Improving the Energy Output of a Geothermal/Solar Hybride Energy System

Gökhan Uçkan*, Emre Çomak*, Orhan Ekren, Ahmet Yılancı****
Department of Computer Engineering, Pamukkale University, 20020 Denizli, TURKEY
**Solar energy institute, Ege University, 35100, İzmir; TURKEY*

Abstract

In these days Renewable Energy Sources (RES) are becoming increasingly more popular. The key reason for this is, perhaps, the increase of prices in fuel oils and other fossil based energy resources. Another effect is the increase of global warming. This work shows the improvement of a Hybrid Electrical Power Plant which is controlled by a developed computer software. The aim of this program is to control the opening angles of three different replaced valves in the Hybrid System. These valves are controlling the warm fluid coming from a geothermal power plant. The binary system where the heat exchangers are replaced are at the same time provided with Parabolic Collectors to increase the heat of the geothermal fluid. The developed program software will find the most suitable valve angles for maximum energy production of the described Hybrid Energy System.

Keywords: *Hybird Solar Energy Systems, Parabolic Collectors, Fuzzy Logic, Binary Geothermal Systems.*

1. Introduction

Hybrid Renewable Energy Systems have become popular because of their high efficiency in energy production. These kind of systems are improving the energy outcome of Renewable Energy power plants. Different types of hybrid energy systems have been developed. One type, is the parabolic collector based geothermal energy power plant. These Hybrid power plants found some applications in Turkey **[1].** The control of these systems are difficult because of their complex structure. A simulation program is developed to show the output performance of a described Hybrid Energy power plant. This power plant is imagined so that it is provided with parabolic collector modules to increase the efficiency of the hole system. The major aim of the developed program is to increase the output energy of the defined Hybrid Energy system by controlling three different replaced operational valves on the system. The control of these

valves will improve the energy output of the system due to the heated fluid coming from the parabolic collector modules. The developed program will compare the heat of the geothermal fluid and the parabolic collectors. The most suitable heat exchanger will be selected from the software for maximum energy gain.

2. Parabolic Power Plants and the Developed Hybrid Power Plant

As described before in this study a Hybrid Parabolic Power Plant is designed. For maximum energy gain of the system a computer program is developed to control three different valves replaced on the system.

2.1 Parabolic Power Plants

Parabolic collectors reinforced power plants are used in warm areas with a strong rate of coming solar beam. A block diagram of a parabolic power plant is given in the Figure below [2]. According to this figure the heat transfer fluid of the system is heated up to a higher level. The heated fluid which comes from the parabolic collector modules will be transferred to the steam turbines for electric energy gain [2]. As known The heat transfer fluid, which carries the heat energy can be a special type of oil or water. At each end of a cycle, the heat transfer fluid will be heated up to a further point while the fluid flows through the parabolic collector modules.
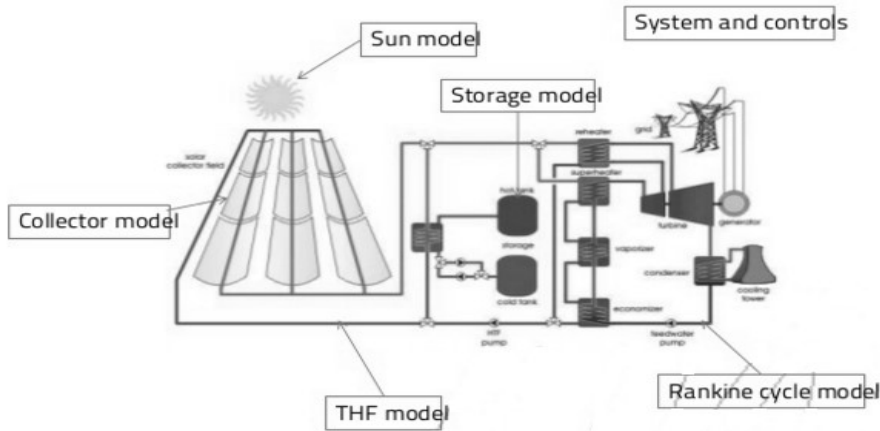

Figure 2 Block Diagram of a Parabolic Power Plant for Electric Energy   Production.

