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47. MEĐUNARODNI KONGRES I IZLOŽBA O GREJANJU HLAĐENJU I KLIMATIZACIJI

47th INTERNATIONAL CONGRESS & EXHIBITION ON HEATING, REFRIGERATION AND AIR CONDITIONING

Beograd, Sava centar, 30. novembar – 2. decembar 2016.

Belgrade, Sava Center, 30 November – 2 December 2016

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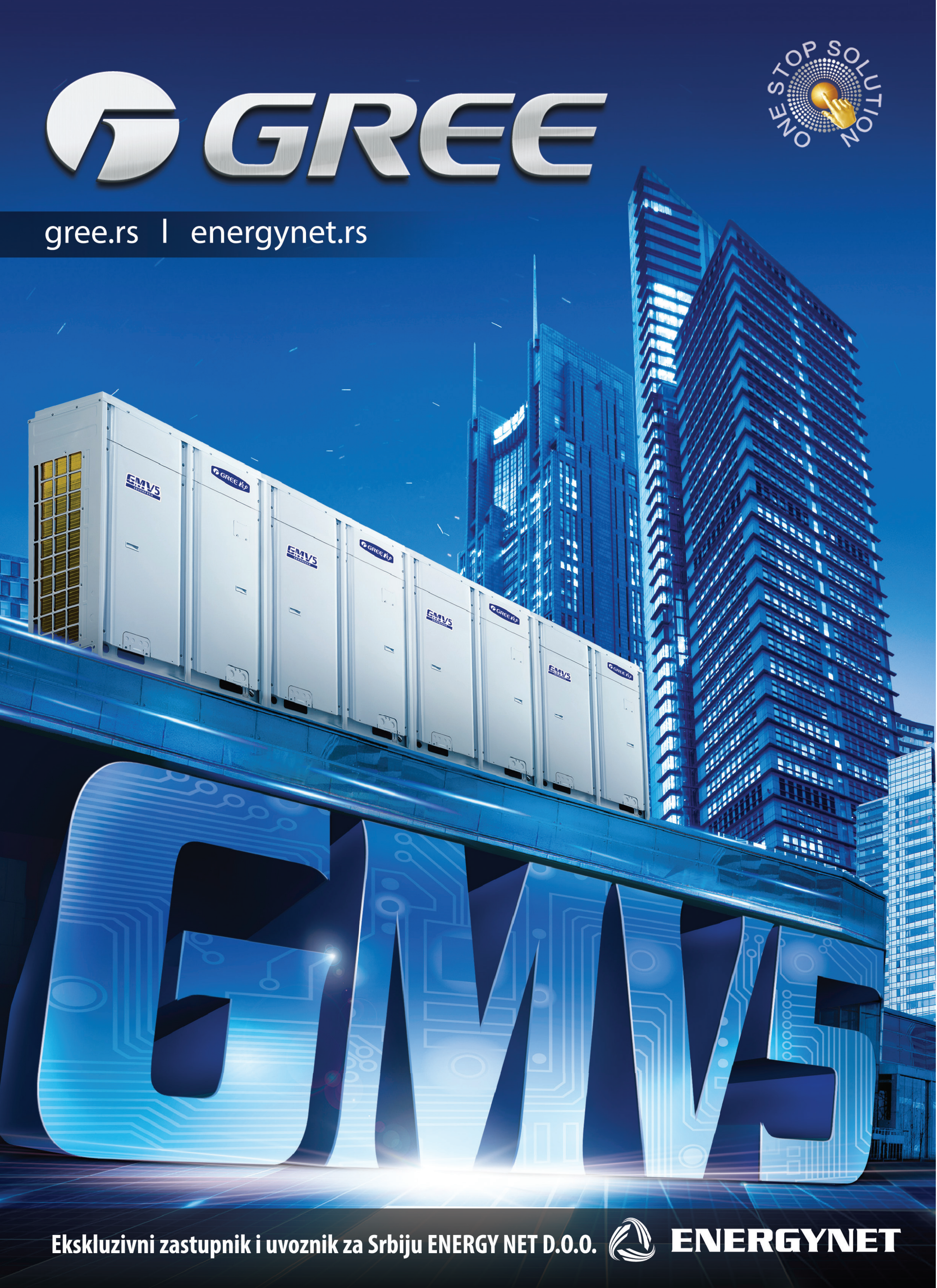
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SREDA • Wednesday			
SALA 1/0 • Hall 1/0		**ANEKS B • Annex B**	
09:00 ~ 09:45	Registracija Participants Registration		
10:00 ~ 10:30	Otvaranje kongresa i izložbe Opening of Congress and Exhibition		
10:30 ~ 13:30	Sesija 1 Plenarna predavanja Keynote Lectures		
13:30 ~ 14:30	**Koktel dobrodošlice • Welcome Cocktail**		
14:30 ~ 17:10	Sesija 2 Standardizacija Standardization	14:30~17:45	Sesija 3 Daljinsko grejanje District Heating

