# RESEARCH ON OPTIMIZING THE AUTOMATION OF A COMPLEX OF GREENHOUSES THAT USE GEOTHERMAL ENERGY FOR HEATING

**Carmen Violeta IANCU[1], Andra Nicoleta Lazăr[1]**

*[1]University of Oradea, Faculty of Environmental Protection, Oradea City, Maghru 26, 410087, Romania Institution*

RESEARCH ARTICLE

**Abstract**

*This paper presents studies and researches on problems related to optimizing the automatic regulation of a greenhouse complex that uses the thermal energy of geothermal waters with moderate temperatures. In order to ensure the proper functioning of the thermal energy installation for the greenhouse complex, it is necessary to develop an automation program to track and adjust its functional parameters.*

**Keywords**: geothermal water; greenhouse; automation loop.

## INTRODUCTION

Geothermal energy refers to the energy contained in the form of heat within the Earth. The origin of this heat is related to the internal structure of our planet and the physical processes that manifest within it. Despite the fact that this heat is present in huge quantities, it is distributed irregularly and often at depths too great to be exploited industrially.

Sometimes, however, it can concentrate in certain areas, which can become such economic interest for their investigation.

Geothermalism addresses all problems related to the study, identification, exploitation and use in conditions of maximum efficiency of geothermal deposits. A geothermal deposit can be described schematically, as Hochstein defines it, as "convection water in the upper crust of the Earth, which in a limited space transfers heat from a deep heat source to an accumulation reservoir and which is usually the free surface of the planet.". (Elena Zierler: 2008, J. W. Tester et all, 2006, Kailash N. et all, 2008, Marcel Rosca: 2007)

So, a geothermal deposit is made up of three elements: a heat source, a reservoir and a fluid that constitutes the transport element that transfers heat. Given the complexity of the approached issues, geothermalism presents itself as a complex, interdisciplinary system, appealing to specialists in the field of geology, well drilling, energetics, agronomy, medicine,etc. (Elena Zierler: 2008, J. W. Tester et all, 2006, Kailash N. et all, 2008, Marcel Rosca: 2007)

It can be considered that current concerns can be directed in the following areas:

a) The origin of geothermal energy as a result of terrestrial thermal energy;

b) Determination of geographical areas with geothermal potential;

c)Exploitation of geothermal deposits;

d)Direct and indirect use of geothermal deposits;

e) Economic and ecological aspects.

a) The origin of geothermal energy as a result of terrestrial thermal energy must be viewed through the prism of multiple scientific disciplines. An important role from this point of view belongs to the theory of global tectonics, which allowed the finding that the surface of the planet is covered by a mosaic of lithospheric plates, and their nature and motion determine, among other things, the thermal field of the Earth. (Elena Zierler: 2008, J. W. Tester et all, 2006, Kailash N. et all, 2008, Marcel Rosca: 2007)

b) The determination of geographical areas with geothermal potential refers to the establishment, precisely, of areas with usable geothermal potential, from all existing geothermal reserves. The geothermal resource base represents the totality of geothermal energy in the earth's crust below a particular region (usually up to a depth of 10 km.), relative to the average annual temperature. The resource base comprises: inaccessible resource base, accessible resource base, useful accessible resources base, residual accessible resources base. Resources, in turn, are economically divided into: subeconomic resources, economic resources, undiscovered economic resources and identified economic resources. (Elena Zierler: 2008, J. W. Tester et all, 2006, Kailash N. et all, 2008, Marcel Rosca: 2007)

c) The exploitation of geothermal deposits refers mainly to production and reinjection wells as well as drilling methods, a field of research very close to the drilling of oil and natural gas wells.

(d) The use of geothermal deposits shall include all possibilities for harnessing the energy of geothermal deposits for community purposes. Among the uses of geothermal energy we mention: electricity production, central heating systems, industrial uses, agricultural uses (especially greenhouse heating, fish farming and aquaculture), balneology, etc.

e) Economic and ecological aspects address the issue of efficient use of geothermal water energies from the point of view of economic efficiency as well as from the point of view of environmental impact.

