REABILITY ANALYSIS OF A GEOTERMAL BINARY POWER PLANT, NO.4, FROM SVARTSENGY, USING MONTE CARLO SIMULATION

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Abstract: The paper presents a reliability study of geothermal plant with secondary fluid made with two computation methods, which are: the Markov chain method and Monte Carlo simulation method. Then, was made a comparison between the obtained results by applied computation methods. This type of plant as working fluid uses isopentane, and its cooling in the condenser is made by water.

Key words: reliability, geothermal plant, Monte Carlo simulation, Markov chains

1. PRELIMINARIES

The renewable energy is defined as a form of energy, derived from a large range of natural resources having capacity of renewing after some renewable cyclic natural processes on a relative short and predictable scale.

The most important renewable energy forms are: the energy of solar radiation (solar energy), the wind (wind energy), of water (hydraulic energy, tidal energy, osmosis potential energy), of biological processes (the obtained energy after oxidation of biogas, bio-ethanol, biodiesel, and biomass) and of the stored heat in the earth's crust (geothermal energy). These forms of renewable energies are nowadays the most recognized energies and may be captured by actual technologies and used directly or indirectly [9].

The reliability is one of the decisive parameters of competitiveness product, because the merchantability degree grows significant for reliable products. After 1990, worldwide the reliability domain entered the new stage of development. If in '60 the reliability referred to control / verification, as in '70 / '80 to assurance, now the key word is the management of reliability with all which it implies: adequate predictable methods, reliability design, process reliability, convergent engineering, total quality control, etc. [8].

Considering all these aspects is important to define the reliability of geothermal plants. To establish the reliability of a certain type of geothermal plant, it was chosen a plant with binary cycle. This plant is the type of Ormat located in Island, at Svartsengy at approximately 40 km from the capital of the land. To make the analyze of the proposed plant it were chosen two computing methods, one, the analytical way with Markov's chain method, as the second way the Monte Carlo simulation method.

2. RELIABILITY OF GEOTHERMAL ELECTRIC PLANTS WITH BINARY CYCLE. CASE STUDY

As was stated above, the analyzed geothermal plant operates with binary cycle, with Clausius Rankine cycle, and for this type of plant the operating condition is that all compounds of the plant must activate. The scheme of the system is given by the equivalent serial reliability diagram, fig.2, and the scheme of the plant is given in fig.1. The mean time between failures and of faults was taken for the great compounds of the plant as: the vaporizer, turbine, generator, condenser, and cycling pump of the work fluid.

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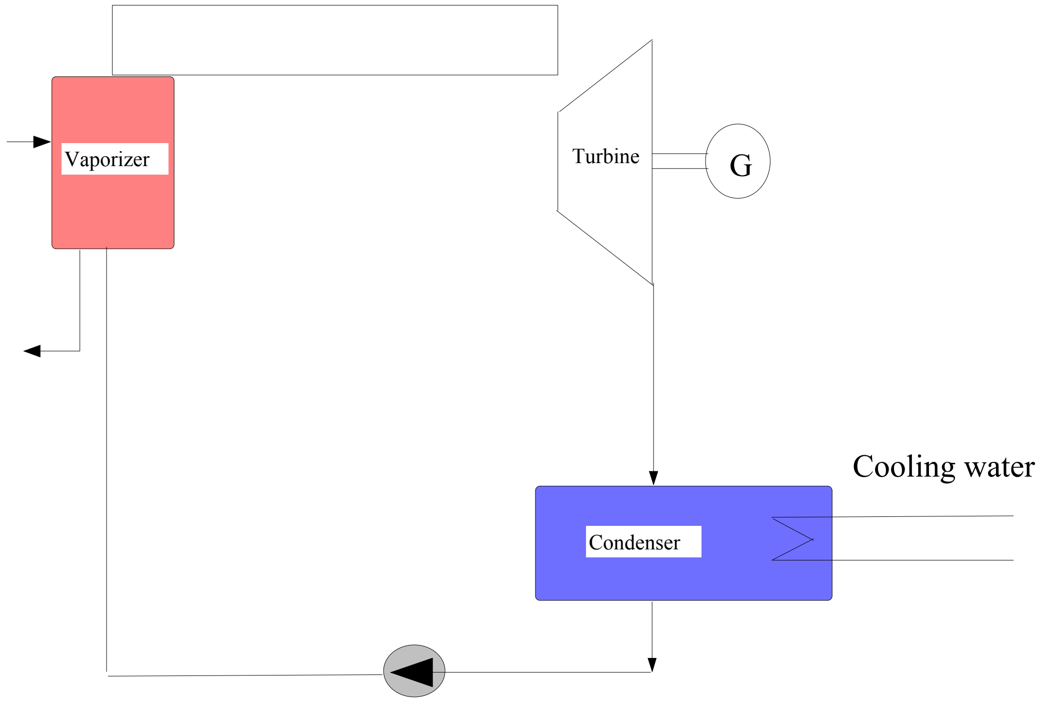

