ASOCIAȚIA INGINERILOR DE INSTALAȚII DIN ROMÂNIA
Filiala Timișoara

UNIVERSITATEA "POLITEHNICA" DIN TIMIȘOARA
Departamentul de Construcții Civile și Instalații

INSTALAȚII PENTRU CONSTRUCȚII ȘI CONFORTUL AMBIENTAL

CONFERINȚĂ CU PARTICIPARE INTERNAȚIONALĂ

Ediția a 22-a

11-12 aprilie 2013
TIMIȘOARA - ROMÂNIA

EDITURA POLITEHNICA

Colecţia "CONFERINŢE"

INSTALAŢII PENTRU CONSTRUCŢII
ŞI
CONFORTUL AMBIENTAL

Lucrările conferinţei

Ediţia a 22-a

Homo sanus in domo pulchra

ASOCIAŢIA INGINERILOR DE INSTALAŢII DIN ROMÂNIA
Filiala Timişoara

UNIVERSITATEA „POLITEHNICA" DIN TIMIŞOARA
Departamentul de Construcţii Civile şi Instalaţii

INSTALAŢII PENTRU CONSTRUCŢII ŞI CONFORTUL AMBIENTAL

CONFERINŢĂ CU PARTICIPARE INTERNAŢIONALĂ

Ediţia a 22-a

11 – 12 Aprilie, 2013
TIMIŞOARA – ROMANIA

EDITURA POLITEHNICA
TIMIŞOARA – 2013

EDITURA POLITEHNICA
Bd. Republicii nr. 9
300159 Timişoara, România

Tel./Fax: 0256/403.823
E-mail: editura@edipol.upt.ro

Consilier editorial: Prof.dr.ing. Sabin IONEL
Redactor: Claudia MIHALI
Tehnoredactare: Claudia MIHALI
Prof.dr.ing. Adrian RETEZAN

Bun de imprimat: 04.04.2013
Coli de tipar: 33,5
ISSN: 1842 - 9491

Tiparul executat sub comanda nr. 26
la Tipografia Universităţii "Politehnica" din Timişoara

CUVÂNT ÎNAINTE

Calitatea mediului ambiant din clădiri este un domeniu de mare importanţă pentru sănătatea oamenilor. Larga arie de investigare referitoare la confortul termic, ventilare – climatizare şi calitatea aerului, efectul pozitiv/negativ al apei, sănătatea şi siguranţa ocupanţilor/clădirilor, modelarea şi monitorizarea, toate în dinamica schimbărilor climatice şi ţinând seama de sustenabilitatea soluţiilor, precum şi de dezvoltarea socioeconomică, conduce, pe lângă colaborarea cu alte specialităţi, la necesitatea/obligativitatea schimburilor de experienţă a celor ce s-au dedicat ştiinţei instalaţiilor pentru construcţii. Dorinţa de mai bine, experienţa anterioară izvorâtă din dictonul « Homo sanus in domo pulchra » şi din paradigma interdisciplinarităţii, înţelegerea holistică a multitudinii de factori/vectori care influenţează confortul, efectele care rezultă asupra oamenilor şi clădirilor, ne-au determinat şi ne motivează să continuăm. Să continuăm a dezvolta şi motiva teorii, în a oferi soluţii şi tehologii, dar şi în a le impune (aceasta însemnând continuarea solicitării sprijinului legislativ/politic, la toate nivelurile – ca exemplu pozitiv, deşi nu ne aparţine nouă, românilor, menţionăm restricţiile referitoare la fumat). Să continuăm : a căuta soluţii care să răspundă dezvoltării sustenabile ; provocărilor date la schimbările climatice ; a găsi tehnologii şi materiale nepoluante care să protejeze consumatorii ; să promovăm energiile curate/neconvenţionale ; să asigurăm flexibilitatea funcţională a instalaţiilor ; să punem OMUL înaintea altor interese.