ČETVRTAK • Thursday					
SALA 1/0 • Hall 1/0		**ANEKS A • Annex A**		**ANEKS B • Annex B**	
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14:00 ~ 15:50	Sesija 5 Srpska regulativa i evropska „F" gas regulativa HFC Policy & Legislative Options in Serbia and European "F" gas legislation	12:15 ~ 15:15	Sesija 8 Projektovanje energetski efikasnih i zdravih sistema za KGH HVAC Systems Design for Energy Efficiency and Health	11:00 ~ 15:30	Sesija 11 Program za studente, mlade inženjere i profesionalni razvoj – kombinovano sa prezentacijama glavnih sponzora Students, Young Engineers & Professional Development Program – Combined with Main Sponsors Presentations
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20.00 h Banket • Banquet					

PETAK • Friday	
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    Marko PAVLOVIĆ1, Veselin ANĐELKOVIĆ1, Milan GOJAK2, Mihajlo GIGOV1, Sandra PETKOVIĆ1, Lazar ANĐELIĆ1; 1 Rudarski institut d.o.o., Beograd, 2 Mašinski fakultet, Univerzitet u Beogradu, Beograd

10.55–14.00 h **XIV.** FORUM: EUROPE, ASIA, AUSTRALIA, AFRICA AND AMERICA HARMONISED RURBAN DEVELOPMENT NEEDS – HVAC & COLD CHAIN, HEALTHY ENERGYPLUS BUILDINGS, ZERO CO2 SETTLEMENTS, SUSTAINABILITY, SECURITY AND RESILIENCE

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47. ADAPT TODAY TO SHAPE TOMORROW
    Tim WENTZ, ASHRAE President

48. ADVANCES IN ENVIRONMENTAL PRESERVATION: THE ROLE OF SOLID WASTE MANAGEMENT
    Doaa M. El-SHERIF, Urban Training & Studies Institute (Uti); Housing & Building National Research Center (Hbrc); Ministry Of Housing, Egypt

49. THE ROLE OF FACADE ON FIRE SPREAD
    Milovan VIDAKOVIĆ, Serbia

50. DISASTER MANAGEMENT IN SMART SETTLEMENT - RESILIENCE APPROACH AND LAYERED APPROACH TO (DISASTER) RESILIENCE ANALYSIS OF URBAN SETTLEMENTS
    Zoran KEKOVIĆ, Ozren DZIGURS, Vladimir NINKOVIĆ, Faculty of Security, Serbia

ANALIZA I OCENA SOLARNIH SISTEMA BUDUĆNOSTI

ANALYSIS AND ASSESSMENT OF SOLAR ENERGY SYSTEM FOR A SUSTAINABLE FUTURE

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Energetski resursi i njihova upotreba povezani su sa održivim razvojem. U postizanju održivog razvoja, važnu ulogu igra povećanje energetske efikasnosti procesa u kojima se koriste održivi izvori energije. Eksergetska analiza se uveliko koristi u projektovanju, simulaciji i proceni karakteristika sistema za solarnu energiju. Solarna energija je čista, ima je u izobilju i lako je dostupna obnovljiva energija. Snaga Sunca koja dospeva na površinu zemlje 1.8×10^{11} MW, što je mnogo puta veće od sadašnje stope svih energetskih potreba. U ovom radu data je eksegetska analiza solarnog sistema. Detaljna energetska i eksergetska analiza obavlja se kako bi se izračunali toplotni i električni parametri tipičnog solarnog kolektora. Pored toga, izvedena je modifikovana jednačina za eksergetsku efikasnost kolektora u pogledu projektnih i klimatskih parametara. U tom pogledu su dati opšti odnosi između energije i eksergije. Ovo vrlo korisno znanje je takođe neophodno za utvrđivanje energetske efikasnosti i/ili mogućnosti očuvanja energije, kao i za formulisanje pravih strategija države za upravljanje energijom i eksergijom.

