DETERMINATION AND OPTIMIZATION OF THE MAIN PARAMETERS OF GEOTHERMAL ELECTRIC POWER PLANTS

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ABSTRACT

In the paper are presented the authors' research directions regarding the computer aid determination and optimization of the main parameters of geothermal power plant from the University of Oradea Also, the methodology regarding the CO, parameters self regulation when disturbances occur is presented with the purpose of realising the power plant automatization. By performing on analysis upon the results, we can conclude that for every *input* parameter (temperatures, geothermal water flow rates and *cooling* water flows) a thermodynamic cycle of maximum rated power can by maintained upon the base of automation methodology presented in this paper.

1. INTRODUCTION

The geothermal electric power plants realizes the conversion of thermal water *energy* resources into electric energy. The approach of operating of that kind of power plants consists in the utilization of an working medium (fluid) which evolves in closed circuit according with a thermodynamic motor cycle between two heat resources- water at high temperature and cooling water, respectively.

For the design of that kind of power plants the correlation between the exchange heat processes, expansion and compression of worlung agent in the driving element and pump respectively and the thermodynamic cycle according with what the work agent evolves must be realized with the purpose of obtaining the maximum power in given conditions and as possible the lowest coat. From technical-economical and functional assumptions on optimization of heat exchange surfaces and of cooling agent must be achieved in order to assure minimum cost per kWh energy.

This paper is a continuation of previous studies (Maghiar et.al., 1992) and it enlarges the research sphere by taking into account some others authors' reports published before (Maghiar et.al., 1992).

The purpose of this paper consists m the exposure of the research directives regarding the determination and the optimization of the main parameters of geothermal electric power plant:

- computer aid determination of differents steady-states of operation for the power plant (differents water flow rates and temperatures) with the specified CO, parametem (pressures and temperatures) in differents characteristicspoints;
- determination, from results analysis, of the optimal thermodinamics cycles for the operation of geothermal electric power plant;
- setting-up the methodology regarding CO, parameters self-regulation when disturbances occur.

2. THE DETERMINATION OF OPTIMAL THERMODYNAMIC CYCLE

The working agent used in plant is CO_2. Starting by the initial proposed thermodynamic cycle (Maghiar et.al., 1992), (see figure 1) the range of possibles thermodynamic cycles was extended both in liquid field and overheat vapours. In this way, for the transformation 3'-4 (the evolution of liquid CO, within pump) not to lead to the apparition of cavitation at suction it is necessary the working fluid reaches such a temperature that when the pressure decreases because of suction to not reach in the biphasic zone. In this way we considered an additional cooling of liquid CO, by prelonging the isobar cooling in liquid zone (3-3', *figure* 1) until the temperature for what the phenomenon of cavitation is elliminated. The point 4 shift to left. We mention the super-cooling is correlated with geothermal and functional parameters of pump (Maghiar et.al., 1992). Taking into account the available temperatures for hot and cold water and the CO, characteristics (Raznjevic, 1978) the overall thermodynamic cycle was achieved, mentioned in a previous paper (Maghiar et.al., 1994). This cycle is presented in figure 1.

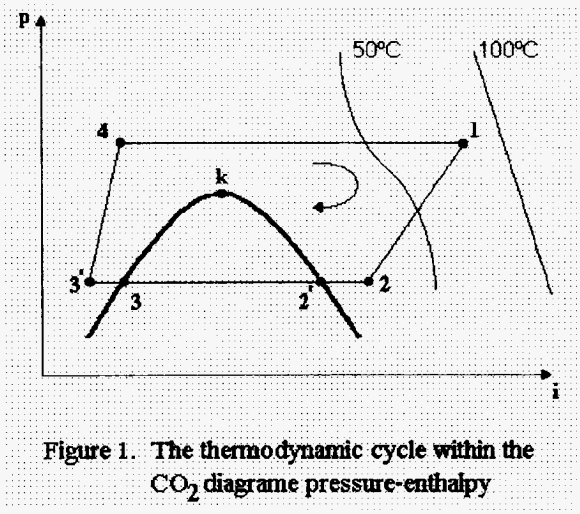


Figure 1. The thermodynamic cycle within the CO_2 diagrame pressure-enthalpy

For the possibles thermodynamic cycles with the same shape as the one presented in figure 1, a computation programe for the determination of optimal cycles depending on input data was realized. We mention the thermodynamic cycle is determined when the pressure and temperature of point 1 and the pressure of point 2 are known.