Fig. 1 - The simplified operation scheme of the electric geothermal plant (C4)

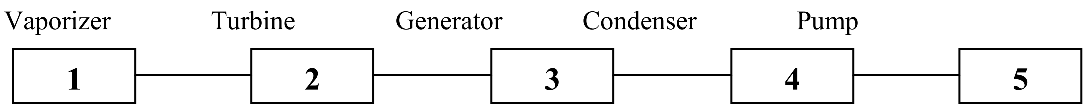

Fig. 2 - The equivalent reliability scheme of the geothermal plant

As input data it was used the values of λ and μ parameters, given in table 1.
Where: λ [h^{-1}] – is the failure intensity;
μ [h^{-1}] – is the intensity of reparation

The values for λ, μ has been calculated based on the exploitation data of mean time between failures and mean time to failure for analyzed geothermal plant with binary cycle.

Table 1 - Input data lambda and miu

Crt.No.	Equipment	λ [h^{-1}]	μ [h^{-1}]
1	Vaporizer	1,98597*10^{-5}	0,058823
2	Turbine	2,046287*10^{-5}	0,0006662
3	Generator	1,98736*10^{-5}	0,01923077
4	Condenser	2,01849*10^{-5}	0,001208
5	Pump	1,9862156*10^{-5}	0,0434782

2.1. Application of Monte Carlo simulation program

The numerical modelling of different processes about the elements' and systems' behaviour in time, is made by relationships including VA, those influences is estimated with some specifically operating and failure coefficients.

In this chapter was simulated the reliability of an electrical geothermal plant with binary cycle, with Monte Carlo simulation software, being an adaption of [6,7,8]. The software was made in MATLAB, a programming language frequently used to resolve scientific problems with research character. The estimated operation and non-operation times are computed by the programme with relations (1.1) and (1.2), where values of VA (random variable) u_i, v_i, are automatic generated by *rand* function of MATLAB [1,2]:

$$t_{func} = -\frac{1}{\lambda_n}\ln(u_i) \qquad (1)$$

$$t_{def} = -\frac{1}{\mu_n}\ln(v_i) \qquad (.2)$$

For the components from fig.1 was introduced the parameters λ and μ, in the simulation Monte Carlo program of the analyzed system, as well as its structure [8].