În concluzie, continuarea înseamnă aprofundarea cunoştinţelor şi diversificarea preocupărilor, respectiv, ca alternativă, lucru în echipe interdisciplinare, înseamnă oportunităţi şi atragerea de noi specialişti talentaţi, dar şi rezolvarea nevoilor sociale (sau măcar răspunsuri pentru acestea) ; înseamnă a acorda atenţie OMULUI prin confortul ambiental, a-l susţine prin a-i asigura noi surse/resurse de energie, prin a-l sprijini să îmbunătăţească/protejeze mediul înconjurător, prin a-i oferi, gradual, educaţia care să-l îndreptăţescă a se considera stăpân pe toate.

Pentru toate acestea, instalatorii în colaborare cu toţi cei care îşi doresc o viaţă mai bună, dată de confort, siguranţă, performanţă, şi-au unit eforturile (inspirate) în elaborarea a 58 lucrări valoroase, repere pentru activităţile viitoare. Aducem călduroase mulţumiri celor 107 autori/coautori care au înţeles importanţa cuvântului scris în împărtăşirea experienţei.

Prof. Adrian RETEZAN

Conferinţa naţională cu participare internaţională
INSTALAŢII PENTRU CONSTRUCŢII ŞI CONFORTUL AMBIENTAL
Ediţia a 22–a
11-12 aprilie, 2013 – TIMIŞOARA, ROMÂNIA

OPTIMAL SLOPE OF A SOLAR COLLECTOR USING PARTICLE SWARM AND HOOKE JEEVES OPTIMIZATION ALGORITHM

Jasmina Skerlic, Danijela Nikolic, Dragan Cvetkovic,
Jasna Radulovic, Milorad Bojic
Faculty of Engineering, University of Kragujevac, Kragujevac, Serbia

Abstract

In Serbia, it is customary to use electricity for domestic hot water heating. As around 70% of electricity is produced by using coal with high greenhouse emission, it is beneficial to environment to use solar energy for domestic water heating. In addition it is important to have the highest possible efficiency of this use that may be obtained for the solar collector placed at its optimal slope. To find the optimum slope, EnergyPlus software is used for modeling solar plant, Particle Swarm Optimization algorithm (PSO) or Hooke-Jeeves optimization algorithm. The operation of these two software codes is connected by using Genopt optimization software. This paper reports that the descrepancies in the incident solar radiation (of the solar distribution models) with the applied calculation timestep are multiplied by the applied software when the final results are obtained such as the optimal slope, solar fraction of the installation and electrical energy used in the installation.

Rezumat

În Serbia, este uzual folosirea energiei electrice pentru încălzirea apei calde menajere. În jur de 70% pentru producerea electricităţii se utilizează cărbune având emisii crescute a efectului de seră, fiind mai benefic mediului de a utiliza energia solară pentru încălzirea apei calde menajere. În plus este important de a obţine cea mai bună eficienţă a acestora, prin montarea colectoarelor solare la o pantă optimă. Pentru găsirea unghiului de înclinare optim al panourilor solare, s-a utilizat softul EnergyPlus, algoritmul de optimizare Hooke-Jeeves sau algoritmul de optimizare PSO (Particle Swarm Optimization). Operarea celor două coduri de program se face cu ajutorul softului de optimizare Genopt. Această lucrare notează diferenţe a radiaţiei solare incidente (modele de distribuţie solară) cu aplicarea multiplă a pasului de timp pentru calcul, cu ajutorul softului în cazul rezultatelor finale, cum ar fi panta optimă, fracţia solară şi energia electrică utilizată în instalaţie.

Keywords: *Solar Fraction, Storage tank, Solar collector, Collector slope, Timestep, Particle Swarm Optimization algorithm, Hooke-Jeeves optimization algorithm*

1. INTRODUCTION

During the first years of the twenty-first century, extensive efforts have been undertaken to alleviate global warming of the earth caused by emission of CO_2 in atmosphere. The emissions may be mitigated when part of energy needs is satisfied by using non polluting energy sources such as solar energy, instead of fossil fuels. Also, another important advantage of the usage of solar energy is that it does not pollute the environment with nitrogen oxides and sulfur dioxide.

In Serbia, it is customary to use electricity for operation of solar domestic hot water systems (SDHWS). As around 70% of electricity is produced by using coal with high greenhouse emission, it is important to use solar energy for domestic water heating. In addition it is important to have a high efficiency of this use.