The determination of the optimal thermodynamic cycle was performed in many versions for different values of input data (hot water flow, input temperature for cold water).

The results of computations were presented in graphics. For examplification we present in figure 2 the range of pressure values for point 2 (the g e o t h d water flow is 30 kg/s and the input temperature of cold water is 10°C) with the limitation of values around the value of pressure corresponding for *optimal* cycle. This limitation was performed by retaining for pressure p_2 only the values for which $P_u / P_{u\,max}$ is within the range (0.8-1), where P_u represents the effective power. From graphic results the domain for p, (56-67bar).

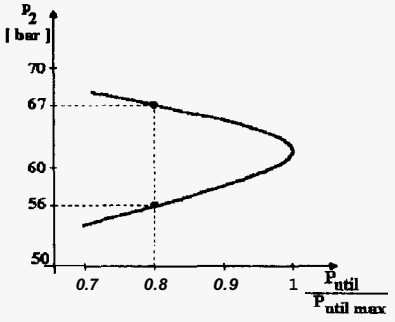


Figure 2. Distribution of pressure values p_2 versus the ratio $\frac{P_{util}}{P_{util\ max}}$

Analysing the results obtained after computation for variants taked into account by the intersection of the domains for the three parameters (p_1, t_1, p_2) the result was a domain where the thermodynamic cycles fits in for the analysed variants:

- for the pressure of point 1 $p_1 = (108 - 118)$ bar
- for the temperature of point 1 $t_1 = (70 - 78)\ ^\circ C$
- for the pressure of point 2 $p_2 = (60 - 66)$ bar

3. THE METHODOLOGY REGARDING THE SELF REGULATION OF CO, PARAMETERS WHEN DISTURBANCES OCCUR

3.1. Overall presentation

For obtainig a maximum rate power it is necessary to maintain the optimal thermodynamic cycle for every operation regime of the power plant, so it is necessary the maintaining of CO, parameters when disturbances occur.

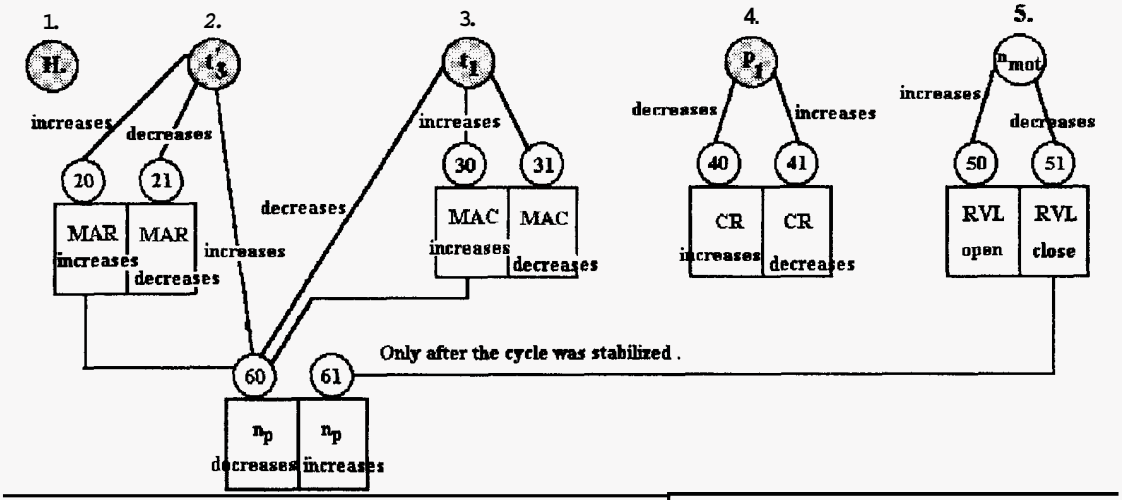
In a certain steady state operation regime of the power plant some disturbances may occur and the results are values changings of CO, parameters, geothermal and cold water parameters, and geothermal engine parameters (i.e. pressure and temperature fluctuations of CO, in plant different poits, flows and temperature fluctuations for the geothermal water and for cooling water and variations of geothermal engine speed, etc.).