***Ključne reči:** analiza; efikasnost; eksergija; obnovljiva energija; solarna, održivost*

Energy resources and their utilization relate to sustainable development. In attaining sustainable development, increasing the energy efficiencies of processes utilizing sustainable energy resources plays an important role. Exergy analysis has been widely used in the design, simulation and performance evaluation of solar energy systems. Solar energy is clean, abundant and easily available renewable energy. The power from the sun intercepted by the earth is about 1.8×10^{11} MW, which is many times larger than the present rate of all the energy consumption. This paper reviews exergetic analysis of solar energy system. A detailed energy and exergy analysis is carried out to calculate the thermal and electrical parameters, tipical solar collector. Further, a equation for the exergy efficiency of a collector is derived in terms of design and climatic parameters. In this regard, general relations between energy and exergy are given. This very useful knowledge is also needed for identifying energy efficiency and/or energy conservation opportunities, as well as for dictating the right energy and exergy management strategies of a country.

***Key words:** analysis; efficiency; exergy; renewable energy; solar; sustainability.*

Introduction

Long-term potential actions for sustainable development are needed if we want to achieve solution to environmental problems that we face today. In comparison to conventional energy sources, renewable energy sources are inexhaustible and offer many environmental benefits At the moment conventional sources meet most of the energy demand, however the role of renewable energy resources and their current advances have to take more relevance in order to contribute to energy supply and support the energy conservation (or efficiency) strategy by establishing energy management systems. Numerous benefits including a decrease in external energy dependence; a boost to local and regional component manufacturing industries; decrease in impact of electricity production and transformation; promotion of regional engineering and consultancy services specializing in the utilization of renewable energy; increase in the level of services for the rural population, etc. are offered by use of renewable energy, Dincer [1] reported the linkages between energy and exergy, exergy and the environment, energy and sustainable development, and energy policy making and exergy in detail. With the aim to highlight the importance of the exergy and its essential utilization in numerous ways he provided the following key points: (a) it is a primary tool in best addressing the impact of energy resource utilization on the environment. (b) It is an effective method using the conservation of mass and conservation of energy principles together with the second law of thermodynamics for the design and analysis of energy systems. (c) It is a suitable technique for furthering the goal of more efficient energy–resource use, for it enables the locations, types, and true magnitudes of wastes and losses to be determined. (d) It is an efficient technique revealing whether or not and by how much it is possible to design more efficient energy systems by reducing the inefficiencies in existing systems. (e) It is a key component in obtaining a sustainable development. Although it does not make the world ‘ready’ for the future generations, sustainable development establishes a basis on which the future world can be built. It may be said that a sustainable energy system is a cost-efficient, reliable, and environmentally friendly energy system that effectively utilizes local resources and networks. As opposed to a conventional energy system, it is not ‘slow and inert’ but it is flexible in terms of new techno-economic and political solutions. An exergy analysis (or second law analysis) has proven to be a powerful tool in the simulation thermodynamic analyses of energy systems. Exergy analysis method is used to detect and to evaluate quantitatively the causes of the thermodynamic imperfection of the process under consideration. It can, therefore, indicate the possibilities of thermodynamic improvement of the process under consideration, but only an economic analysis can decide the expediency of a possible improvement. The concepts of exergy, available energy, and availability are essentially similar. Exergy is also a measure of the maximum useful work that can be done by a system interacting with an environment which is at a constant pressure and temperature. Many authors dealt with renewable energy resources in terms of exergetic aspects. They also compared renewable and nonrenewable energy sources. Their conclusion is that some of the systems seem to have high efficiencies, and in some cases they are greater than the efficiency of systems using non- renewable energy sources [2, 3].

This paper reviews exergetic analysis of solar energy system. A detailed energy and exergy analysis is conducted to calculate the thermal and electrical parameters, typical solar collector. Further, a modified equation for the exergy efficiency of a collector is derived in terms of design and climatic parameters. In this regard, general relations between energy and exergy are given. This very useful knowledge is also needed for identifying energy efficiency and/or energy conservation opportunities, as well as for dictating the right energy and exergy management strategies of a country.