In households, the high amount of domestic hot water (DHW) is used for shower, tap, cloths-washing (machines), and dish-washing (machines). If this water is heated by electricity which is generated by coal burning, then the highest amount of CO_2 is released to atmosphere. Accordingly, the most rewarding application of solar energy is when it replaces this type of electrical energy for heating of hot water in households. Then, the highest decrease in CO_2 emissions may be expected. In renewable energy field, SDHWS have arisen a great research interest [1,2]. To use SDHWS with the greatest benefit, SDHWS must have adequate design, installation, and operation.

To obtain an optimum performance of SDHWS, the operation of the SDHWS may be investigated by using simulation and optimization. Then, the captured solar energy would be determined as a function of a position of the solar collector toward the sun. For energy simulation, EnergyPlus software would be used and for the optimization, Hooke-Jeeves search algorithm (HJ) and Particle Swarm search algorithm (PSO). These two programs would be controlled by using GENOPT software.

This paper explains if there is different time step in calculation of the operation of the solar collector installation when using EnergyPlus with Genopt software and different optimization routine how the errors of the solar distribution models reflect to the final results such as the optimal slope, solar fraction of the installation and electrical energy used in the installation. The paper also compares the final results based on the use two different optimization algorithms - Particle Swarm optimization routine and Hooke-Jeeves search algorithm.

2. SOFTWARE

Simulation Software - EnergyPlus: In this study, the simulation software EnergyPlus (Version 7.0) was used. EnergyPlus is made available by the Lawrence Berkley Laboratory in USA [3]. Its development began in 1996 on the basis of two widely used programs: DOE-2 and BLAST. The software serves to simulate building energy behavior and use of renewable energy in buildings. The renewable energy simulation capabilities include solar thermal and photovoltaic simulation. Other simulation features of EnergyPlus include: variable time steps, user-configurable modular systems, and user defined input and output data structures. The software has been tested using the IEA HVAC BESTEST E100-E200 series of tests[4].

To model, the solar hot water heating system in EnergyPlus environment, we used models of different components that are embedded in EnergyPlus such as that of flat-plate solar collector, storage tank, tempering valve, and instantaneous water heater. Water in the storage tank was heated by solar energy and water in the instantaneous water heater by electricity.

Optimization Methodology: *Particle swam optimization* is a new heuristic optimization method based on swarm intelligence. PSO algorithms exploit a set of potential solutions to the optimization problem. Each potential solution is called a particle, and the set of potential solutions in each iteration step is called a population. PSO algorithms are global optimization algorithms and do not require nor approximate

gradients of the cost function. The first population is typically initialized using a random number generator to spread the particles uniformly in a user-defined hypercube. A particle update equation, which is modeled on the social behavior of members of bird flocks or fish, schools, determines the location of each particle in the next generation [5,6].

Each particle keeps track of its coordinates in the problem space. They are associated with the best solution (fitness) it has achieved so far. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the neighbors of the particle. When a particle takes all the population as its topological neighbors, the best value is a global best..

Hooke-Jeeves algorithm (HJ) is a direct search and derivative free optimization algorithm [7]. In Hooke Jeeves algorithm, only the objective functions and the constraint values are used to guide the search strategy. In this research, the adaptive precision Hooke Jeeves algorithm is used. Compared to the fixed precision Hooke Jeeves algorithms in [8], the adaptive precision Hooke Jeeves algorithms have a test that controls the precision of the approximating cost functions. The test causes the optimization algorithms to use coarse approximations to the cost function in the early iterations and progressively to increase the precision of the approximating cost functions as the sequence of iterates approaches a stationary point. Another difference between the adaptive Hooke and Jeeves algorithms and the fixed precision Hooke Jeeves algorithms is that the adaptive algorithms can be parametrized so that they only accept iterates that reduce the cost sufficiently.

GENOPT software. GenOpt is an optimization program for the minimization of a cost function that is evaluated by an external simulation program [9]. It has been developed for optimization problems where the cost function is computationally expensive and its derivatives are not available or may not even exist. GenOpt can be coupled to any simulation program that reads its input from text files and writes its output to text files. The independent variables can be continuous variables (possibly with lower and upper bounds), discrete variables, or both, continuous and discrete variables. Constraints on dependent variables can be implemented using penalty or barrier functions.. GenOpt is applicable to a wide range of optimization problems, has a library with adaptive Particle Swarm optimization algorithm and adaptive Hooke Jeeves algorithm.

