OPTIMIZATION OF THE WOOD DRYING PROCESS USING GEOTHERMAL WATER

Carmen Violeta IANCU, Mariana Florica BEI, Camelia Mihaela BARA, Lucian Vasile BARA, Ionel Marius OȘVAT, Isabel Andromeda DAVID*

12345University of Oradea, Faculty of Environmental Protection, Oradea City, Magheru 26, 410087, Romania Institution

*Student at the Control and Expertise of Food Products specialization, University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048, Oradea, Romania

Abstract

Geothermal energy is a renewable resource capable of delivering heat and electricity continuously, regardless of external conditions such as weather or season. Its constant availability makes it a valuable addition to a diversified energy mix. Moreover, geothermal energy is practically inexhaustible and can be accessed in many regions across the globe.

The present paper aims to investigate optimization strategies for the drying of the wood by regulating the use of geothermal water. The objective is to determine which method of integrating geothermal energy into existing technological equipment offers the highest efficiency.

Keywords: optimization, wood drying, geothermal water, regulation, control system

INTRODUCTION

The natural heat stored in the Earth's crust gives rise to geothermal energy, which may be of low or high temperature. Theoretically, low-temperature geothermal energy can be accessed anywhere in the world due to the natural increase in temperature with depth (approximately 3°C per 100 m). High-temperature geothermal energy is characteristic of volcanic areas. In contact with hot rocks, underground water can reach temperatures of several hundred degrees, often undergoing partial vaporization; this heat source can then be harnessed in a power plant.

An artificial geothermal option consists of using the heat of magma that has infiltrated certain areas close to the surface, at depths of about 2,000–7,000 m. In this case, wells are drilled and water is injected, producing superheated steam. (Åström K. J., 2002; Setel A., 2008)

Geothermal energy has applications in a wide range of fields, such as the use of hot water for domestic, commercial, or industrial needs, heating and cooling systems, and electricity generation through the conversion of high-pressure steam. Since geothermal resources are relatively constant, they can be used to meet energy demands both under normal operating conditions and during peak load periods.

Worldwide, geothermal power plants have a total installed capacity of over 8,000 MW. Systems that convert geothermal energy can supply electricity with an annual capacity factor of over 90%.

In Romania, hydrogeothermal resources (extracted through drilling) include low-enthalpy geothermal systems (with temperatures between 25°C and 60°C in deep aquifers) and medium-temperature geothermal systems (from 60°C to 125°C in mesothermal waters). Low-enthalpy geothermal resources are used for heating and domestic hot water production in individual households, social services (offices, education, commercial and community spaces, etc.), the industrial sector, and agricultural facilities (greenhouses, solariums, livestock farms, etc.). (Åström K. J., 2002; Setel A., 2008)

Romania's currently exploitable geothermal energy reserve is approximately 167 thousand toe (7,000 × 10^6 GJ/year). The amount of equivalent energy produced and delivered at the wellhead is about 30.171 thousand toe (1,326 × 10^6 GJ/year), with an average annual utilization rate of 22.3%.

The economic drilling and extraction limit for geothermal waters has been set at a depth of 3,300 m, a threshold that has been reached in certain areas of Romania, such as the Bucharest North–Otopeni geothermal basin and specific zones within the localities of Snagov and Balotești.

In 2003, Romania had 70 operational wells supplying local heating and domestic hot water needs (with temperatures above 60°C) for residential complexes, public or industrial buildings, and agricultural facilities in various regions. Additionally, 45 wells with certified energy potential are currently preserved or held in reserve. (Åström K. J., 2002; Setel A., 2008)

The operating lifetime of the existing installations exceeds 20 years, and the materials and equipment used exhibit significant physical and technological wear. The management of geothermal energy consumption (billing of delivered/used energy) is carried out on a flat-rate basis, relying on periodic readings of wellhead parameters with industrial-grade instruments, due to the absence of proper meters or the use of low-precision equipment.

The degree of utilization of geothermal energy resources in Romania remains low, primarily because of insufficient financial support needed to foster the development of this energy sector, which has the potential to generate substantial economic benefits.