2.2 Geothermal/Solar Binary Parabolic Power Plant

To be able to increase the energy output of a system, binary cycles are used. In this work a binary system is designed to improve the energy output of a geothermal reservoir with parabolic collector support. A Binary Geothermal/Parabolic Collector Power Plant will look like as shown in Figure. 3. The heated fluid coming from the parabolic collectors will be directed to a heat exchangers for heat transfer to the binary system. After heating the fluid of the binary circle, the energy of the fluid will be given to the turbine for electrical energy production.
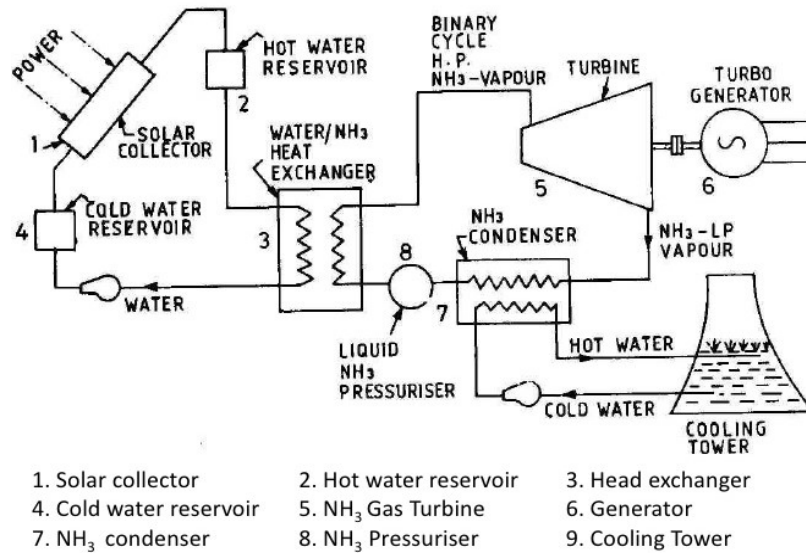
1. Solar collector
2. Hot water reservoir
3. Head exchanger
4. Cold water reservoir
5. NH_3 Gas Turbine
6. Generator
7. NH_3 condenser
8. NH_3 Pressuriser
9. Cooling Tower

Figure 3 A Binary Parabolic Power Plant.

2.3 Design of the Developed Hybrid Geothermal System

Hybrid Geothermal power plants start to find applications in the last years. One of them is the hybrid geothermal power plant replaced in Denizli/Kizildere. The block diagram of the geothermal hybrid energy power plant in Kızıldere/Denizli is given in Figure 4. As seen on Figure 4 the coming heat fluid from the geothermal plant is heated up through the parabolic collector modules to a further step for maximum electric energy production. Using Fourier heat transfer equations the heat efficiency of the geothermal power plant is increased to a further step. In Table-1 the flow rate, heat and pressure for some given points of the system are given. As seen on the table below, the heat of the fluid at point 7 and 8 is increased. This shows how the parabolic collectors are effective on the increase of fluid heat which flows to the turbines for electric energy convergent.
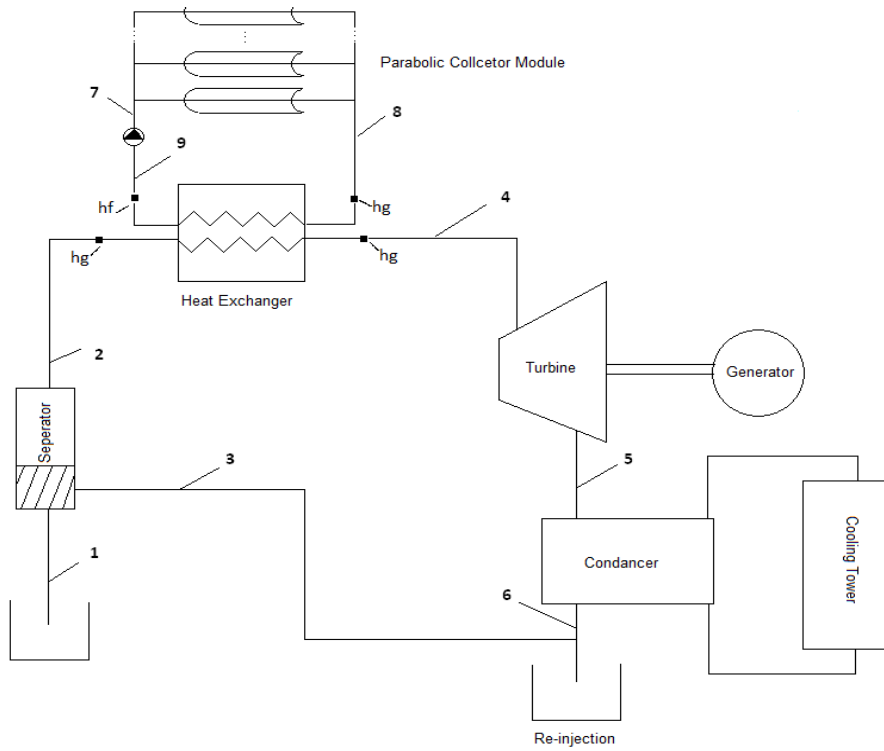
Figure 4 Block Diagram of the Parabolic Reinforced Power Plant.