3. MATHEMATICAL MODEL

EnergyPlus Model for SDHWS: SDHWS serves to heat domestic hot water. The system heats the water by using solar energy and electric energy. The domestic hot water is used for heating of sink water, bath and shower water, and water for dish washing and cloth washing machines. Schematics of the solar hot-water system for heating of domestic hot water in EnergyPlus environment is shown in Fig.1. The system consists of the solar collector, storage tank, instantaneous heating tank, and tempering valve. Solar energy is captured by using solar collector. This energy heats water that flows through the collector. Furthermore, the water from collector heats water in the storage tank to some temperature that may be higher or lower than the needed (hot-water set-up) temperature. If this temperature is higher than the needed temperature, then this temperature is lowered by using cold water through the tempering valve. If this temperature is lower than the needed temperature, this water is heated by electric energy in the instantaneous water heater.

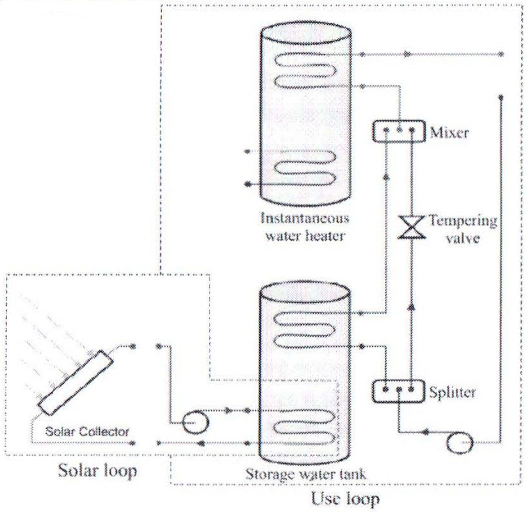

Fig.1 Schematics of the solar hot-water system for heating of domestic hot water (taken from [10])

Calculation of energy consumption: Calculation of energy consumption during the calculation period gives two electrical energies *E* and *R* consumed for DHW production. The energy *E* is consumed by the electric heater when the solar collector is present and operating, and

energy *R* is consumed when no solar collector is employed. The objective function is the performance of the installation is evaluated by calculating the solar fraction (*f*) by:

$$f = 100\ (R-E)/R \qquad (1)$$

Solar Collector (Thermal Performance): Solar Collector is of Flat Plate type produced by, Alternate Energy Technologies (AE-32) with length of 3.66m and width of 2.43m. The thermal efficiency of a collector is defined as

$$\eta=(q/A)/I_{solar} \qquad (2)$$

where q = useful heat gain, A = 8.89m^2 gross area of the collector, and I_{solar} = total incident solar radiation. Note that the efficiency η is only defined for $I_{solar} > 0$.

For η, the following quadratic correlation is used

$$\eta = c_0 + c_1\frac{(T_{in}-T_{air})}{I_{solar}} + c_2\frac{(T_{in}-T_{air})^2}{I_{solar}} \qquad (3)$$

Both first- and second-order efficiency equation coefficients from [11] are given as c_0 = 0.691, c_0 = 3.396 W/m2-K, and c_0 = 0.00193 W/m^{2}K^2.

Collector Surface Geometry: Calculations require that the collector surface is described geometrically. Here, the collector is placed to the building roof that is rectangular in shape (see Fig.2). Its size and shape is the same as that of the roof, where the length of the collector is designated as (a) and the width of the collector as (b). The building height is designated as h. Finally, the collector surface is described by the coordinates of their vertices 1, 2, 3, and 4 in a three dimensional Cartesian coordinate system.

The collector is south facing. Its tilt angle (β) is the angle between the Z-axis and the normal to the surface of the collector (or between the collector surface and the horizontal). The convention assumed here is that $-90^0<\beta<90^0$ the surfaces with positive β face south and with negative β face north.