Energy and exergy modeling

Dincer et al. [4] reported that, to provide an efficient and effective use of fuels, it is essential to consider the quality and quantity of the energy used to achieve a given objective. With regard to this, the first law of thermodynamics deals with the quantity of energy and asserts that energy cannot be created or destroyed, whereas the second law of thermodynamics deals with the quality of energy, i.e., it is concerned with the quality of energy to cause change, degradation of energy during a process, entropy generation and the lost opportunities to do work. To be more specific, the first law of thermodynamics is concerned only with the magnitude of energy with no regard to its quality; whereas the second law of thermodynamics asserts that energy has quality as well as quantity. By quality, it means the ability or work potential of a certain energy source having certain amount of energy to cause change, i.e., the amount of energy which can be extracted as useful work which is termed as exergy. First and second law efficiencies are often called energy and exergy efficiencies, respectively. It is expected that exergy efficiencies are usually lower than the energy efficiencies, because the irreversibilities of the process destroy some of the input exergy. Exergy is the expression for loss of available energy due to the creation of entropy in irreversible systems or processes. The exergy loss in a system or component is determined by multiplying the absolute temperature of the surroundings by the entropy increase. Entropy is the ratio of the heat absorbed by a substance to the absolute temperature at which it was added. While energy is conserved, exergy is accumulated. Exergy analysis provides a method to evaluate the maximum work extractable from a substance relative to a reference state (i.e., dead state). It should be noticed that exergy is always evaluated with respect to a reference environment (i.e. dead state). When a system is in equilibrium with the environment, the state of the system is called the dead state due to the fact that the exergy is zero [3].

Simulation softwares

Simulation Software – EnergyPlus: In this study, the building energy simulation software EnergyPlus (Version 7.0) was used to predict solar energy and electrical energy use in solar installation for heating of DHW in several cities in Serbia.

Then, the solar fraction was determined for its different design, installation and operation parameters. EnergyPlus is made available by the Lawrence Berkley Laboratory in USA [5]. 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 [6]. 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 [7]. Modeling of the SDHWS in EnergyPlus environment required models of different components embedded in EnergyPlus such as that of flat-plate solar collector, storage tank, tempering valve, and instantaneous water heater [8]. Water in the storage tank was heated by solar energy and water in the instantaneous water heater by electricity.

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 has a library with local and global multi-dimensional and one dimensional optimization algorithms, and algorithms for doing parametric runs [10]. An algorithm interface allows adding new minimization algorithms without knowing the details of the program structure. GenOpt is written in Java so that it is platform independent. The platform independence and the general interface make GenOpt applicable to a wide range of optimization problems. GenOpt has not been designed for linear programming problems, quadratic programming problems, and problems where the gradient of the cost function is available. For such problems, as well as for other problems, special tailored software exists that is more efficient.

Optimization Algorithm: For optimization, the Hooke–Jeeves algorithm is used together with EnergyPlus simulation. These two programs are connected together by using Genopt software [9]. In this research, the adaptive precision Hooke-Jeeves algorithm is used. Hooke Jeeves algorithm is a direct search algorithm [13]. In direct search methods, only the objective functions and the constraint values are used to guide the search strategy. The methodology of search is given in [11, 13] in sufficient details. The used Hooke Jeeves algorithm is the adaptive precision algorithm. This algorithm progressively increase the precision of the approximating cost functions as the sequence of iterates approaches a stationary point. In addition, the algorithm only accepts iterates that reduces the cost sufficiently. It reduces the computation time up to a factor of four compared to the standard Hooke–Jeeves algorithm.

Mathematical model

To obtain performance of SDHWS, the operation of the SDHWS was investigated by using simulation and optimization. The mathematical model was developed in EnergyPlus simulation environment and the optimization was performed by using Hooke-Jeeves search algorithm.

This part of the paper provides the mathematical model used to simulate the energy behavior of SDHWS and different parts of its installation: solar collector, thermal tanks (storage & heaters), tempering valve, and SDHWS-control devices.

EnergyPlus Model for SDHWS: The SDHWS heats DHW by using solar and electric energy. The DHW is used as water for sink, bath, shower, dish washing and cloth washing. The SDHWS is schematically shown in Fig.1 in EnergyPlus environment. The SDHWS consists of the following main elements explained separately in the text below: the solar collector, storage water tank, instantaneous water heater, tempering valve, and temperature controls. These elements are located in two inner loops of the SDHWS: the solar loop and the use loop. The solar loop is a loop through the solar collector. The use loop is a loop for DHW consumption. The solar loop consists of the solar collector, water pump, and spiral pipe heat exchanger (inside the hot water storage tank). The use loop consists of the splitter, storage water tank, instantaneous water heater, tempering valve, and mixer. Inside the solar loop, the solar collector captures solar energy. This energy heats water that flows through the solar collector. Furthermore, the hot water heats DHW in the storage water tank. In the use loop, the cold DW reaches the splitter. From the splitter, the DW may go to the storage water tank or to the tempering valve. In the storage water tank, DW is heated from the solar loop via the spiral pipe heat exchanger. From the storage water tank, the hot water goes to the instantaneous water heater where can be additionally heated. Then the hot water from the instantaneous water heater and the cold water from the tempering valve go to the mixer and after that as DHW to the consumers. The water temperature in the storage tank may be higher or lower than the needed (hot-water set-up) DHW temperature. If this water temperature is higher than the needed DHW temperature, then this water temperature is lowered in the mixer by using the cold DW through the tempering valve. If this water temperature is lower than the needed DHW temperature, this water is heated by electric energy in the instantaneous water heater to the needed DHW temperature. The investigated solar collector is of flat plate type.