The methodology regarding the selfregulation of CO, parameters when disturbances occur was elaborated starting with the interdependence between the parameters mentioned above. This interdependence was analysed for every situation based upon the CO, diagram, the phenomena of overall heat transfer from heat exchange the liquid CO, pump operation characteristics and the geothermal engine. Based upon these interdependences the diagram showed in figure 3 was elaborate where the corespondences between parameters which must be maintained within the domain (t_3, t_1, p_1, n_{mot}) and parameters we have to modify are presented.

For the examplification, we present the CO, temperature decrease at the entrance of engine influence upon the other parameters. If due to some disturbances the temperature t_1 decreases according with figure 1 results that the point 1 shift to left (t_1 decreases) which involve a movement to left for point 2 (t_1 decreases); considering that the temperature and the cooling water flow are maintained constant, results that either point 3 will shift to left (t_3 decreases) and point 4 will corespond to a lower temperature. We can conclude that all thermodynamic cycle shifts to left which will determine, in case of stabilization for the new values of CO, parameters, the operation of the electric plant according with a thermodinamic cycle with lower rated power.

For anihilating the disturbance which involve a CO, temperature decrease, it is necessary to increase the geothermal water flow (see figure 3, the correspondence 3-30). If the peak value for available g e o t h d water is reached, it is necessary to decrease the pump rotation speed (see figure 3, the correspondence 3-60) which will have effect the decrease of CO, flow; for the same quantity of received heat from geothermal water will result in that situation enthalpy increase and the temperature t_1 increase also (see *figure* 1).

In *figure* 4 is shown the diagram conceived for the automatization of geo-



1. H - CO_2 liquid level within buffer rezervoir
2. t_3 - CO_2 liquid temperature (at entrance in the pump af CO_2 liquid)
3. t_1 - CO_2 gaz tempera—— (at entrance in geothermal engine)
4. p_1 - CO_2 gaz pressure (at entrance in geothermal engine)
5. n_{mot} - rotative speed of engine

MAR – coldwater flow
MAC – geothermal water flow
CR – resistant torque at geothermal engine shaft
RVL – throtting valve for by-pass gethermal engine
n_p – rotative speed of CO_2 liquid pump

Figure 3. The corespondences between the parameters wich must be maintained in a range and the parameters on wich we have to operate

thermal power plant with the purpose of maitaining the parameters (t_3, t_1, p_1, n_{mot}) m the domains found in chapter 2. In the same diagram the liquid CO, level (H_{min}) is tracked. Ifthe level mentioned is below the minimum value the plant isn't control m close loop. If all parametem are in the domain the electric plant can be coupled at the national energetic *system. After* coupling, the control of parameters is re-handled.

When one of the parameters is out of domain, the system leads in a control loop according with the direction in which was out of domain.

We will present for example the *gas* CO, temperature (t_1) control loop.

3.2. The gas CO_2 temperature (t_1) control within the pre-set limits

Ifthe temperature t_1 falls below 70°C, the system leads in control loop 30, and if that temperature arise above 78°C, the system leads in control bop 31 (see *figures* 4,5,6).