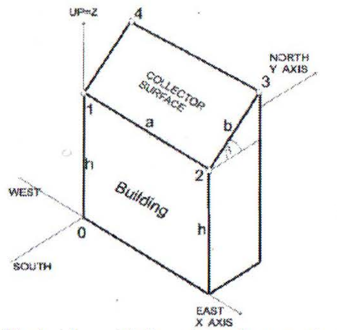

Fig.3 The buiding with the solar collector at its roof. The surface area of the solar collector 1234 is equal to that of the building roof.

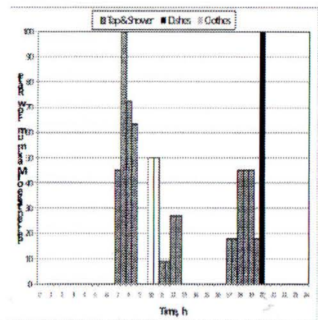

Fig. 2 Schedule of hot water use for (a) tap and shower, (b) dish and clothes washer.

Hot Water Consumption: This installation generates four different types of hot water: Fig.2 provide hot water characteristics: temperatures, maximum flow rates and daily schedules that may be valid for family of four in Serbia. Regarding its application, the water would be heated to two temperatures: 43.3 (tap and shower) and 50^{0}C (dish and clothes washer). For water with lower temperature and for water with higher temperature used in dish washer, the daily schedule is the same for each day throughout entire summer. The cloth washer operates only on Sunday. For water with higher temperature used in the cloth washer, the daily schedule is the same for each Sunday throughout the entire summer.

Timestep: The timestep object in EnergyPlus specifies the "basic" time-step for the simulation. The value entered here is usually known as the zone timestep. This is used in the zone heat balance model calculation as the driving timestep for heat transfer and load calculations. The value entered here is the number of timesteps to use within an hour. Longer length of time-steps has lower values for number of time-steps per hour.

4. RESULTS AND DISCUSSION

This paper explains if there is variation in the optimal slope for installation of a solar collector when there is different time step in calculation of the operation of the solar collector installation when using EnergyPlus with Genopt and Particle Swarm optimization routine (PSO), or HookeJeeves optimization routine (HJ). As an example, these software tools are applied to SDHWS in Belgrade, Serbia.

This investigation is performed with two solar distribution models: (1) full interior and exterior, (2) full exterior with reflections. Their applications gave the same results.

Figure 4 and 5 shows collector slope as a function of the applied time step per hour. The figures shows that the optimum slope mean value is 36.84^0 (PSO), 37.46^0(HJ) and the standard deviation σ = 1.34^0 (PSO), σ = 0.352^0 (HJ).

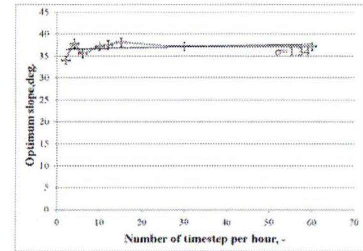

Fig.4 Collector slope as a function of the applied time step per hour.(PSO)

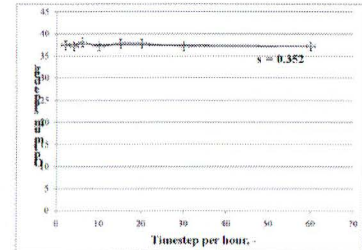

Fig.5 Collector slope as a function of the applied time step per hour.(HJ)

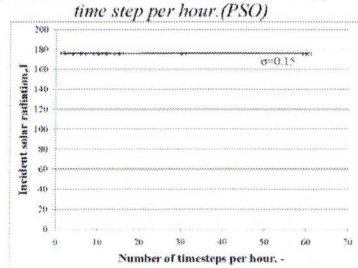

Fig.6 Incident solar radiation as a function of the applied time step per hour.(PSO)

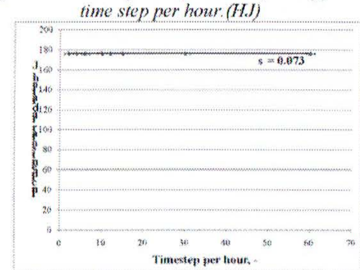

Fig.7 Incident solar radiation as a function of the applied time step per hour.(HJ)

Figure 6 and 7 shows the incident solar radiation to the collector as a function of the applied time step per hour. The figure shows that the mean value of the incident solar radiation is 176.045 J (PSO), 175.99 J (HJ) and the standard deviation is 0.15 J (PSO), 0.073 J (HJ) that is 0.084% (PSO), 0.04% (HJ) of the mean value. This shows that the incident solar radiation is not responsible for the variation of the optimum collector slope with the time step.