In Table1, Parametric values for the system described in Figure 4. are given. Some of these values are taken as an reference value in the developed parabolic reinforced geothermal system.

Table 1. Parametric Values for Power Plant Kızıldere/Denizli

Number	Flow (kg/s)	Heat T (OC)	Preasure (MPa)
1	72,93	240	3,337
2	12,38	162	0,600
3	60,55	162	0,600
4	12,38	166,68	0,600
5	12,38	50	0,01
6	2,378	16	0,004
7	0,35	150	3
8	0,35	233,8	3
9	0,35	150	0,476

The developed hybrid geothermal system is developed using parabolic collector modules **[1],** which will reinforce the geothermal system seen in Figure 5.
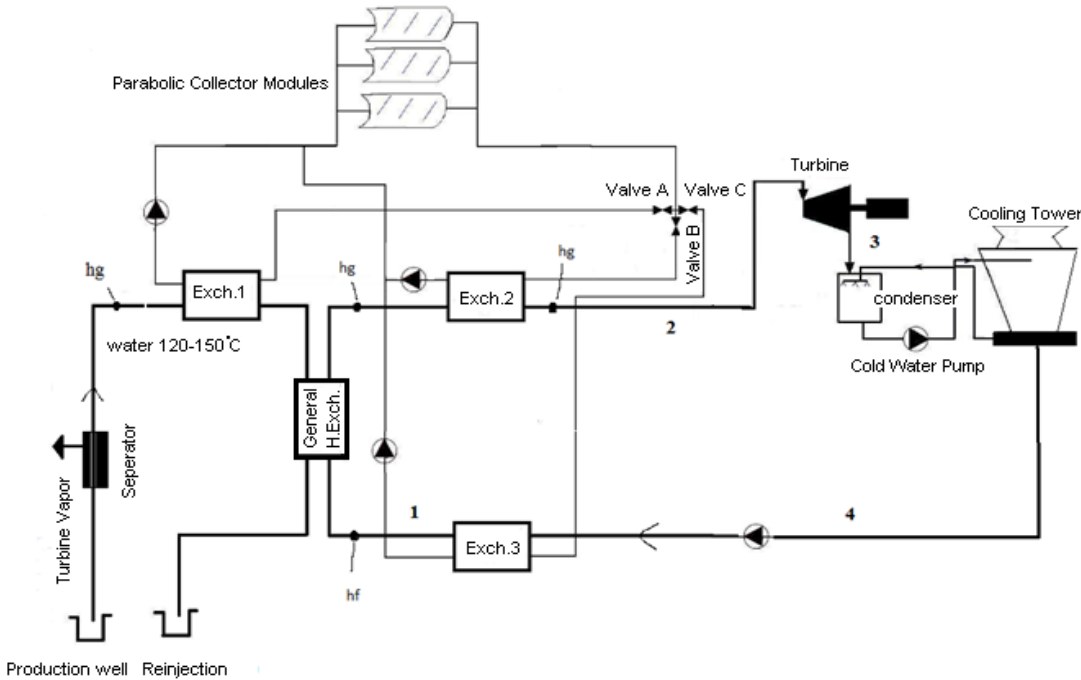

Figure 5. Blok Diagram of the Parabolic Geothermal Hybrid System.