Surface geometry. Calculations require that the solar collector surface is described geometrically. Here, the solar collector is placed to the building roof. The solar collector is rectangular in shape with its length designated as (a) and its width as (b). The building height is designated as h. Finally, the solar collector surface is described by the coordinates of their vertices 1, 2, 3, and 4 in a three dimensional Cartesian coordinate system. This right-hand coordinate system has the X axis pointing east, the Y axis pointing north, and the Z axis pointing up that is characteristics of EnergyPlus Cartesian coordinate system. The vertices are recorded in counter-clockwise sequence (as the surface is viewed from outside its zone).

The solar collector is south facing. Its tilt angle (β) is the angle between the Z-axis and the normal to the surface of the solar collector (or between the solar 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. Its azimuth angle (γ) is defined as the displacement angle between the projection on a horizontal plane of the normal to the collector surface and due north. The convention assumed here is that $-180^0 < \gamma < 180^0$.

The surface of the solar collector is rectangular and defined by 4 vertices. Vertex 1 has coordinates: $x_1 = b \cos\beta \sin\gamma$, $y_1 = b \cos\beta \cos\gamma$, $z_1 = b \sin\beta + h_{12}$. Vertex 2 has coordinates $x_2 = 0$, $y_2 = 0$, $z_2 = h_{12}$. Vertex 3 has coordinates: $x_3 = a \cos\gamma$, $y_3 = b \sin\gamma$, $z_3 = h_{12}$. Vertex 4 has coordinates: $x_4 = b \cos\beta \sin\gamma + a \cos\gamma$, $y_4 = b \cos\beta \cos\gamma + a \sin\gamma$, $z_4 = h_{12} + b \sin\beta$.

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:

$$f = 100\,(R-E)/R = f(\beta_i, \gamma_i)$$

If $f = f_i$ is larger, the SDHWS better protects the environment. Variable f_i is a function of tilt β_i and azimuth angle γ_i.

It should be maximized in the constrained region of β_i and γ_i. As a result of the optimization, we obtain the maximum solar fraction $f_{i,max}$, and the optimum tilt $\beta_{i,opt}$, and optimum azimuth angle $\gamma_{i,opt}$.

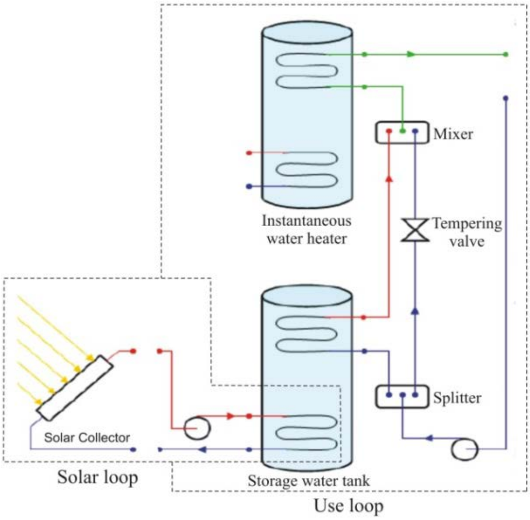

Figure 1 *- Schematics of SDHWS for heating of DHW (adapted from [8])*

Each solar collector that stays at optimal position generates the highest amount of heat from the incident solar energy. Then, the SDHWS uses this heat for the DHW heating instead of the electrical energy from the electricity network. This means that such a SDHWS avoids use of the highest amount of electrical energy from the electricity grid for the DHW heating. In addition, this avoids the highest amount of electrical energy generation by the national power plants.