MATERIAL AND METHOD

The primary purpose of geothermal installations is to prepare the thermal agent for transport to the consuming systems and then return it to the heat source. The specific equipment used depends on the nature and parameters of the thermal agent, as well as the intended thermal applications. (Åström K. J., 2002; Setel A., 2008)

When steam is used as the thermal agent, the basic equipment includes steam collectors, measuring, control, and regulation devices for the thermal agent parameters (pressure, temperature, flow rate), condensate collection tanks, and pumps for condensate removal.

For the use of hot water or warm water as the thermal agent, the main equipment consists of heat exchangers for heating, heat exchangers for domestic hot water preparation, circulation pumps, softening stations, expansion vessels, valves, automation and control systems, and corrosion protection installations.

Verifying the correct functioning of the automation program is possible only when the system is operating, which requires numerous experiments that are both costly and time-consuming. For this reason, the simulation program becomes particularly valuable, serving not only in the design of the automation logic but also in its validation.

System management block diagram (Fig. 2)

– The primary purpose of the simulation program is to validate the automation program and, in particular, to analyze the behavior of installation parameters under various disturbance conditions (A. Zavala-Río et al., 2009; Setel A., 2008).

– A further objective is to determine the constants of the PID (Proportional, Integral, Derivative) controllers. Different sets of PID constants will produce different system responses when disturbances occur. By running the simulation repeatedly with various PID values, one can identify the optimal parameters to be implemented in the actual automation program (Åström K. J., 2002; Setel A., 2008).

– A secondary, yet operationally important objective is the training and assessment of personnel who operate the pre-drying and drying installation, for whom the simulation provides a safe and practical learning environment.

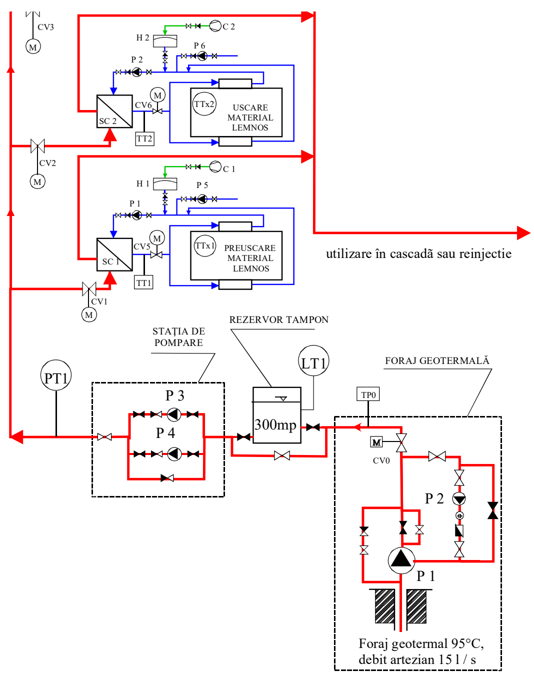

Figure 2 System Driving Block Diagram

With the configuration shown in Figure 3, the trainee can monitor the operation of the pre-drying and drying installation on Computer 2, where the InTouch graphical interface displays the system diagram and all relevant parameters. In actual operation, the same interface is used, but during simulation the real-time signals are replaced by the mathematical model developed in ACSL-GM and run on Computer 1. The evaluator, positioned at Computer 1, can generate any operating scenario and then observe the trainee's responses.

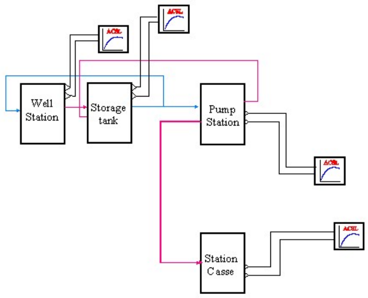

Figure 3 Block scheme corresponding to the pre-drying-drying complex

The required flow rate is maintained through the commands issued by the RG03, RG02, and RG01 controllers, based on the system pressure measured by the PT1 pressure transducer.

It should be emphasized that the control strategy is unified, consisting of seven interdependent regulators integrated to ensure the proper functioning of the entire system. The determination of the PID constants for these seven regulators, as well as the configuration of their interconnections, will be addressed further.