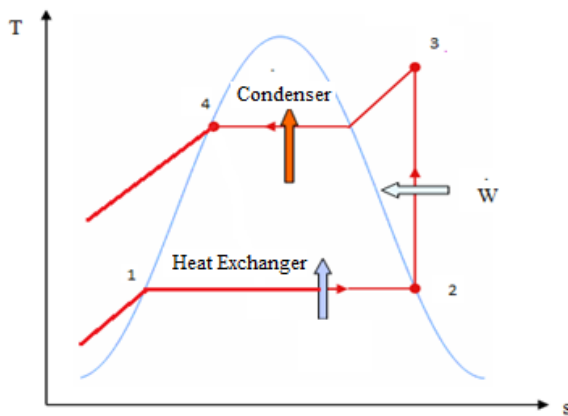Due to this the thermodynamic working ranges are given on Figure 6. As seen in Figure 6

Figure 6. Graph of the Thermodynamic Working Ranges.

Fourier heat transfer equations are used to calculate the heat output of the fluid of the main system. A simulation program is developed using Visual C#.Net forms applications. Again seen on the figure below, the heated fluid of the parabolic system is directed to the most suitable heat exchanger for maximum heat transfer. The selection of the suitable heat exchanger is done by a developed control program which is a part of the simulation program. This program

calculates all possible outputs. The best output option is taken. And the valve openings are stored to a database for future analyses. These analyses are used for defining the rule tables used inside the fuzzy program.

3. The Developed Simulation Program software

Fourier heat transfer equations are used to calculate the heat output of the fluid of the main system. The main equation used is the Fourier heat transfer equation **[3]** given in Equation.1

$$\Delta Q = c_p \rho \, \Delta u \qquad (1)$$

Due to this equation; a change in internal energy per unit volume in the material, ΔQ, is proportional to the change in temperature, Δu. where c_p is the specific heat capacity and ρ is the mass density of the material. Choosing zero energy at absolute zero temperature, this can be rewritten as in Equation 2.

$$Q = c_p \rho u \qquad (2)$$

These main equations are used inside the developed simulation program to calculate the heat of the flow coming to the turbine.

3.1 Developing The Program Which Calculates The Output Heat of the Parabolic Fluid

The simulation program is developed using Visual C#.Net. Again seen on the figure below, the heated fluid of the parabolic system is directed to the most suitable heat exchanger for maximum heat transfer. The selection of the suitable heat exchanger is done by the control program which is a part of the simulation program. For the decision of the most suitable heat exchanger the output degree of the parabolic modules has to be known. This is done by one module of the developed simulation program given in Figure 7, 8 and 9. In Figure 7 the parabolic collector with, length of each parabolic collectors, coordinates of the parabolic collectors are defined through the user interface shown on Figure 7.

Figure 7. Defining the design parameters of each parabolic collector **[5],[6].**

Figure 8. Defining special parameters of the parabolic collectors **[6].**

In Figure 8 the user interface program is shown where special parameters **[5,6],** like the inner and outer dimensions, heat coefficient of the fluid, viscosity of fluid, heat transfer coefficients of absorber pipe, flow rate of fluid or specific heat are defined by the user. These parameters are used to calculate the heated fluid output of the parabolic collectors.

Figure 9. Defining special parameters of the parabolic collectors.

