Optimization of energy consumption of residential buildings using genetic algorithm

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Abstract*— In this study, the amount of energy cost savings for a period of ten years has been calculated using the P_1-P_2 method, which is one of the economical methods of energy life cycle insulation analysis. This method is one of the most popular and practical methods available to calculate the cost of energy savings as well as the thickness of thermal insulation for long periods of time. In this research, genetic algorithm method has been used for optimization. In a genetic algorithm, each optimization variable is a gene, and the combination of all the optimization variables together forms a chromosome. Finally, the results of energy saving for the optimal insulation thickness over a period of ten years using the P_1 – P_2 method for the four heating and cooling systems for insulation only and insulation mode considering the reduction of system size in Tehran using The method of optimizing the genetic algorithm is investigated. In this study, the amount of energy cost savings for a period of ten years has been calculated using the P_1-P_2 method, which is one of the economical methods of energy life cycle insulation analysis. This method is one of the most popular and practical methods available to calculate the cost of energy savings as well as the thickness of thermal insulation for long periods of time. In this research, genetic algorithm method has been used for optimization. In a genetic algorithm, each optimization variable is a gene, and the combination of all the optimization variables together forms a chromosome. Finally, the results of energy saving for the optimal insulation thickness over a period of ten years using the P_1 – P_2 method for the four heating and cooling systems for insulation only and insulation mode considering the reduction of system size in Tehran using the method of optimizing the genetic algorithm is examined.

Keywords*—Genetic algorithm optimization, insulation thickness optimization, insulation thickness calculation and energy saving*

I. INTRODUCTION

in this study, the method of genetic algorithm is used to find optimal amount of thermal insulation and the amount of energy saving for the period of ten years, regardless of the size of heating and cooling systems volume for the city of Tehran. Finally, the results of energy saving for optimum insulation thickness for 10 years using mode P _ 1 - p _ 2 for the four thermal and cooling systems for only insulation and insulating mode are investigated using the optimization method of genetic algorithm in MATLAB software. In this context, design of design for building energy systems for building energy systems is presented in this context, using genetic algorithms [2], using Ryozo Ooka [3-5]. An efficient method for energy system provides the best combination of equipment capacity and best operational planning for cooling, heating and power simultaneously with respect to certain criteria such as energy consumption, CO emissions, and so on. And in another paper, Design and Control of PV - Lopez using a hybrid PV system with an independent PV system using a classical PV system using a classical design method based on energy available in worst case conditions. In both cases, demand and radiation are the same. The computational results show the economic benefits of the PV hybrid system. In the paper referred to as Optimization of PV Systems Using Systems [6], Drik manger has been developed in the case of a modular simulation model from a developed PV battery system and integrated into a genetic algorithm framework to assess the optimal size of such systems in different boundary conditions. The presented paper describes the simulation hypotheses and compares the optimization results for a PV battery system that has the DC topology, compares the current economic states with budgeting and without it [7].

II. SOLUTION METHOD

A. Calculation of the thickness of the insulation and energy saving for the period of 10 years.

In this study, the amount of energy cost savings for the period of ten years is calculated using the method which is one of the economic methods of energy analysis of life cycle energy analysis. This method is one of the most popular and efficient methods for calculating the cost of energy conservation as well as thermal insulation thickness for long - term time domain. the method is based on two economic indexes. the energy cost rate during the life cycle is proportional to the energy cost in the first year and the cost of maintenance and maintenance during the insulation lifetime is due to the initial investment amount of the

maintenance and maintenance of insulation that its relations are defined as follows

$$P_1(N,i,d) = \sum_{j=1}^{N} \frac{(1+i)^{j-1}}{(1+d)^j} = \begin{cases} \frac{1}{d}[1-(\frac{1+1}{1+d})^N] & if\ i \neq d \\ \frac{N}{1+i} & if\ \ i = d \end{cases} \quad (1)$$

$$P_2 = 1 + P_1 M_s - R_v (1+d_f)^{-N} \quad (2)$$

In which, the cost rate of maintenance and maintenance is higher than the initial cost [7-9], which is considered equal to zero in this study. As a result, Eq. (2) is equal to one.