In *figure 5,* the presented control loop reacts on the direction of growth of water flow taking into account the followings:

- if the 330 delay was started (which considers the fact that the process is slow) at the control of water flow increase;
- if the 33 1 delay was started at the control of the water flow decrease and it is maintained that will be cancel, fact signalled;
- if the 330 delay was started and it pass over, then flow will be checked to see if it growths with DQ; if "yes", the loop is tracked and if "no", the operator will be signalled that even the valve opening was controled, the flow doesn't rise,
- if the valve is completely open due to the repeated opening controls and the temperature t, doesn't rise, then *according* to the diagram, the level of geothermal water is tested to see if it reached the *peak* value and if the result is "yes", that means a failure is present and it is signalled and if the result is "no", the system leads m the control loop for CO, pump speed (n_p) m the direction where the speed decreases (*see* figures 4 and *5).*
- in the situation when 330 delay started and the *delay* time doesn't pass, the *system start* to control an other parameter (Var+1).

In *figure* 6 is presented the temperature t, control loop, a control m the *sense* of negative direction, which is perform by closing the *regulating* valve from geothermal water. *Similar* with previous situation, the *starting* off 331 delay, its pass, and geothermal flow are tested. According to the situation a decision is made. When the signalling show closed valve, situation reached by repeated closings the type of failure will be signaled: the defecte valve or the fault measuring temperature t_1.

The others control loops are much alike. All the control system is in a closed loop which can track and maintain under a permanent control the parameters t_3, t_1, p, and n_{mot}.

An exemple of system on which we can implement the presented diagrams is the controler TI 305 (Maghiar et. d., 1993 si Series 305. User's Manual. Texas Instruments, 1990).