1. Regulation scheme for obtaining the hot-air preparation agent required in the wood-drying process

The block diagram illustrating the automation loops for generating the hot-air preparation agent used in the pre-drying stage of wood is presented in Figure 4.

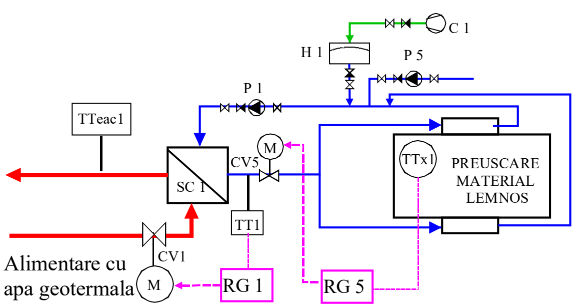

Figure 4 Conduction block scheme for obtaining the hot air preparation agent, necessary for the technological process of pre-drying wood

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

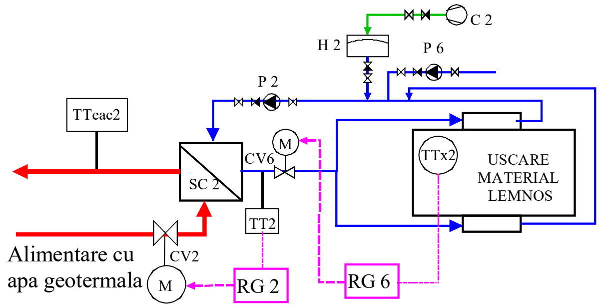

Figure 5 Driving block scheme for obtaining the hot air preparation agent, necessary for the technological process of wood drying

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 wood 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 wood 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 implementing the simulation program for the operation of the wood and wood pre-drying/drying installation, the program was executed in order to achieve the proposed objectives (verification of the proposed control system and tuning of the PID controllers). As a result of the simulation, considering various operating scenarios and correlating the obtained data with those resulting from the analysis of the tested subsystems, the PID controllers were successfully tuned. Below are several scenarios taken into account in the study.

a. Transient operating regime during the start-up of the wood and wood pre-drying/drying installation

Using the simulation program, the method by which the system reaches steady-state conditions at start-up was determined. After this, the parameters corresponding to controllers RG1, RG2, RG3, and RG4 were adjusted so that the time required to reach steady state would match the functional parameters observed in practice.

a.1. Transient regime for the wood pre-drying installation

Figure 6 shows the evolution of the main parameters until steady-state conditions are achieved, namely the temperature t1 (measured by TT1) at the outlet of the secondary agent from the heat exchanger (IPUMLTT1), and the temperature teac1 (measured by TTeac1) at the outlet of the geothermal water from the heat exchanger (IPUMLTTEAC1), under the condition that the temperature inside the pre-drying chamber tx1 (measured by TTx1) is 60°C (IPUMLTTX1). It can be observed that the regime stabilizes after approximately 7,200 seconds (120 minutes), a duration consistent with practical data. In this case, the steady-state parameters reach 65°C for the secondary agent and 50°C for the geothermal water.

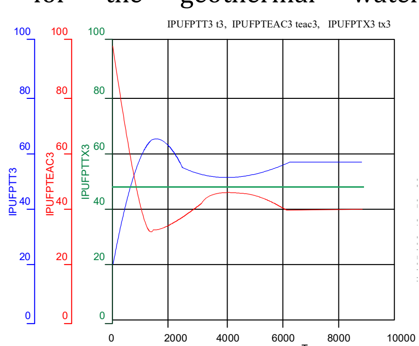

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Figure 6 Evolution of the outlet temperatures of the primary and secondary agents for the wood pre-drying installation until reaching steady-state conditions (at start-up).