Below in Figure 10. The user interface for the calculation of the turbine energy output is shown. According to this, again Fourier heat transfer equation is used to develop the main equation which will calculate the heat transfer of each heat exchanger.
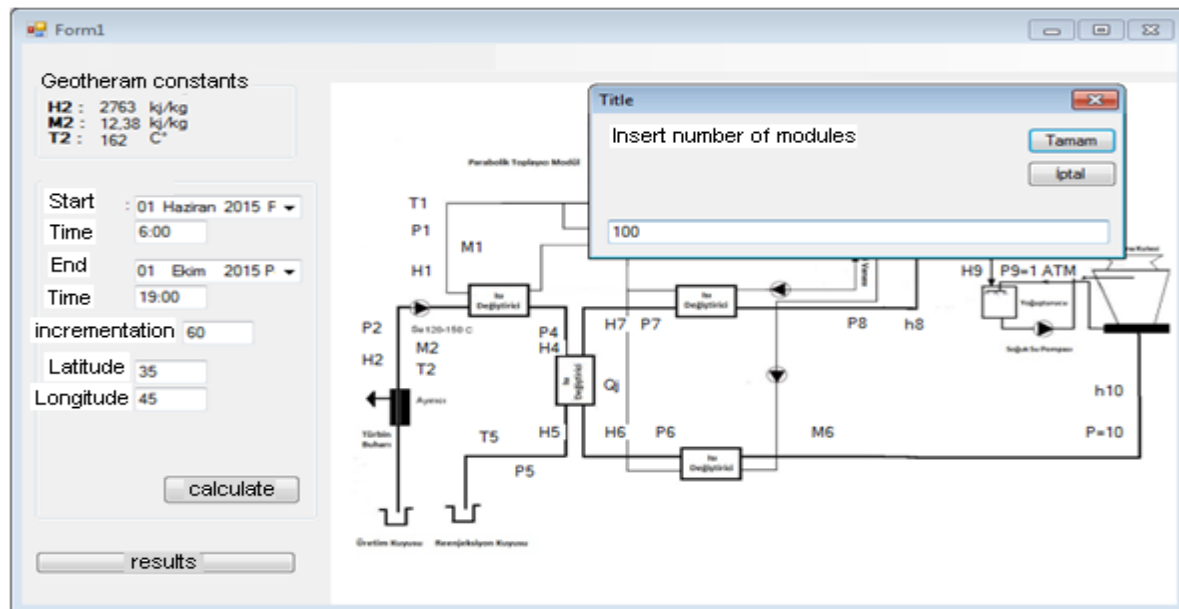

Figure 10 The user interface for the calculation of the turbine energy output.

$$Qp1 = mp.Cp.(Tpc - Tpg) \tag{3}$$

$$Qj1 = (mj * hr) - (mj * hj1) + (Vp * Id * Ka * Ks) \tag{4}$$

$$Qj1 = (mj * hr) - (mj * hj1) + \left(Vp * \frac{Qg}{\eta optik * Agac} * Ka * Ks\right)$$ (5)

Given above some brief calculations are given for defining the heat transfer through the heat exchanger number1. According to the given parameters;

Qp1: The energy gain of the parabolic collectors ,

Qj1: Energy gain from the geothermal system

Qg: Gross energy gain from the parabolic collectors

mp: Fluid flow rate of inside the parabolic collectors

Cp: Molar heat capacity at constant pressure

Tpc: Heat of the input fluid into the parabolic collectors

Tpg: Heat of the output fluid from the parabolic collectors

 mj: Fluid flow rate of the geothermal system

hj1: Enthalpy of geothermal fluid

 Id: Intensity of the direct coming beam to the parabolic collectors

Equation 3, shows the main equation for the heat transfer of the parabolic modules to the heat exchanger number 1, Equation 4 for the heat transfer between the geothermal reservoir to the main system using heat exchanger number 2 and Equation 5, shows the heat transfer equation where "Id" is calculated with a second equation.

4. Developing the Fuzzy Logic Module

 As seen on Figure 5 the heated fluid output of the parabolic modules, will be directed to a suitable heat exchanger with respect to fuzzy logic **[7].** The rule table in the fuzzy logic program is arranged according to the parabolic fluid heat, coordinates, time and the geothermal reservoir heat degree.
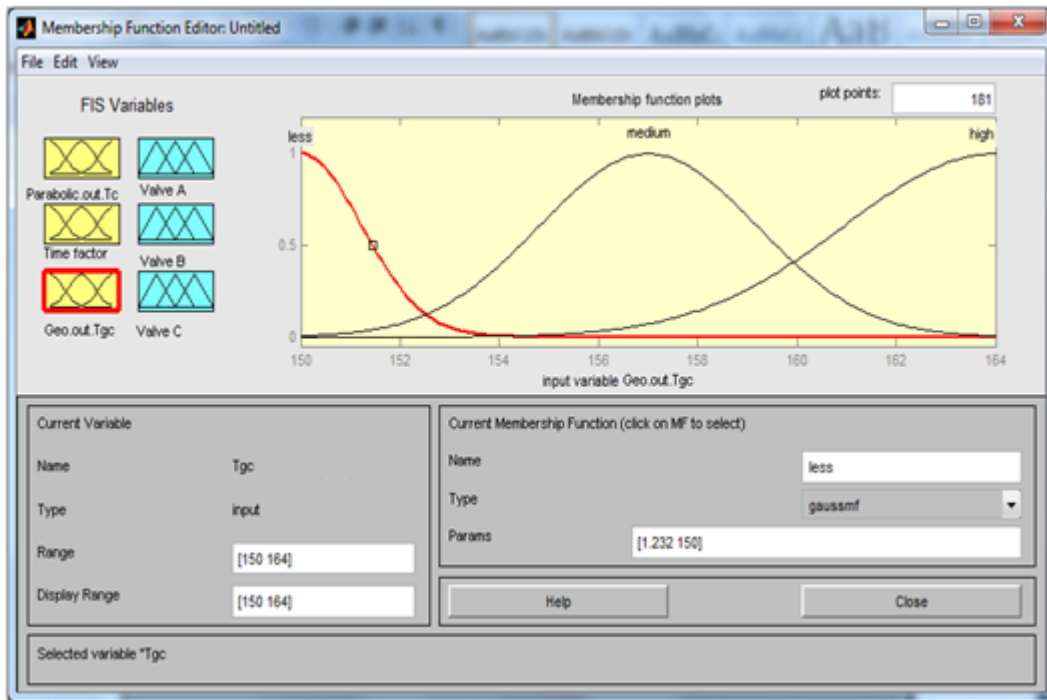
Figure 11 Defining the range of fuzzy function variables, due to time parameter.