If the solar collector of a SDHWS does not stay at the optimum position due to some reason, then it will generate smaller amount of exergy for the DHW heating than the maximum amount it would generate when it stays at the optimum position. As the heating of DHW uses the electrical energy, the SDHWS will use more electrical energy for the DHW heating than that when the SDHWS has its solar collector at the optimum position [14, 15].

For this case, the deficit solar fraction is defined as

$$D_i = \frac{100 \cdot (f_{i,tot} - f_{i,max})}{f_{i,max}} . \tag{1}$$

For this case, the deficit in avoided exergy is defined as

$$DE_{xi} = \frac{100 \cdot (E_{x,i} - E_{i,max})}{E_{i,max}} . \tag{2}$$

Solar Collector (Thermal Performance): Solar Collector is of Flat Plate type produced by, Alternate Energy Technologies (AE-32) with length of 3.66 m and width of 2.43 m, A = 8.89 m^2 = gross area of the collector.

Exergy analysis: The Solar system for sanitary water heating is the most popular way of using the solar energy due to its technical feasibility and cost efficiency in comparison with other types of the solar energy use. The maximum value of the exergy level of efficiency of the solar heating system SWH is determined through the exergy analysis. The maximum exergy efficiency level is achieved corresponding the maximum solar intake when the solar collector is optimally positioned.

The exergy efficiency rate η_x is the aim function in the optimization process, and is given by the equation (8.6) [92, 93, 94]:

$$\eta_x = \frac{E_{x,con}}{E_{x,C}} , \tag{3}$$

Where:

$E_{x,con}$ – exergy obtained from the consumers (tap, shower, dishwasher and the washing machine [J];

$E_{x,C}$ – The Sun exergy [J].

The Sun exergy is calculated based on the mean annual insolation value for Belgrade I = 5.22 J/m^2, and in the case of six months estimations, for the period between 15th April and 14th October the value I = 1.328 J/m^2 is used, whereas the period between 15th October and 14th April has the value of I = 3.724 J/m^2, estimated based on the mean daily insolations according to the months in question.

The exergy of the end consumers refers to the shower $E_{x,shower}$, sink $E_{x,sink}$, washing machine $E_{x,wash.mach.}$ And the dishwasher $E_{x,dishwas}$. Due to the lower water temperature necessary for the use of the shower and dishwasher, it is necessary to mix it with cold water, thus in the exergy optimization the exergy of cold water is taken into consideration which is added to the system $E_{x,coldw}$. The cold water exergy is calculated for the mean annual cold water temperature values of the cold water which is used in the house and which is 14.72 °C. The temeparature differences are smaller in the six months` estimations for the period between 15th October and 14th April, and bigger for the period between 15th April and 14th October .

The exergy obtained through the solar collector in the sanitary water heating system $E_{x,con} = E_{x,\ consumer}$ equals the total of the ened users` exergies:

$$E_{x,con} = E_{x,shower} + E_{x,\sin k} + E_{x,wash.mash} + E_{x,dishwas} \quad . \tag{4}$$

The solar receiver exergy efficiency represents the ratio between the exergy of the solar collector $E_{x,sol.col}$ and the solar exergy, and is given in the equation (5):

$$\eta_{sol.col} = \frac{E_{x,sol.col}}{E_{x,C}} \quad . \tag{5}$$

The exergy of the solar collectors $E_{x,\ sol.col}$ is given in the equation (6):

$$E_{x,sol.col} = C_p \cdot \dot{m} \cdot \left[\left(T_{col} - T_0 \right) - T_0 \cdot \ln \frac{T_{col}}{T_0} \right], \tag{6}$$

In which is: T_{col} = 323 [K] (defined as the input database of *EnergyPlus*), $\dot{m}$ - mass flow of the solar receiver [kg/s], T_0 – the temperature of the surroundings / environment [K], C_p = 4186 [J/kgK].

The exergy at the exit of the accumulation boiler can be represented by the equation (7), supposing that the value of the boiler temperature is linear.

$$E_{x,t} = C_p \cdot \dot{m} \cdot \left(\frac{T_{in} - T_{\text{out}}}{2} - T_0 \right) - C_p \cdot \dot{m} \cdot T_0 \left(\ln \frac{T_{\text{out}}}{T_0} - 1 \right) - \frac{T_{\text{out}} \cdot C_p \cdot \dot{m} \cdot T_0}{T_{in} - T_{\text{out}}} \cdot \ln \frac{T_{in}}{T_{\text{out}}} \ , \tag{7}$$

Where: $E_{x,t}$ – is the exergy at the exit of the accumulation boiler [J], T_{in} – the temperature at the entrance to the accumulation boiler [K], T_{out} –the temperature at the exit from the accumulation boiler [K].