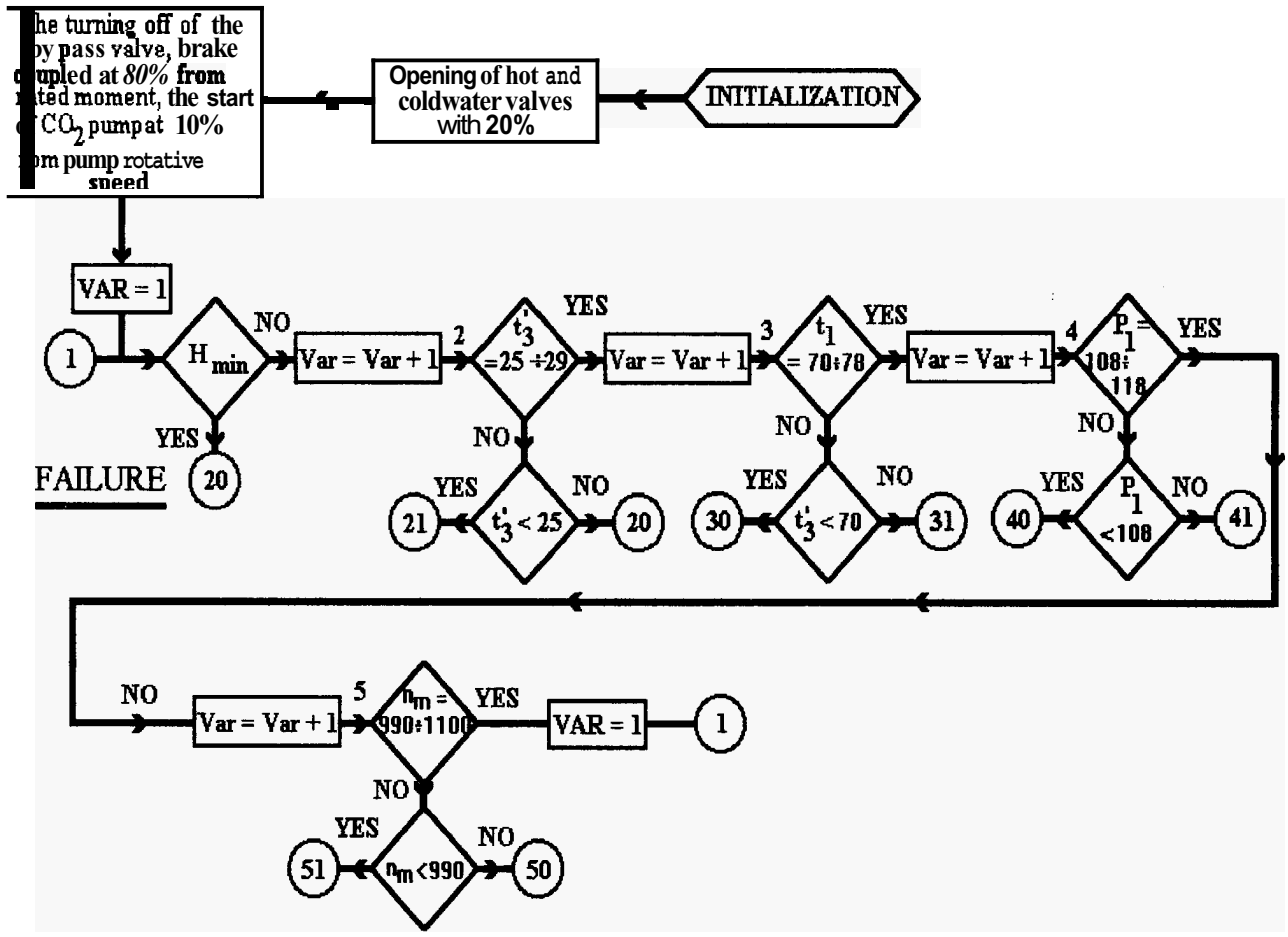


Figure 4. *General* diagram (the main branch)