As seen on Figure 11, fuzzy function parameters for the opening degrees of valve A, B and C are defined with respect to the time parameter. For this example; İf the time interval for winter is between 15:00 and 18:00', then valve C has to be open more than valve A or B. Because during this time interval the solar beam is weak and the fluid coming from the parabolic collectors should be directed to the third heat exchanger.
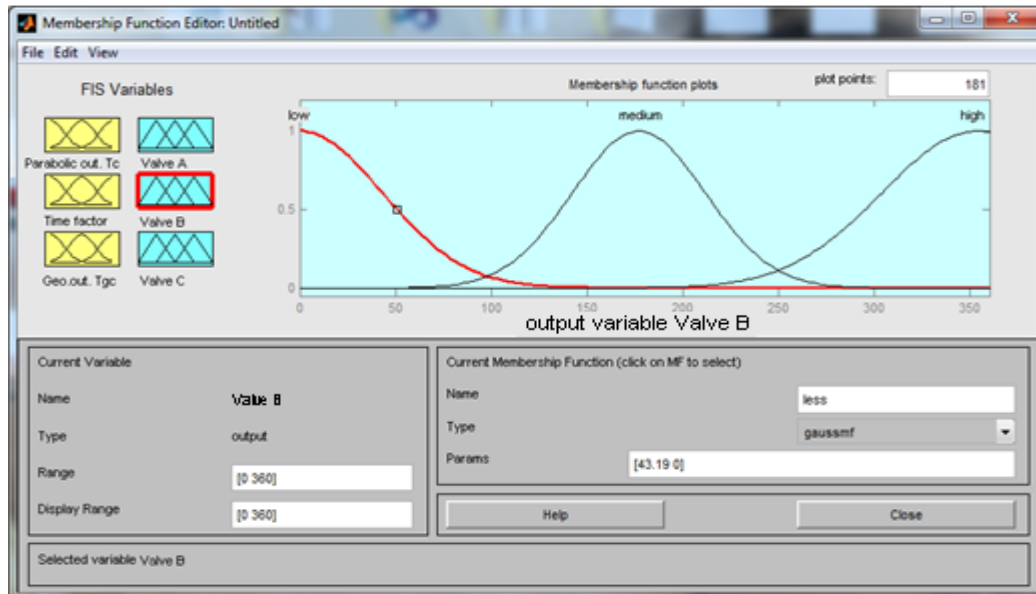