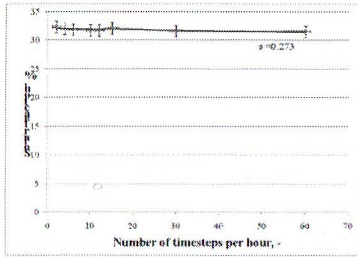

Fig.8 Solar fraction as a function of the applied time step per hour.(PSO)

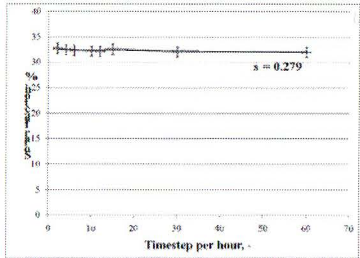

Fig.9 Solar fraction as a function of the applied time step per hour.(HJ)

Figure 8 and 9 shows the solar fraction to the collector as a function of the applied time step per hour. The figure shows that the mean value of the solar fraction is 31.848 (PSO), 32.3 and the standard deviation is $\sigma = 0.273$ (PSO), $\sigma = 0.279$ (HJ) that is 0.855% (PSO), 0.863% (HJ) of the mean value.

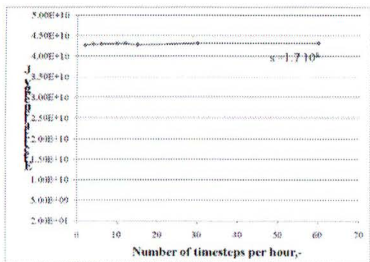

Fig.10 Electrical energy as a function of the applied time step per hour.(PSO)

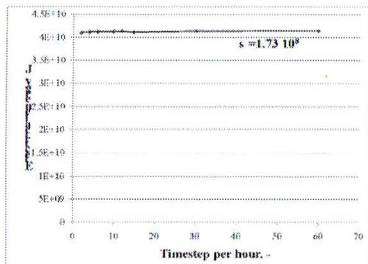

Fig.11 Electrical energy as a function of the applied time step per hour.(HJ)

Figure 10 and 11 shows the electrical energy to the collector boiler as a function of the applied time step per hour. The figure shows that the mean value of the electrical energy is 4.3 10^{10} (PSO), 4.12 10^{10} (HJ) and the standard deviation is $\sigma = 1.7\ 10^8$ (PSO), $\sigma = 1.73\ 10^8$ (HJ) that is 0.4% (PSO), 0.42% (HJ) of the mean value.

5. CONCLUSION

This paper reports how the selection of the timestep in EnergyPlus software with the modified, Particle Swarm optimization algorithm methodology or Hooke Jeeves direct search methodology influences the determination of the optimal slope for installation of a solar collector and the optimum solar fraction. As an example, the optimum slopes of solar collector due to south and the collected solar energy are calculated for each

month during entire year that enable the maximum amount of the solar energy and the solar fraction for SDHWS in Belgrade, Serbia.

The collector slope depends slightly on the applied time step per hour. The incident solar radiation to the collector does depend slightly on the applied time step per hour (0.084% (PSO), 0.04% (HJ) of the mean value). The solar fraction to the collector varies with the applied time step per hour by around 0.855% (PSO), 0.863% (HJ) of the mean value. The electrical energy to the collector varies with the applied time step per hour by around 0.4% (PSO), 0.42% (HJ) of the mean value.

This means that the final variables (the solar fraction, the optimum collector angle and the electrical energy to the collector boiler) have the larger discrepancies with the timestep than that of the incident solar radiation.

The appled solar distribution models does not influence to the calculation. The applied algorithms are approximately the same results, which indicates their precision.