The boiler exergy $E_{x,tank}$ represents the total exergy at the exot from the boiler and the electric energy, where the electric energy E_e which is used for the heating of water in the boiler when the temeperature drops under the set value.

$$E_{x,\tan k} = E_{x,t} + E_e \; . \tag{8}$$

The ratio between the necessary and obtained exergy e_x, of the solar system is defined:

$$e_x = \frac{e_{x,needed}}{e_{x,obtained}} \; . \tag{9}$$

The ratios between the necessary and obtained exergy on the users $e_{x,потребна}$ and $e_{x,obtained} = E_{x,con} = E_{x,\ consumer}$, should be as small as possible, because in this case the obtained exergy is bigger [16].

Simulation and optimization

For simulation and optimization to run, it is necessary to know the hot water consumption and climate.

Hot Water Consumption: This installation generates four different types of hot water: that of tap, shower, dish-washer, and cloth-washer. Regarding its application, the water would be heated to two temperatures: 43.3 (tap and shower with the maximum flow rate of 0.0000945 m^3/s) and 50^0C (dish and clothes washer with the maximum flow rate of (0.000063 m^3/s). 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.

Weather data: The investigated SDHWS is located in the city of Belgrade. Their meteorological data are used in the form of EnergyPlus weather files. These are either measured by the meteorological stations or calculated by the software Meteonorm for sites where data from meteorological stations are not available.

Belgrade has the average height above sea-level of 99 m. Its latitude is 44.82°N, longitude 20.27°E, and time zone GMT +1.0 Hours.

Results and discusion

By the use of the exergy optimization the maximum value of the exergy efficiency degree of the solar system for heating the SWH is determined. The maximum exergy efficiency degree, analogous to the maximum value of the solar share in the function of the slope and azimuth angle, is achieved by placing the solar receiver to the optimum position. The values of the solar shares as the function of the aim with the exergy optimization are the same as with energy optimization.

The deficit of the avoided exergy in the function of the deviation of the slope angle and azimuth at the optimum slope angle and azimuth for Belgrade is shown in fig 2. Figure 2 shows that when β_a and $\gamma_{a,}$ departs below $\beta_{a,opt}$ and $\gamma_{a,opt}$ for $\Delta\beta_a$ and $\Delta\gamma_{a,}$,the avoided exergy is lower than that when β_a и γ_a departs above $\beta_{a,opt}$ and $\gamma_{a,opt}$

for $\Delta\beta_a$, respectively $\Delta\gamma_a$ [17]. Analyzing the maximum exergy on the annual level for the solar systems for heating DHW with SC#1, SC#2 for Belgrade, the difference of the maximum values of the avoided exergy for the solar system for heating SWH with SC#2 in comparison with SC#1 is obtained. For SC#2, the difference is by 7 % higher in comparison to the achieved results with the stationary receiver. The analyzed solar systems for heating DHW with SC#1 is the immobile stationary solar receiver which operates on one slope angle throughout the year. The values $\beta = \beta opt = 28.75°$ and $\gamma_{opt} = 25°$ and thus $f = f_{max} = 35.8$ % are given for Belgrade, Serbia.

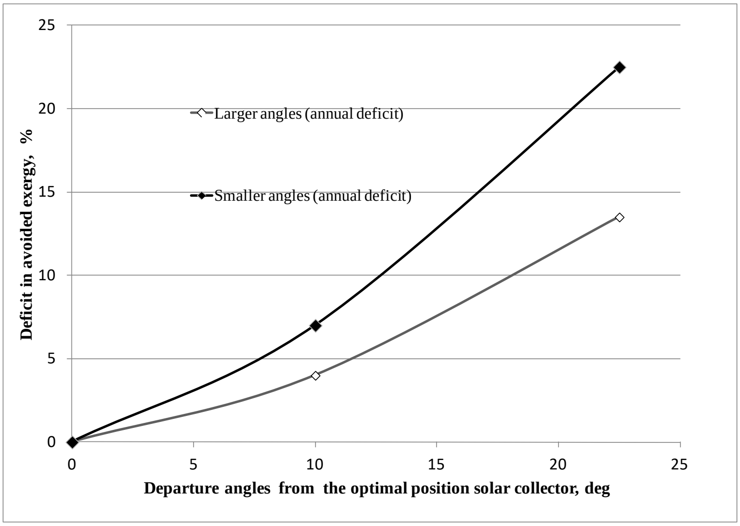

Figure 2 *- Deficit avoided exergy versus departures angles from the optimal position of the solar collector for SDHWS in Belgrade, Serbia*