MAC - INCREASE $\Delta Q = Q_{mas}(\tau+1) - Q_{mas}(\tau)$

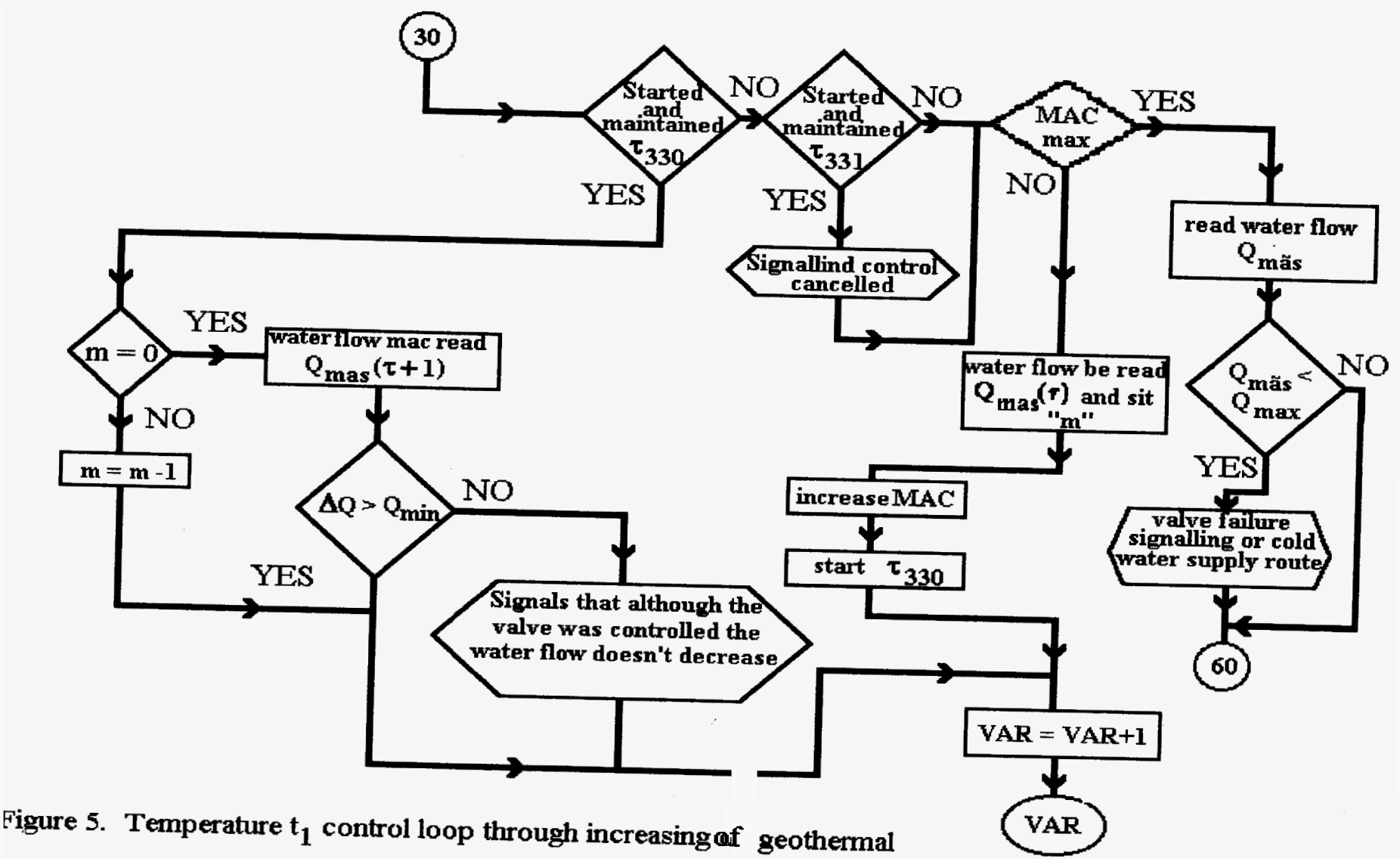


Figure 5. Temperature t_1 control loop through increasing of geothermal water flow