Figure 12 Opening levels for valve B

As seen on Figure 12, fuzzy function parameters for the opening degrees of valve B is defined with respect to the time parameter, output heat of the parabolic collector fluid and the output heat of the geothermal fluid heat is defined.
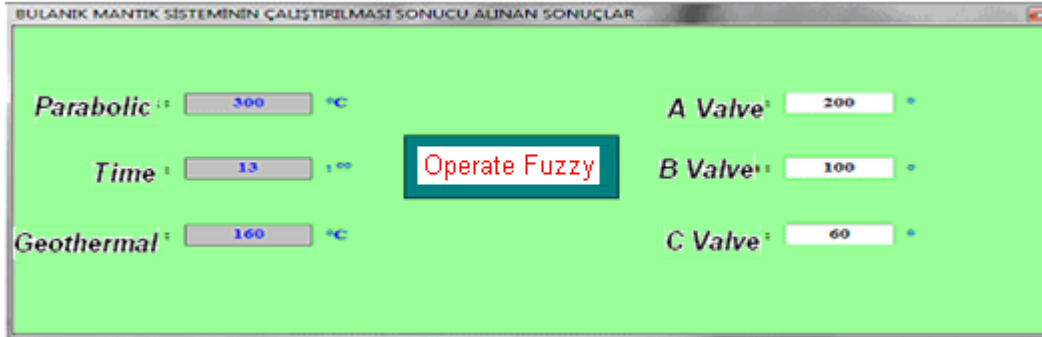

Figure 12. Defining the valve openings due to the input parameters.

Above in Figure 12. The valve output degrees are calculated using the fuzzy logic functions according to the input parameters like; heat of the parabolic fluid, time and the fluid heat of the geothermal reservoir.

5. Results

The developed program will redirect the coming heated fluid from parabolic collectors to the most suitable heat exchangers replaced in a Geothermal Energy System by controlling the valve positions. The valves opening positions on the system are controlled with the developed fuzzy program output due to the defined rule tables. According to the valve positions the fluid coming from the Parabolic collectors is redirected to the most suitable heat exchanger. As a result the valve opening degrees will have the opening values due to the coming parabolic heat degree of the fluid seen in Figure 13.
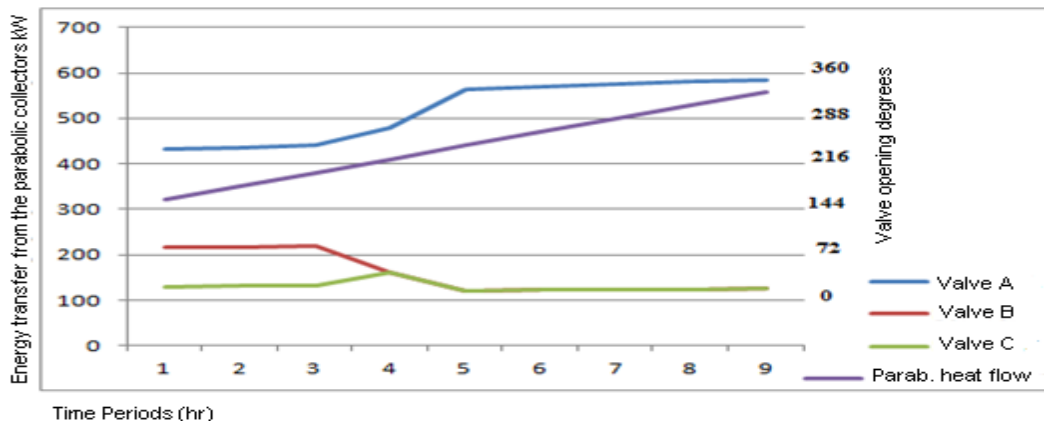

Figure 13. Valve opening degrees

Shown in Figure 14 shows the additive of the parabolic collectors to the system by using fuzzy logic.
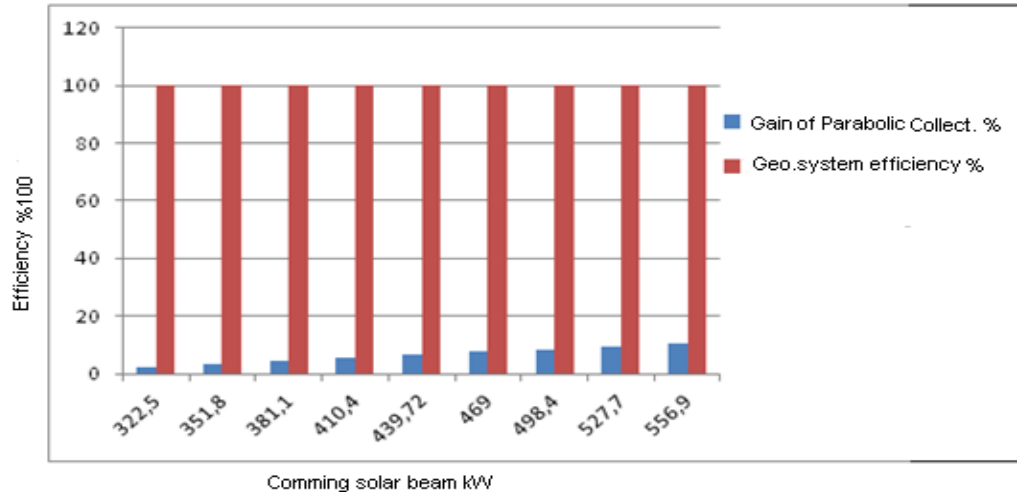