The imposition of geothermal energy as a viable alternative to fossil fuels was supported by the technical and economic advantages it presents by the fact that 80 countries have significant geothermal resources. (Elena Zierler: 2008)

The uses of this energy resource are based as a general principle on capturing caloric energy from reservoir waters and using it directly, as a heat source or indirectly by converting it into electricity. Compared to other energy sources, geothermal energy has three defining characteristics:

1. it is renewable in principle, which makes it practically inexhaustible under certain conditions;

2. it is clean, and therefore with negligible impact on the environment;

3. It is a latent caloric energy that already exists in the deposit and only needs to be captured.

Revolving energy is available energy that occurs in nature and is continuously replenished, economically exploitable under current conditions or in the foreseeable future. Among the renewable energies, the one produced by hydropower plants has been used for a long time, but the hydraulic power cannot be increased as much as possible, the ecological and social impact generated by hydropower plants becoming increasingly problematic. From the categories of renewable energies, a special place was represented by the energy of geothermal deposits. (Elena Zierler: 2008, J. W. Tester et all, 2006, Kailash N. et all, 2008]

According to specialists, the use of geothermal energy is divided into two categories: direct use and indirect use. Direct use means the use of thermal energy of geothermal waters by direct heat transfer to a user or by means of another fluid. Direct use of geothermal energy is divided into four groups:

1. heating rooms and domestic hot water preparation;

2. agricultural uses (greenhouses, aquaculture, fish farming);

3. balneology;

4. utilizări industriale.

Indirect use is carried out using geothermal fluid energy in turbines or through binary power plants for electricity production. (J. W. Tester et all, 2006, Kailash N. et all, 2008, Marcel Rosca: 2007)

The scope of use depends on the temperature of the geothermal fluid. Lindal studied the main areas in which geothermal energy can be used in conditions of technical and economic efficiency, depending on the temperature of the geothermal fluid [Elena Zierler: 2008], made a diagram bearing his name, shown in figure 1.

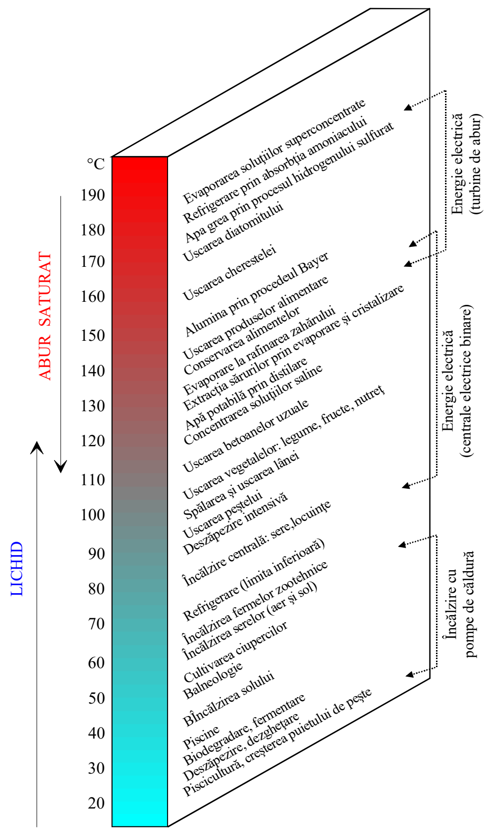


**Figure 1. Linda Chart I**

The use of geothermal energy in Romania is carried out in 38 localities where geothermal resources exist, being put into operation 98 wells (of which 37 for baths and balneology) with a total and maximum use, with an average temperature of 71°C for intake and 28°C for evacuation. (Kailash N. et all, 2008, Marcel Rosca: 2007)

The total capacity is 152 MWt (t=thermal) which produces 2,870 TJ annually. The direct use of geothermal energy is mainly made for: space heating – 37.4%, bathing and swimming including balneology – 30.4%, greenhouse heating – 23.1%, industrial uses – 7%, fish farming and natural farms – 2.1%, with a capacity factor of 0.6% [J. W. Tester et all, 2006]

One of the secondary users foreseen in this study is the greenhouse complex that uses geothermal wastewater from the geothermal power plant. (Elena Zierler: 2008) In the dimensioning project, a significant role is played by the energy or heat balance through the greenhouse structure.