MAC DECREASES

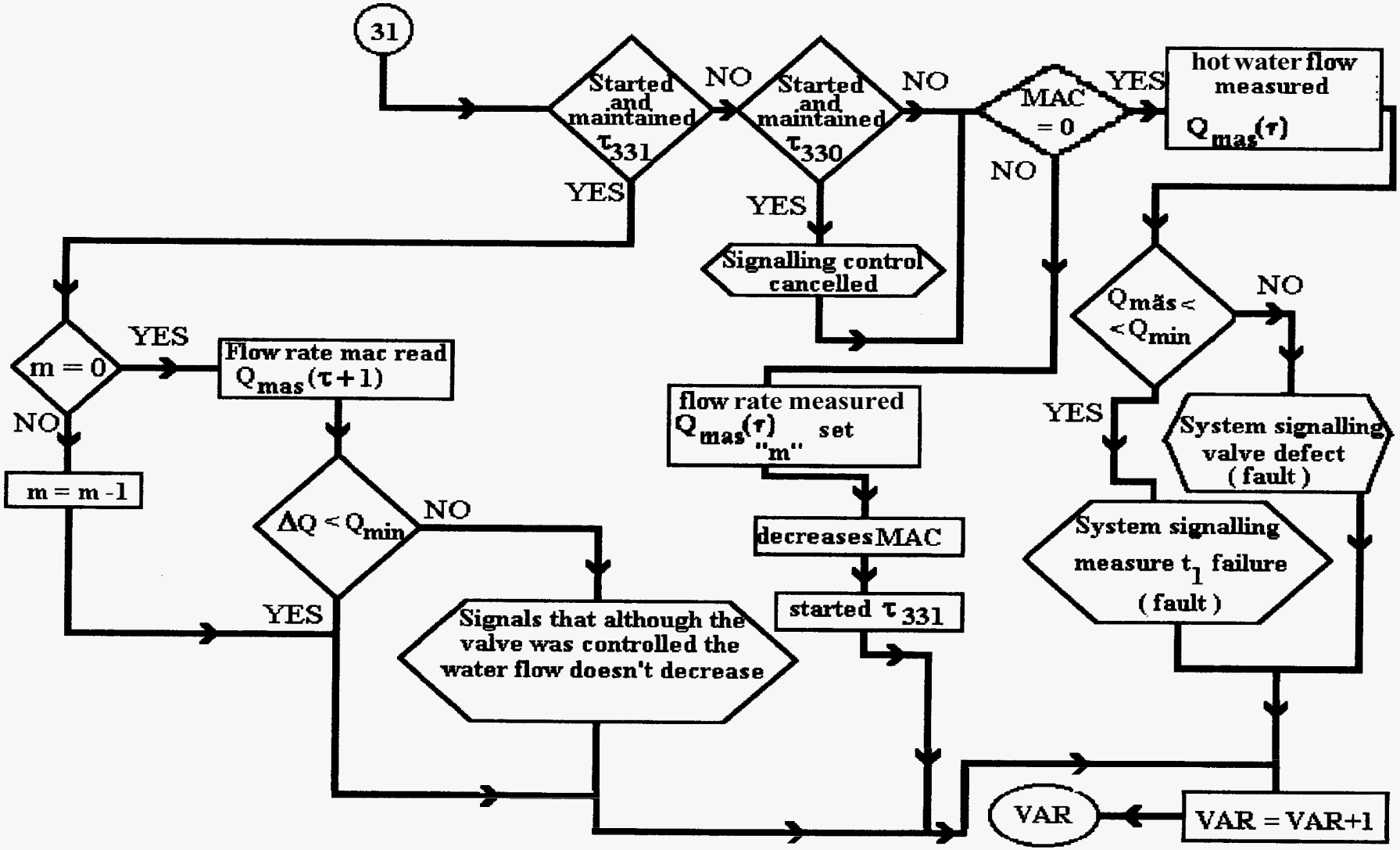


Figure 6. Temperature t_1 control loop through decreasing of geothermal water flow

4. CONCLUSIONS

By performing an *analysis* upon the results obtained, results that for *every* variant of inout parameters (flow rate and temperature of the geothermal water, coolig water respectively) an *optimal* thennodynamic cycle exists, though a thermodynamic cycle which enable to obtain the maximum utile power. To maintain this optimal thermodynamic cycle the automation of power system is recquired.

With the elaborated diagram, the automation of geothermal power plant can be achieved using a single-processor operating in cycle. The times which occur in process are so high that the system, for example TI 305, can follow all control loops adjusting the parameters $t_{„}$, $t_{,}$, p_{1}, n_{mot} with the purpose of reaching an optimal operation for the power plant.

The presented diagrams show us an approach for performing the hand controls necessary m the first startings for the process identification. The identification is necessary in order to obtain the times mentioned in diagrams.

REFERENCES

Maghiar T., Leuca T., Gordan M., Gordan C., Antal C., Gavrilescu O., Popa M., Manole A. and Nascu G. (1992). Computer Aid Design of Geothermal Electric Power Plants. University of Oradea Annals. , Vol. 2, pp. 327-332.

Maghiar T., Cornea C., Antal C., Gavrilescu O., Manole A., Crăciun D., Bara G. and Grosu F. (1992). Surveys regarding the dependence between cold water flowrate and the rotative speed of liquid CO, pump. University of Oradea *Annals*, Vol. 2, pp. 333-337.

Maghiar T., Fodor D., Antal C., Gavrilescu O. and Popa M. (1992). *Surveys regarding* the efficiency of thermodynamic operation cycle of geothermal electric power plant. University of Oradea Annals, Vol. 2, pp. 344-347.

Maghiar T., Popa M. and Blaga F. (1992). Surveys regarding the usability of criterial equations for the thermal calculus of geothermal electric power plant. University of Oradea Annals, Vol. 2, pp. 354-361.

Maghiar T., Gavris M. and Gergely E. (1993). *An* approach for the implementation of automation scheme of geothermal electric power plant with the programmable controller TI 305. University of Oradea Annals, Vol. 1, pp. 419-427.

Maghiar T., Leuca T. and Antal C. (1994). Contribution to the devlopment of the geothermal *energy* potential for the generation of electric-power. Geothermics 94 in Europe. Document BRGM n° 230, pp. 513-516.

Raznjevic K., (1978). Tabels and thermodynamic diagrams. Editura tehnică, Bucuresti, 371 pp.

*** (1990). Series 305. User's Manual. Texas Instruments Inc.