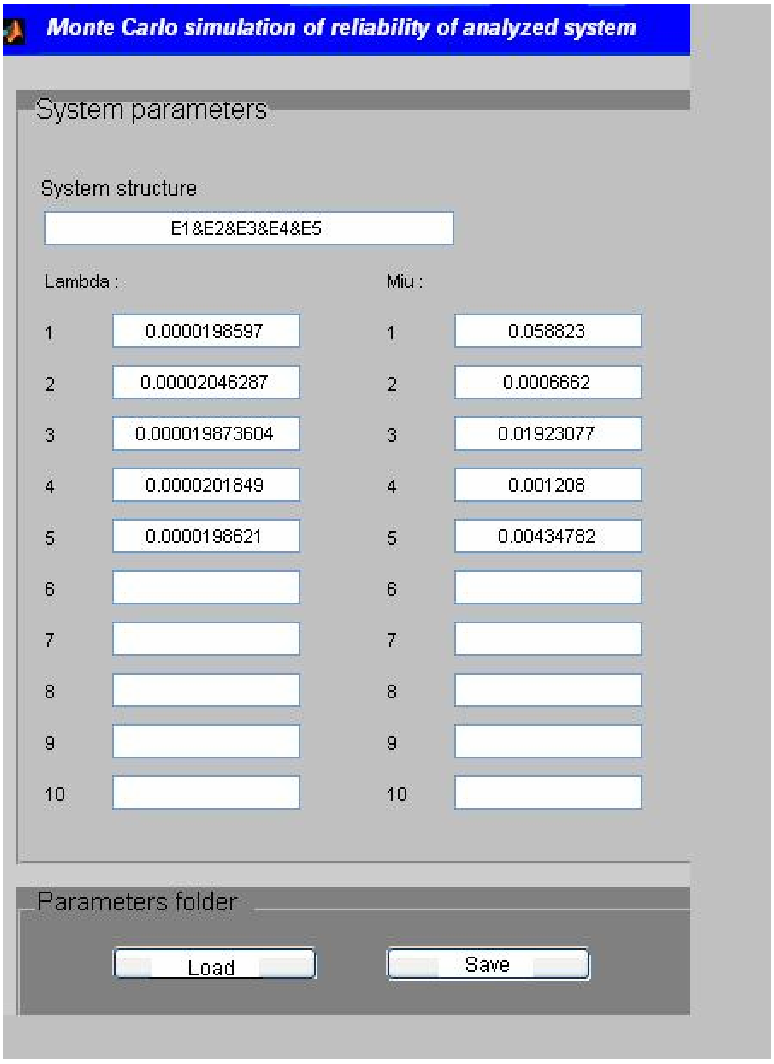

Fig. 3 - Parameters of the system

After introduction the parameters (λ, μ) and equation of the system, the user has the possibility to save the data, in order to be able to restore it if necessary, figures 3, 4, and 5.

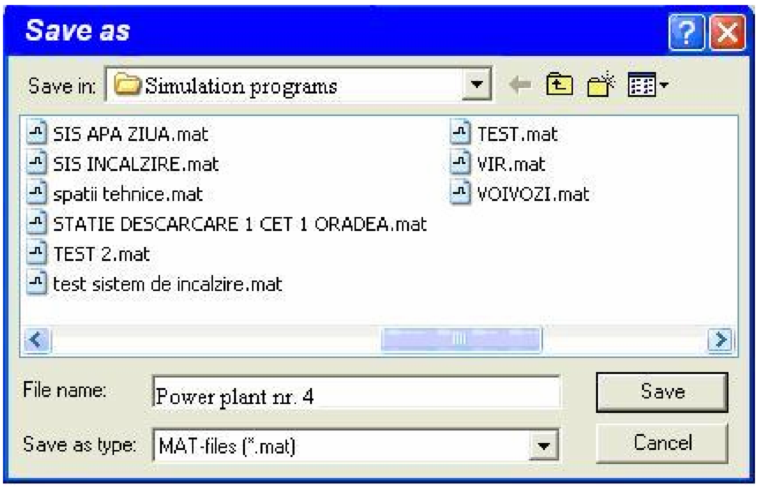

Fig. 4 - Module of the saving program of data

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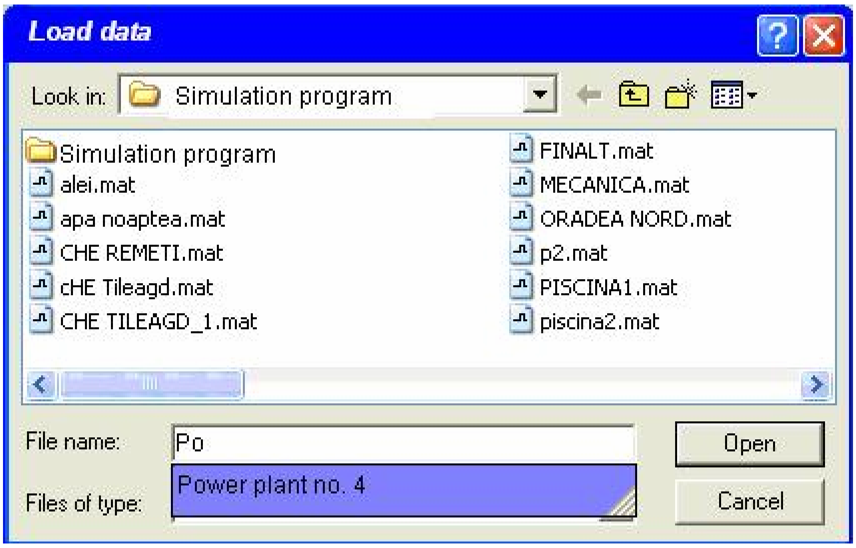

Fig. 5 - Module of the input program of data

After the system parameters introducing (μ, λ, and the system structure) the user will introduce the parameters of simulation that refers on:

- the number of simulation / analyze of TA (analyzed time);
- number of simulation N;
- number of simulation intervals, after this, will be successive accessed the results of numerical calculus, displaying the operation diagram and the diagram of reliability, all these have a saving action. In figures 6 – 9, will be presented some captures of window with precisions.