## MATERIAL AND METHOD

### *STRUCTURAL HEAT BALANCE*

Of particular importance in solving the problem of climate control in the greenhouse are the heat balance and response of the crop, the air of the greenhouse, the roof and the soil structure of the greenhouse. The hemisphere of the greenhouse also influences energy and mass changes. (Crispin Allen 1990, Curtis D.J. 1988, F. S. Blaga,: 2009, Iancu Carmen, 2010) The heat balance consists of heat and mass exchanges to and from the greenhouse environment. The parameters involved in the physical processes of the greenhouse are in an energetic balance with the environment and all together are in an energetic balance with the interior of the greenhouse. The heat exchange processes involved can be sketched as shown in figure 2. (Crispin Allen 1990, Danfoss 1986, Iancu Carmen, 2010, T.-J. Yehet all, 2009)

The energy balance in a greenhouse can be simplified expressed:

$$Q_{tot}=Q_{gain}-Q_{loss}$$

where: $Q_{tot}$ = total amount of energy (net energy exchange) [W];
$Q_{gain}$ = the amount of energy entering the greenhouse [W];
$Q_{loss}$ = the amount of energy coming out of the greenhouse [W]

Determination of greenhouse heat requirements for different internal and external climate conditions means determination of all heat transfers of energy balances and climatic parameters. (Crispin Allen 1990)

They depend on the values of heat transfer coefficients, temperature, humidity differences between interior and exterior, material property, radiation, form factors and characteristics of the canopy of plants in the greenhouse, characteristics of heating and cooling installations. (Crispin Allen 1990)

Some of the factors mentioned above are constant or nearly constant and can be easily determined by calculations. Others depend on changes in temperature and humidity, which means they must be determined for changing or so-called dynamic conditions. Solar radiation and outdoor air temperature change their values without depending on indoor conditions.

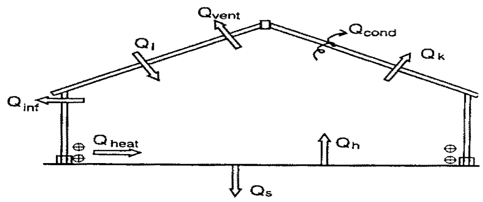


**Figure 2. Energy transfer through the structure, greenhouse. condensation energy; energy of the heating system; infiltration energy; transmission through the roof; solar radiation; Evaporation; ventilation energy; Transmission through soil**

The amount of heat entering the greenhouse is:

$$Q_{gain} = Q_h + Q_l + Q_w$$

unde: $Q_h$ = heat produced by the heating system [W];
$Q_l$ = heat obtained from solar radiation [W];
$Q_w$ =căldura datorată transpirației [W]

### *LOSS OF THERMAL ENERGY IN THE GREENHOUSE*

The amount of energy leaving the greenhouse can be estimated with the following equation::

$$Q_{loss} = Q_k = Q_s = Q_{cond} = Q_v = Q_{inf}$$

$Q_k$ = heat lost by convection outwards [W];
$Q_s$ = heat lost through conduction to the ground [W];
$Q_{cond}$ **=** heat loss due to condensation [w];
$Q_v$ = heat transfer due to ventilation [W];
$Q_{inf}$ = heat transfer due to infiltration [W].

*HEAT LOSS BY CONVECTION OUTWARDS*

It consists of heat losses through the greenhouse shell, from internal to external air, and can be calculated using the equation:

$$Q_k = hxA_c(T_{in}-T_0)$$

where: $T_0$ = outside temperature [k];

h = overall heat exchange coefficient [w/m²k];

$A_c$ = Area of the greenhouse shell [m²];

$T_{in}$ = indoor air temperature [k].