If (i), where the inflation rate and (d) which are the bank's interest rates are equal, Eq. (1) turns to Eq. (3)

$$P_1 = \frac{N}{1+i} \quad (3)$$

The cost of insulation will also be obtained from Eq. (4).

$$C_{ins} = C_i x \quad (4)$$

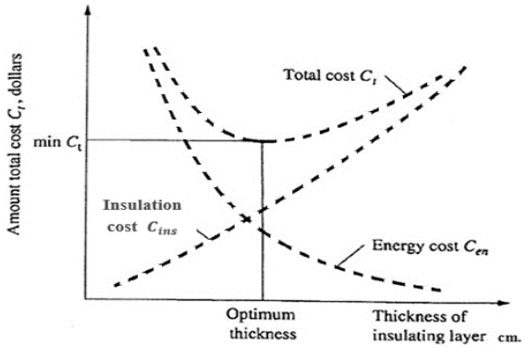
It is the cost of insulation to the dollar per square meter and the cost of insulation with the dollar per cubic meter. The amount of energy saving in the lifetime is calculated as Eq. (5).

$$S = C\_en\ P\_1 - P\_2\ C\_ins \quad (5)$$

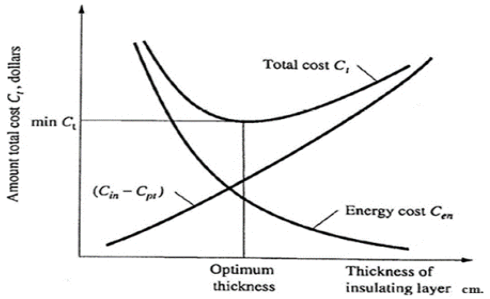
Considering the effect of the volume of the system, different results will be obtained compared to the state that is only insulated. The major difference between the two modes is also shown in Eq. (6). The main reason for this difference is the reduction of the amount of capital obtained, the reduction of the cost of the system difference from the total cost of insulation (shown)and its relationship is shown in Eq. (6)

$$C_t = C_{ins} - C_{pt} + C_{en} \quad (5)$$

in this thesis, (C_t) is the total cost and (C_{en}) is cost of energy, calculated by natural gas and gas bills for each building unit, is calculated according to the cost of steps stated by the ministry of energy. The following figure presents an example of the calculation of the amount of gas used for a class of the building in an avalanche in the city of Tehran for the last six months of the year. In it, the cost of the range means the cost of gas consumption, which will be obtained from the multiplication of two gas - set prices in the range of consumption. Figure 1 - Example of the volume of gas used for the total of a floor of the building in Bahman (January) month in the city of Tehran for six months.



A



B

Fig.1. Total cost of insulation. (A): regardless of system size reduction, (B): considering system size reduction

B. optimization with genetic algorithm

in this study, genetic algorithm method has been used for optimization. In the genetic algorithm, each optimization variable is a gene and the combination of all the optimization variables together form a chromosome. In this algorithm, at first the size of the population is randomly generated as zero codes and one. after calculating the objective functions of chromosomes (functions which will answer all needs as well as the main optimization on them), the selected chromosome is selected. Selected chromosomes are integrated according to a set of principles. The composition principles try to pass the good genes of the previous generation to the next generation, and the principles of mutation try to transmit genes to the next generation, which do not exist in the previous generation; thus, they exit the search space. the new generation of the new generation will replace the weak ones of the previous generation. The new generation must now take the process of calculating the objective function, choice, composition, mutation, and replacement in successive iterations. With many iterations, different chromosomes dominate each other until one of the constraints of the stopping algorithm is satisfied. in this study, the combination of genetic algorithm is considered of two - point type. because this type of compound is more accurate because of the chromosome cut from two places than one single - point type. in this method two points are randomly selected in the parent chromosomes and then the genes between the selected points are exchanged. As the number of selected points is high, performance will also increase. An example of a two - point compound is showed below [3]. Step 1: At this stage, a good number of chromosomes are selected to be used in the later stages. chromosomes that have high salience value may be selected several times in the production stages, while chromosomes that are low in fitness may never be selected. Stage 2: In this stage, the compound operator has operated on the parent chromosome and by combining them produces a new chromosome. in this case, new information is typically extracted based on the information contained in the present chromosomes (the chromosomes present in the parents' population). If there are certain information for some reason Restrictions on information storage (restrictions in number of population members) The loss of information in the selection step. (Because the information is in low fitness.)

Then the compound operator will not be able to create new structures that contain the missing information.Step 3: In this step the action of the mutation has been made on the chromosome from the action of the composition, and with the changes of the ¬ or the genes of these chromosomes, there is a way of entering new information.Stage 4: In this

stage in order to assess the children, the new fitness value is calculatedStep 5: At this stage, the new population is chosen to enter the next step of the algorithm.Step 6: At this stage, everyone in the new population will be evaluated. as the algorithm ends, the algorithm ends and otherwise the population will be used as the primary population for the next stage. The termination conditions of the genetic algorithm can be determined by the problem or condition such as the execution time of the algorithm, a limited number of productions in the algorithm or not changing the best answer for a certain number of production stages