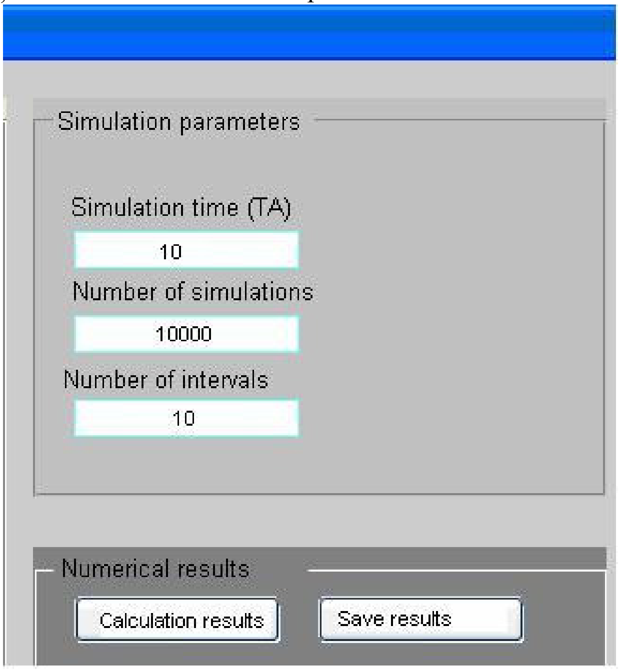

Fig 6 - Example of simulation parameters introducing

Fig. 7 - Calculation of the results of simulation

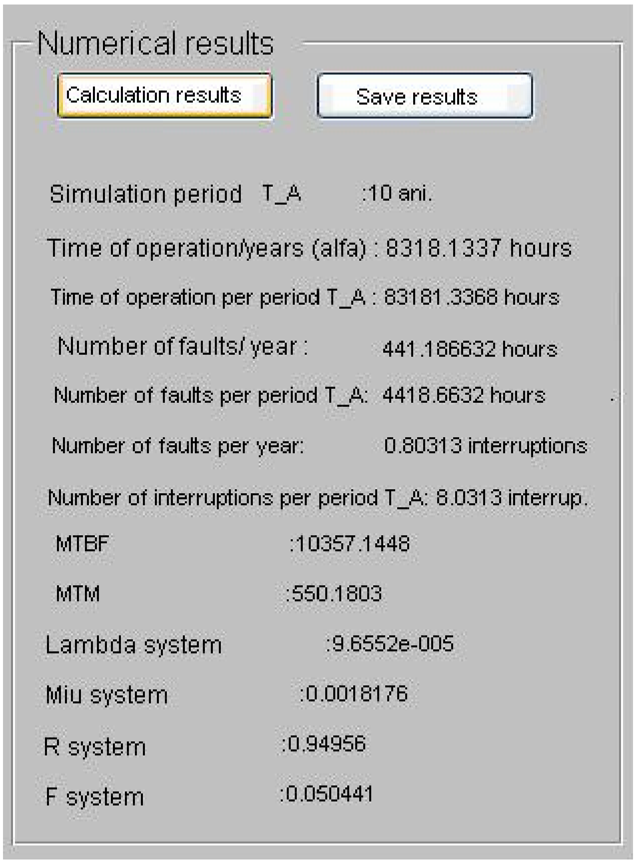

Fig. 8 - Numerical results of the simulations

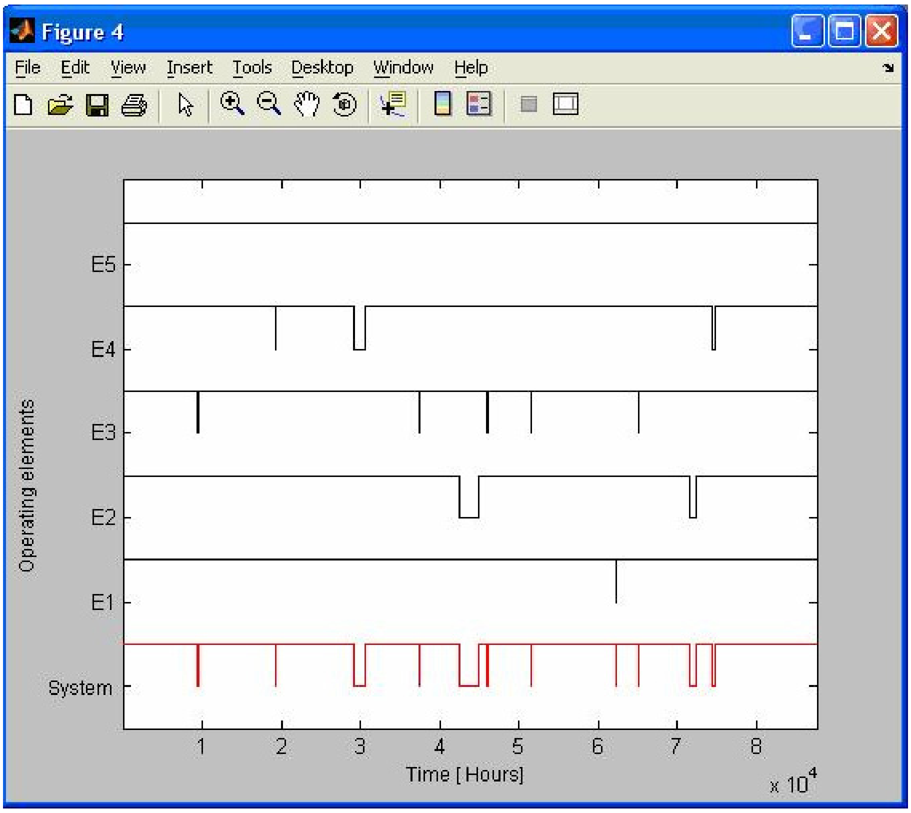

Fig. 9 - Operating diagram for the analyzed system after the analyze of the simulation and saving

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2.2. Comparison of the obtained results applying the Markov and Monte Carlo simulation methods

In table 2, are given the results obtained from simulation, simultaneously a comparison study between analytical and simulation results for the analyzed plant. In the left column of the table 2, are the results obtained by Markov chains method, and in the right column are the results obtained from the Monte Carlo simulation obtained by the program.

The results obtained by analytical method with Markov chains have been taken from [9], these calculus were made for the same system as the analyzed one in this article and the analyzed period being the same.

For Monte Carlo method, the investigation period is 10 years, because it is useful to observe the system's behaviour for a longer period, but there were evidenced the indicators resulted from the calculus for one year.

Table 2 - Comparative analyze between the obtained results by simulation Monte Carlo and analytical way Markov Chain

No.	*Indicators*	*Symbol*	*Units*	*Monte Carlo simulation*	*Markov chain*
1.	*Time of operation/ year*	α	*h*	*8318.3368*	*8348.80*
2.	*Number of faults/ year*	β	*h*	*441.8663*	*412.841*
3.	*Number of interruption / year*	ν	*intreruption*	*0.80313*	*0.83691*
4.	*Mean time between failure*	*MTBF*	*h*	*10357.1448*	*9975.74*
5.	*Mean time of maintenance*	*MTR*	*h*	*550.1803*	*493.31*