Figure 14 Additive of the parabolic system to the main system using fuzzy logic

In Figure 15 the fuzzy effect on the system is shown. Due to this it is seen that the fuzzy logic application is improving efficiency of the system output.
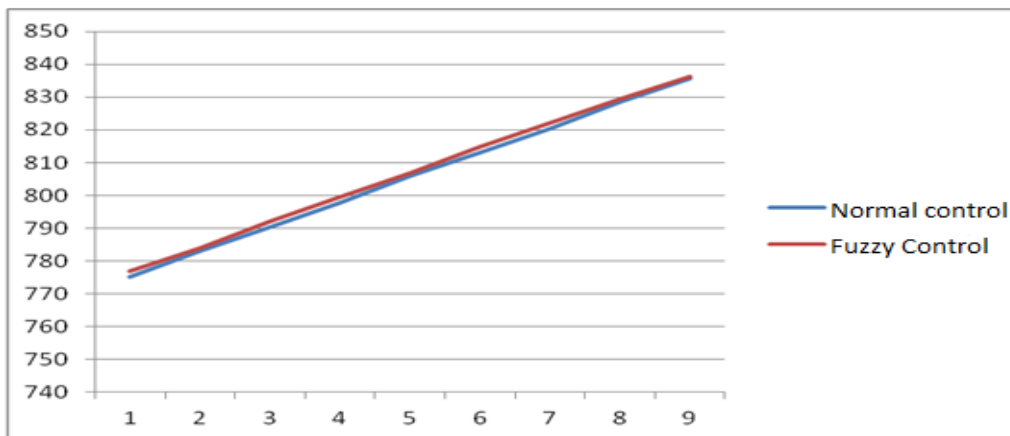

Figure 15 The fuzzy effect on the system

6. Conclusion

Seen on Figure 14 and Figure 15 it is seen that the fuzzy program has a small benefit on the efficiency of the system output. İf we compare the results of the classical program with the fuzzy program on Figure 15. It is seen that the time period is just taken for 10 hours of a specific day. But, if this is taken for a hole year it will be seen that the output of the graph will be periodical, instead of a straight line. And according to this the gain will be seen better. This system can't be tested with a real system because there is not alike system in real applications.

References

[1] **Baker.K.D., Özalevli.C.C., Sömek.S.K.,** Technical Study of a Hybride Solar Geothermal Power Plant and It's Application to a Thermal Design Course. Progress in Clean Energy.Vol.2 Novel Systems and Applications.

[2] **Östholm. R., Palsson.J.,** Dynamic Modelling Of A Parabolic Through Solar Power Plant, 10'th International Modellica Conference, Lund Sweden, 2014.

[3]**Lieberhard.J.H,** A Heat Transfer Textbook Fourth Edition, Dover Publications Inc Mineola, New York, 2011.

[4] **S. A. Kalogirou, S. Lloyd, J. Ward, P. Eleftheriou** Design and performance characteristics of a parabolic-trough solar-collector system, Applied Energy, Volume 47, Issue 4, Pages 341-354, 1994.

[5] **George C. Bakos**, Design and construction of a two-axis Sun tracking system for parabolic trough collector (PTC) efficiency improvement Renewable Energy, Volume 31, Issue 15, Pages 2411-2421, December 2006.

[6] **Çolak, L.,** Technical Optimisation, Design and Developing a Mathematical Model for Parabolic Trough Sun Tracking System , Gazi University, Ankara, 268

[7] **J.S. Roger Jang, Ned Gulley**, MATLAB User's Guide Fuzzy Logic Toolbox Computation-Programming-Visualization, Version 1,2003.