In the equation above, the overall heat exchange coefficient combines the effects of convection, conduction and thermal radiation. This coefficient does not take into account the infiltration of air through cracks and gaps through windows or doors of the greenhouse. (ErtuğrulÇam: 2007, F. S. Blaga,: 2009, H. Silaghi et all, 2009, Ilhan Kocaarslan, 2006, Michael Anderson et all, 2007, SzymonOgonowski: 2010)

For the calculation, the overall heat exchange coefficient is calculated using the following equation, where w is the wind speed [m/s]:

$$H = 2,8 + 1,2w$$

*Heat lost in the soil*

The flow of heat to the ground is complicated to determine because it is associated with water circulation. In most cases, it is enough to consider the flow of heat to the ground using apparent thermal conductivity, which includes the effect of water flow. (Crispin Allen 1990, G. Ionescu, et all, 1983, H. Silaghi et all, 2009, Iancu Carmen, 2010)

In the calculations, it is considered that the earth is divided into 3 uniform layers in depth and the temperature in the center of each layer is T1, T2 and Tb respectively. The temperature Tb at the lower layer is a boundary condition and the temperature at the soil surface is considered the indoor temperature of the greenhouse. (Crispin Allen 1990, H. Silaghi et all, 2009)

According to the energy balance equation, the heat flow in the soil during dt is expressed by dq/dt, and is adapted to the temperature exchange using mass properties:

$$\frac{dQ}{dt} = C_p \times \rho \times \frac{d\theta}{dt}$$

In heat transfer by conduction the energy balance can be written as:

$$C_p V_s \frac{dT_1}{dt} = K_s A_s \left( \frac{2(T_{in} - T_1)}{dz} + \frac{T_2 - T_1}{dz} \right)$$

$$C_p V_s \frac{dT_2}{dt} = K_s A_s \left( \frac{(T_1 - T_2)}{dz} + \frac{T_B - T_2}{dz} \right)$$

## RESULTS AND DISCUSSIONS

In order to ensure the proper functioning of the thermal energy installation for the greenhouse complex, it is necessary to develop an automation program to track and adjust its functional parameters. The aim is to maintain the temperature inside the greenhouse, measured using the TT6 temperature transducer. This allows a correlation between the measured parameters and the command of the execution elements. Figure 3. It includes the automation loop and the fault loop for the thermal energy supply installation for the greenhouse complex.

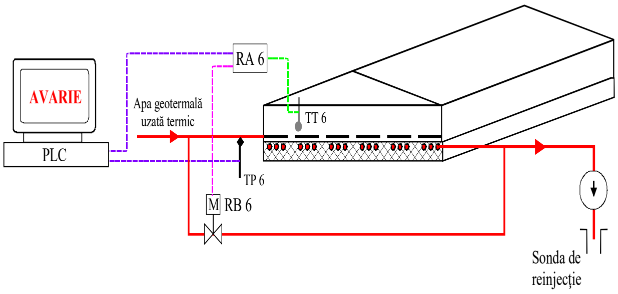


**Figure 3. Automation and fault loops for the thermal energy supply installation for the greenhouse complex**

A. AUTOMATION LOOP

The automation loop of the thermal energy supply installation for the greenhouse complex aims to achieve the condition: maintaining the temperature in the greenhouse within 18... 20°C. Geothermal water feeds the heating system from the ground surface and then passes into the ground heating system. The temperature inside the greenhouse must be maintained within 18... 20°C; This condition is achieved by regulating the geothermal water flow, obtained by opening/closing the RB6 tap, mounted on the geothermal water pipe that short-circuits the greenhouse..

If the temperature transducer TT6 located inside the greenhouse shows a temperature higher than the maximum permissible limit for this temperature, i.e. lt6 (lt6=20°C), after the TTMP 2 delay time has elapsed (ttmp 2=240 sec) since the last setting command was executed, and if the automatic valve controller on the geothermal water supply route meets the ra6 - 100 % inequality (the valve is not fully open), Open the RB6 valve with XRB6 value (XRB6=0,25 rot.) by the control given by the RA6 controller. if the tt6 transducer shows a temperature lower than the minimum permissible limit for this temperature, i.e. lt6 (lt6=18°C), after the TTMP 2 delay time has elapsed since the last setting command was executed, and if the automatic valve regulator on the geothermal water supply route satisfies the RA6-0% condition (valve not closed), Close the RB6 valve with XRB6 value by the given command.

