly, 23 minutes.

The adjustment loops that intervene in this case are: TX3÷RG7÷CV7, respectively. TT3÷RG3÷CV3

In this case, the values at which the system is stabilized are: TTx2=50°C;

REFERENCES

Ahmed Maidi, Moussa Diaf, Jean-Pierre Corriou: Boundary geometric control of a counter-current heat exchange. Journal of Process Control nr.19, 2009, pg. 297–313, ELSEVIER;

Alejandro H. González, Darci Odloak, Jacinto L. Marchetti: “Predictive control applied to heat-exchanger networks. Chemical Engineering and Processing nr.45, 2006, pg. 661–671, ELSEVIER

Angel Vidal, Alfonso Bãnos: “Reset compensation for temperature control: Experimental application on heat exchangers” in Chemical Engineering Journal nr.159, 2010 pg. 170–181, ELSEVIER;

Astrom K. J., Control System Design, Lund Institute of Technology, 2002.

Babi Y., A. Dobbi, M. Saighi, B. Bouchekima: “Heating an agricultural greenhouse by using geothermal energy” in Revue des Energies Renouvelables CER’07 Oujda, 2007, pg.265-268;

Bara A. Sisteme Fuzzy, Aplicaţii la Conducerea Proceselor, Ed. U.T. Press Cluj-Napoca, 2001, ISBN 973-9471-75-7;

BurkhardSanner: Geothermal energy opportunities for desert regions in Global Conference on Renewable Energy Approaches for Desert Regions, Amman, Jordan 2006

Crispin Allen (1990): Programmable Logical Controllers and Their Engineering Applications, McGraw Hill, 1990.

Curtis D.J. (1988): Process Control Instrumentation Technology, Prentice Hall International, 1988.

Danfoss (1986): Modulating pressure and temperature regulators, RK.09.A1.02, Danfoss Nordborg, Denmark, 1986.

Denis Marcotte, Philippe Pasquier: “Fast fluid and ground temperature computation for geothermal ground-loop heat exchanger systems” in Geothermics nr.37, 2008 pg. 651–665, ELSEVIER;

Elena Zierler: “Geothermal energy an alternative for Romania” in AnaleleUniversităţii din Oradea, Seria Geografie, Tom XVIII, 2008, pag. 140-143

Eui-Jong Kim, Jean-Jacques Roux, Gilles Rusaouen, Frederic Kuznik: “Numerical modelling of geothermal vertical heat exchangers for the short time analysis using the state model size reduction technique” in Applied Thermal Engineering nr.30, 2010, pg. 706–714, ELSEVIER;

F. S. Blaga,: “Teoria Sistemelor şi Reglaj Automat”, ed. Universităţii din Oradea, 2009 ISBN978-973-759-807-3;

Liao Z, A.L Dexter: “An experimental study on an inferential control scheme for optimizing the control of boilers in multi-zone heating system” in Energy and Buildings nr. 37, 2005, pg. 55–63, ELSEVIER

Pantea C., G.M. Rosca, C. A. Blaga, Power generation from low enthalpy geothermal resources” in Journal of sustenable energy, vol.1, nr.2 (2010);

Popescu C., D .Popescu, S.Dale: ngineria Reglării Automate, Ed. Universităţii din Oradea 2001, curs.

Setel A. Utilizarea energiei geotermale în silvicultură, Teză de doctorat, 2008

Zavala-Río A, C.M. Astorga-Zaragoza, O. Hernández-González: “Bounded positive control for double-pipe heat exchangers” in Control Engineering Practice nr.17, 2009, pg. 136-145, ELSEVIER;