ransient operating regime for the wood-drying installation

Figure 7 illustrates the evolution of the main parameters until steady-state conditions are reached, namely: the temperature t2 (measured by TT2) at the outlet of the secondary agent from the heat exchanger (IUMLTT2), the temperature teac2 (measured by TTeac2) at the outlet of the geothermal water from the heat exchanger (IUMLTTEAC2), under the condition that the temperature inside the drying chamber tx2 (measured by TTx2) is 80°C (IUMLTTX2). It can be observed that the system stabilizes after approximately 6,000 seconds (100 minutes), a duration consistent with practical data. In this case, the steady-state parameters reach 85°C for the secondary agent and 60°C for the geothermal water

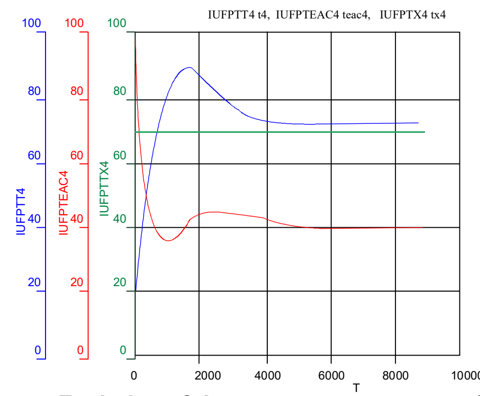

Figure 7 Evolution of the output temperatures of the primary and secondary agents for wood drying plant until steady state (start-up)

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

It is considered the situation in which the temperature in the wood 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)

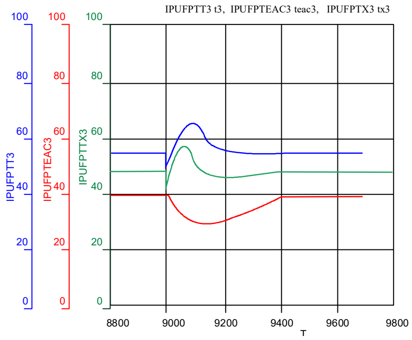

Figure 8 Evolution of the output temperatures of the primary and secondary agents for the wood drying plant until the steady state is reached (when disturbances occur

Figure 9. illustrates the evolution of the main parameters until steady-state conditions are reached, namely the temperature t1 (measured by TT1) at the outlet of the secondary agent from the heat exchanger (IPUMLTT1), the temperature teac1 (measured by TTeac1) at the outlet of the geothermal water from the heat exchanger (IPUMLTTEAC1), and the temperature tx1 (measured by TTx1) inside the pre-drying chamber (IPUMLTTX1). It can be observed that the system stabilizes after approximately 600 seconds (10 minutes), a duration consistent with practical data. In this case, the steady-state values are: 60°C for the chamber temperature, 65°C for the secondary agent, and 50°C for the geothermal water.

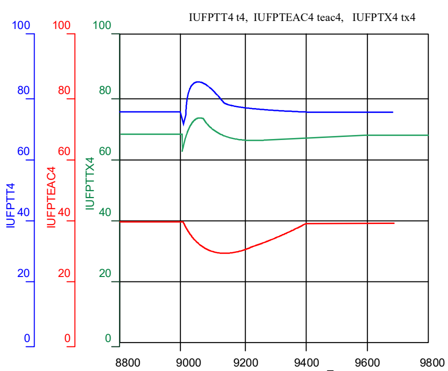

Figure 9 Evolution of the output temperatures of the primary and secondary agents for the plant drying of the wood until the steady state is reached (when disturbances occur)

CONCLUSIONS

The main objectives of the simulation program were the verification and qualitative validation of the proposed control strategy for the wood pre-drying/drying installation, by analyzing the behavior of the parameters that define its operation, as well as determining the parameters of the PID controllers used. The corresponding values of the controller parameters can be viewed by consulting the.CSL source program presented in Annex 5.

In this context, the control loops corresponding to the physical processes were analyzed, and the mathematical models of the associated component equipment were detailed. After identifying the appropriate start-up conditions for the wood pre-drying/drying installation and the potential disturbances that may occur, the simulation program was tested by examining several variants, each variant having different sets of start-up conditions and considered disturbances. Each action essentially has a stabilizing effect.

For the variants presented, the values of the controller parameters that will initially be used in the automation program were selected. Their final values will be established only during the commissioning of the designed installation.

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