6.	*Lambda system*	λ_e	h^{-1}	*9.6552e-005*	$10.0243 * 10^{-5}$
7.	*Miu system*	μ_e	h^{-1}	*0.0018176*	0.0020271
8.	*Reliability of system*	R_{system}	-	*0.94956*	0.952878
9.	*Non- reliability*	F_{system}	-	*0.050441*	0.047122

The differences between the indicators aren't significant; they are due to the number of simulations, due to the fact how Mathlab works in its memory with 14 decimals, even if displays fewer differences that are on the limit of an admissible computation error; also the simulation results are influenced by evolution of the systems in time, taking into account the failures appearing the period of analyze.

3. CONCLUSIONS

The reliability analyze of electric plants are a need for the manufacturers of equipment's, as well as for potential customers. The scientific literature is poor in treatment of electric geothermal plants reliability. For a reliability indicator computation of electric geothermal plants, may be used the classical analytical methods, but it is preferable to apply a simulation method, for example the Monte Carlo simulation method. The simulation program in Mathlab allows:

- the reliability indicator computation for the secondary fluids in geothermal plants;
- drawing of operation diagrams for all elements and for system;
- drawing its reliability diagrams.

The obtained values by Monte Carlo simulation for the reliability function, confirms the accuracy of the method. The differences are between allowable limits and appear due to the decimals with the Mathlab works, and to the fact because the results of the simulation are supposed to the influence of evolution in time of the system.

The obtained results by applying the two computation methods show, that the analyzed system has a very good reliability.

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