## B. FAULT SIGNALLING AND SYSTEM RESPONSE IN THIS CAZ.

In the operation of the installation, inconsistencies may occur between its functional parameters and the prescribed conditions, inconsistencies that the automation program fails to correct. In this case, the operator is warned of the situation and waits for his decision to remedy the malfunction. Damage signalling (figure 3.) and the reaction of the system in this case is one of the most important parts of the automation program for the greenhouse in that it avoids accidents that may occur, warns the operator about the operation

The most dangerous damage that can occur in operation is that the pressure of geothermal water at the entrance to the greenhouse exceeds the maximum permissible limit.

If the TP6 pressure transducer, mounted on the geothermal water pipe at the entrance to the greenhouse, indicates a pressure higher than the maximum permissible value Lp6 (Lp6=4 bar), for more than ttmp av2 (ttmp av2=60 sec.) (situation caused by possible obstruction of the geothermal water circuit, especially in the area of the ground surface heating system or ground heating system), the system signals "FAILURE OF DEFECTIVE PIPES".

If the TT6 transducer shows a temperature lower than the minimum permissible limit for this temperature, i.e. lt6 (lt6=18°C), after the TTMP2 delay time has elapsed since the last setting command was executed, and if the automatic valve controller on the geothermal water route corresponds to RA6=0% equality (valve is closed), the system signals "FAILURE of faulty RB6 valve".

In order to determine the possible variations for the Ti parameter, several measurements were made, corresponding to a number of 20 experiments. It should be noted that each value was calculated as an average of 16 different measurements carried out on a case-by-case basis. In figure 4. a graphical representation of the results of the determinations made for parameter T1 is made.

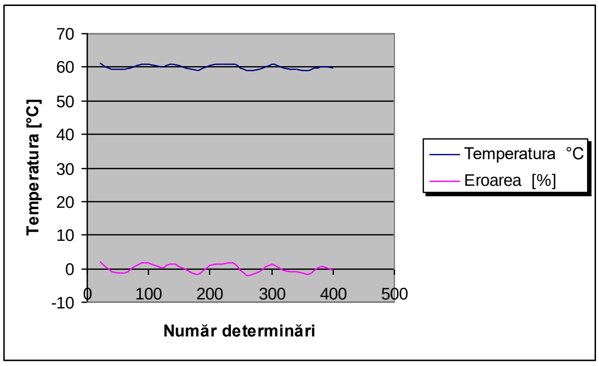


**Figure 4. Graphical representation of the results of the determinations carried out for parameter LT6**

In figure 5. a graphical representation of the results of the determinations made for parameter T3

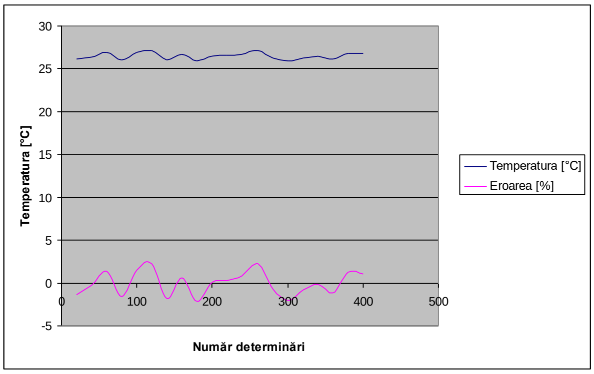


**Figure 5. Graphical representation of the results of determinations made for parameter Ti**

## CONCLUSIONS

Of particular importance in solving the problem of climate control in the greenhouse are the heat balance and response of the crop, the air of the greenhouse, the roof and the soil structure of the greenhouse. The hemisphere of the greenhouse also influences energy and mass changes. The heat balance consists of heat and mass exchanges to and from the greenhouse environment. The parameters involved in the physical processes of the greenhouse are in an energetic balance with the environment and soil structure of the greenhouse. The hemisphere of the greenhouse also influences energy and mass changes. The heat balance consists of heat and mass exchanges to and from the greenhouse environment. The parameters involved in the physical processes of the greenhouse are in an energetic balance with the environment and all together are in an energetic balance with the interior of the greenhouse.