C. Performance of the genetic algorithm on the optimization problem of the insulation thickness

in this study, the method of genetic algorithm is used to find optimal amount of thermal insulation and the amount of energy saving for the period of ten years, regardless of reducing the size of heating and cooling systems for the city of Tehran. Therefore, one must choose a function as the objective function. The objective function in this problem lies in Eq. (5), which is indeed the energy savings, and the relations are defined in this algorithm. The table (1), as an example, is intended only for mode of consideration of polystyrene insulator without considering reducing the size of the system and only for the heating system of the city of Tehran. data coding, insulation cost and energy cost are listed in table (1). according to table (1), the genetic algorithm is used to represent the design variables increasing from 0 to 10 cm thick, using a eight - bit chromosome.

according to the points mentioned above and in accordance with the theory of the best, we need to use the operators and reproduction operators to reproduce the next generation. before the composition of the compound, the pairs that have to be merged are determined. these pairs are randomly assigned according to the five - table column (1). as mentioned here, we use the integration operator of the two points that are randomly applied across the field. column 6 and 7 are expressed in terms of integration and column 8 of the table (1) also shows the second - generation population after the integration operation. Similarly, the operation will be repeated for the second generation. this operation continues until all of the strands of chromosomes with respect to Eq. (5) that are defined in the genetic algorithm are defined as the objective function; to an answer that will be optimal solution. in the end, the achieved chromosome code is the optimal solution (minimum cost of insulation and energy) according to the required parameters of the method for ten years.

For example, the chromosome number 81, which corresponds to an insulated thickness of 8 cm, and the No. 2 chromosome that is related to the insulation thickness is 1 / 0, as the parent is positioned to blend together. first, both of the eight bits are extracted from the first cut site and the second cut site, the second and sixth place where each line is located in the chromosome, as the following shape is marked with red arrow. then the combination of two points is carried out, so that in the form below, two genes, two primary and final bits are taken from the number 81, and the rest of the other genes are taken from the other parent chromosome, the chromosome 2.

Table (1): The optimization operation of the genetic algorithm and the generation of the next generation from the parent combination of two chromosomes.

Return on investment considering the system (years)	Energy savings for ten years considering the system ($)	Optimal insulation thickness for a period of ten years (centimeters)		Tehran City
		For insulation only mode For mode	with system size in mind	
3.3	4282	6.5	5.2	Package heating system
3.4	4113	6.3	5.1	Central engine room heating system
2.8	4969	6.7	5.2	Air conditioner cooling system
3.2	3924	6.3	5.3	Water cooler cooling system

Table (2): Comparison of the optimum insulation thickness for mode only insulation and mode considering the size of the system for Tehran

1	2	3	4	5	6	7	8	9	10
No	**Binary Coding**	**Insulatin Thickness (cm)**	C_{ins} , C_{en}	**Mate**	**CS1**	**CS2**	**Population After Crossover**	**Insulatin Thickness (cm)**	C_{ins} , C_{en}
1	00000000	0	0 , 723	6	2	6	00000001	0.5	79 , 610
2	00000001	0.1	46 , 668	23	2	6	00010101	2	248 , 399
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
23	00010111	2.2	270 , 381	1	2	6	00000011	0.3	62 , 642
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
81	01010101	8	824 , 164	2	2	6	01000001	6.1	689 , 197
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
101	01101010	10	1009 , 136	81	2	6	01010110	8.1	831 , 162

III. RESULTS AND DISCUSSION

the mutation in this algorithm is considered as the one that is more likely to change the gene from one chromosome with the gene from another chromosome in this method. the number of generations considered to continue the optimization process is equal to one hundred generations. finally, the results of energy saving for optimized insulation thickness for 10 years using method - for the four thermal and cooling systems for insulation only and insulating mode were achieved by using genetic algorithm optimization method in MATLAB software.

according to the results and figures obtained for the city of Tehran, the amount of energy saving and return of capital for the period of ten years as well as the type of heating and cooling system for the period of ten years as well as the type of heating and cooling system were selected as the system size was chosen, in Tables (2) and (3) as arranged.

Table (2): Comparison of the optimum insulation thickness for mode only insulation and mode considering the size of the system for Tehran

Optimal insulation thickness for a period of ten years (centimeters)		Tehran City
With insulation and system change	No insulation	
Haydn.16-16kw	Parma24Rsi-24kw	Package heating system
Shoofazh kar super300-9 blade-231kw	Shoofazh kar super400-13 blade-342kw	Central engine room heating system
TOSHIBA-S10-10000$^{Btu}/_{h}$	GREE-GWH30LB 30000$^{Btu}/_{h}$	Air conditioner cooling system
Absal-40AC-4650$^{m^3}/_{h}$	Absal-58AC 6350$^{m^3}/_{h}$	Water cooler cooling system

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