REFERENCES

[1] A.S. Nafey, Simulation of solar heating systems—an overview, Renewable and Sustainable Energy Reviews, 9 (2005) 576–591

[2] X.Q. Zhai, R.Z. Wang, Experiences on solar heating and cooling in China, Renewable and Sustainable Energy Reviews, 12 (2008) 1110–1128

[3] Anonymous, ENERGYPLUS, Input Output Reference - The Encyclopedic Reference to EnergyPlus Input and Output, University of Illinois & Ernest Orlando Lawrence Berkeley National Laboratory, 2009

[4] R.H. Henninger, M.J. Witte, D.B. Crawley, Analytical and comparative testing of EnergyPlus using IEA HVAC BESTEST E100-E200 test suite, Energy and Buildings 36 (8) (2004) 855–863.

[5] R. C. Eberhart and Y. Shi. Particle swarm optimization: Developments, applications and resources. In Proceedings of the 2001 Congress on Evolutionary Computation, volume 1, pages 84–86,Seoul, South Korea, 2001. IEEE.

[6] J. Kennedy and R. C. Eberhart. Particle swarm optimization. In IEEE International Conference on Neural Networks, volume IV,pages 1942–1948, Perth, Australia, November 1995.

[7] R. Hooke, T.A. Jeeves, Direct search solution of numerical and statistical problems, Journal of the Association for Computing Machinery 8 (1961) 212–229.
[8] C. Audet, J.E. Dennis Jr., Analysis of generalized pattern searches, SIAM Journal on Optimization 13 (3) (2003) 889–903.
[9] M. Wetter, Simulation-Based Building Energy Optimization, Phd. Degree dissertation , University of California, Berkeley, 2004. Wetter, M., 2004. GenOpt, Generic Optimization Program. User Manual, Lawrence Berkeley National Laboratory, Technical Report LBNL- 54199, p. 109.
[10] Tamara G. Kolda, Robert Michael Lewis, Virginia Torczon, Optimization by direct search: new perspectives on some classical and modern methods, SIAM Review 45 (3) (2003) 385–482.
[11] M. Wetter, Simulation-Based Building Energy Optimization, Phd. Degree dissertation , University of California, Berkeley, 2004. Wetter, M., 2004. GenOpt, Generic Optimization Program. User Manual, Lawrence Berkeley National Laboratory, Technical Report LBNL- 54199, p. 109.

Acknowledgment
This paper is a result of two projects: TR33015 supported by the Ministry of Science and Technological Development of Republic of Serbia and KNEP supported by the Center for Scientific Research of the Serbian Academy of Sciences and Arts and University of Kragujevac. The authors thank these institutions for their financial support.

Conferința națională cu participare internațională
INSTALAȚII PENTRU CONSTRUCȚII ȘI CONFORTUL AMBIENTAL
Ediția a 22–a
11-12 aprilie, 2013 – TIMIȘOARA, ROMÂNIA

IMPACT OF THE LATERAL COLLECTOR EDGES ON THE IRRADIATED AREA OF THE LOWER ABSORBER SURFACE OF THE BIFACIAL SOLAR COLLECTOR

N. Nikolić, N. Lukić, M. Bojić
Faculty of engineering, University of Kragujevac, Serbia
Sestre Janjić 6, 34000 Kragujevac

Abstract
The bifacial flat-plate solar collector (BFPC) is a solar collector that can absorb solar irradiation from its upper as well as lower absorber surface (LAS). Absorption of a solar irradiation from its LAS is achieved using flat plate reflector placed below the collector. The reflector is parallel with collector. Compared to a conventional flat-plate solar collector, the insulation of the analyzed collector, placed in the bottom of the box, is replaced by glazing. This paper presents the mathematical model for determining the irradiated area of the LAS when the impact of the lateral collector edges on the irradiated area of the LAS of the BFPC is included.
Rezumat
Colectoarele solare plane bifacial (BFPC) sunt colectoare solare care pot absorbi radiația solară la suprafața sa superioară la fel ca și la suprafețe de absorbție mai mici (LAS). Absorbția radiației solare de la suprafețele LAS se realizează utilizând un panou reflector amplasat sub colector. Panoul reflector este paralel cu colectorul, Comparativ cu un colector solar plat convențional placa de izolare amplasata la partea inferioară este înlocuită cu sticlă la colectorul analizat. Această lucrare