In order to ensure the proper functioning of the thermal energy installation for the greenhouse complex, it is necessary to develop an automation program to monitor and adjust its functional parameters. the aim is to maintain the temperature inside the greenhouse, measured using the TT6 temperature transducer. This allows a correlation between the measured parameters and the command of the execution elements. In order to determine the possible variations for the Ti parameter, several measurements were made, corresponding to a number of 20 experiments. It should be noted that each value was calculated as an average of 16 different measurements carried out on a case-by-case basis.

## REFERENCES


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.

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

ErtuğrulÇam: 2007*"Application of fuzzy logic for load frequency control of hydroelectrical power plants"* in Energy Conversion and Management nr.48, 2007, pg. 1281–1288, ELSEVIER;

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

G. Ionescu, R. Dobrescu, B Droaşcă, A. Guţu, I. Hohan, S. Molin, I. Musceleanu, D. Popescu, V. Sgîrciu, A. Strenc, R. Vârbănescu: 1983 *"Traductoare pentru Automatizări Industriale", Ed. Tehnică,* 1983;

H. Silaghi, V. Spoială, L. Coroiu, Z.T. Nagy: 2009 *"Atomate Programabile-Operare, Programare, Aplicaţii"*, ed. Universităţii din Oradea, ISBN 978-973-759-940-7, ;

Iancu Carmen**,** 2010 *Modeling the regulation of the malt drying with geothermal water using fuzzy controller*, International Symposium, Risk Factors for Environment and Food Safety, Faculty of Environmental Protection, November 5-6, 2010, Analele universităţii din Oradea, Fascicula Ecotoxicologie, Zootehnie şi Tehnologii de Industrie Alimentară, pp 1242-1247, I.S.S.N. 1583 – 4301, Oradea,

Iancu Carmen 2010 *Modeling the regulation of the malt drying with geothermal water using PID controller***,** International Symposium, Risk Factors for Environment and Food Safety, Faculty of Environmental Protection, November 5-6, 2010, Analele universităţii din Oradea, Fascicula Ecotoxicologie, Zootehnie şi Tehnologii de Industrie Alimentară, pp 1242-1247, I.S.S.N. 1583 – 4301, Oradea;

Ilhan Kocaarslan, Ertuğrul Çam, HasanTiryaki: 2006 *"A fuzzy logic controller application for thermal power plants"* in Energy Conversion and Management nr.47, 2006, pg. 442–458, ELSEVIER;

J. W. Tester, B. J. Anderson, A. S. Batchelor, D. Blackwell, Ronald DiPippo, E. M. Drake: 2006 *"The Future of Geothermal Energy",* 2006, ISBN: 0-615-13438-6;

K. Leiviskä, L. Yliniemi: 2005 *"Design of Adaptive Fuzzy Controllers",* in Stud Fuzzy nr 173, 2005 pg. 251–265, Springer-Verlag;

Kailash N. Bhardwaj and S. C. Tiwari: 2008 *"Geothermal energy resource utilization: Perspectives of the Uttarakhand Himalaya"* in Current Science, vol. 95, nr. 7, 2008, pg. 846-850;

Marcel Rosca: 2007 *"Geothermal Energy Use in Romania"* RENEXPO 1st International Conference 2007, Budapest Hungary;

Michael Anderson, Michael Buehner, Peter Young, Douglas Hittle, Charles Anderson, Jilin Tu, David Hodgson:2007 *"An experimental system for advanced heating, ventilating and air conditioning (HVAC) control"* in Energy and Buildings nr. 39, 2007, pg. 136–147, ELSEVIER;

SzymonOgonowski: 2010*"Modeling of the heating system in small building for control"* in Energy and Buildings nr. 42, 2010, pg. 1510-1516, ELSEVIER;

T.-J. Yeh, Yen-Hung Chen, Jin-Long Lin: 2009 *"Control of air-conditioning systems in heating mode to enhance transient performance and steady-state efficiency"* in Energy and Buildings nr. 41, 2009, pg. 1391 – 1400, ELSEVIER;