As one of the important indicators of the exergy flows in the analyzed solar system is the ratio of the necessary and obtained exergy as has been mentioned before. The figure 3 shows the values of the necessary and obtained exergy for the solar systems for heating DHW with SC#1, SC#2 in the function of the number of the optimum slope angle and the optimum azimuth angles. Thus, we have that the solar system for heating DHW with SC#1, the value of the necessary exergy is 4.6 times bigger than the value of the obtained exergy. For the solar system for heating DHW with SC#2, for the period X-IV when we have the work SC#2 October to 14th April, the value of the necessary exergy by 5.89 times bigger than the value of the obtained exergy, and for the solar system for heating DHW with SC#2 for the period from IV-X when we have the work SC#2 from 15th April to 14th October, by 4.3 times. The striving is to reduce this ratio in order to obtain the bigger exergy values.

By the use of the additional analysis due to the changes in the warm water consumption, the temperature of the hot water in the boiler, the consumption timetable, i.e. the consumption of the hot water by the end consumers can influence the reduction of this ratio and on the obtaining the optimum values of the exergy exploitation degree of the solar system. The exergy exploitation degree, η_x for the investigated solar system at the already set conditions (the consumption of the hot water, the timetable of the hot water consumption, the set hot water temperature) has the value of 1.3 % for the solar system for heating DHW with SC#1. The exergy degree of exploitation of the system is somewhat bigger than when compared with Xiaowu and Ben [17] investigated solar system. As can be noted Xiaowu and Ben exergy efficiency degree takes the value of 0.77 %. Their value is somewhat smaller due to the bad quality of the exit energy. The accumulation boiler shows great exergy loss due to the mixing of water and is perhaps possible to redesign in other to reduce the unnecessary mixing. It is possible to increase the exergy efficiency of the system for heating DHW by the change of the dimensions of the receiving solar panel as for example in [17]. The exergy efficiency of the system for DHW can also be increased by the increase in the number of coverings. By maximizing the solar share in this doctoral dissertation, with the maximum solar receiver efficiency it is possible to obtain bigger values of the exergy efficiency of the solar system for DHW. Taking into consideration the exergy flows in the research, exergy efficiency of the DHW system, when we predominantly use SC#2, is even better.

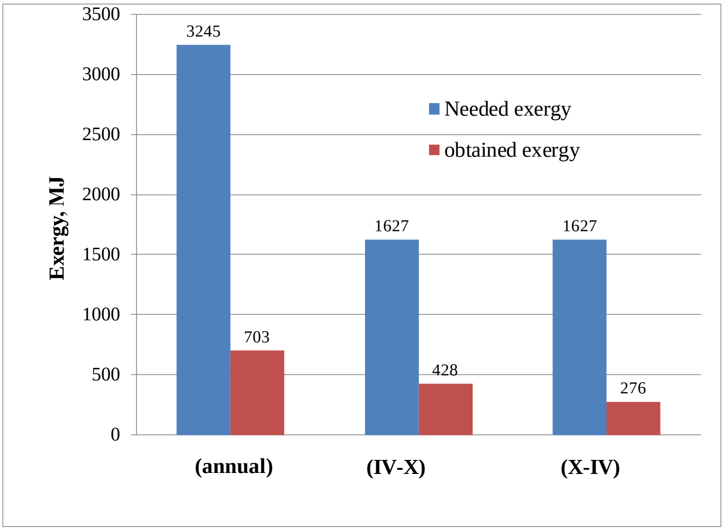

Figure 3 *– Needed and obtained exergy optimizing the solar system for heating DHW with SC#1, SC#2*

Conclusion

To use SDHWS with benefit, it has to be optimally designed, installed, and operated. In this paper, it is analyzed how the SDHWS can be optimally installed by using EnergyPlus software with the modified Hooke Jeeves direct search methodology. As an example, Hooke-Jeeves algorithm is used to obtain the maximum amounts of these performances for different SDHWS as a function of number of optimum positions of the solar collector in SDHWS during year for the city of Belgrade, Serbia.

By the exergy optimization the maximum exergy exploitation degree, analogus with the maximum value of the solar share in the function of the slope angle and azimuth, is achieved by positioning the solar collector to its optimum position. The energy degree of exploitation, η_x for the analyzed solar system, according to the beforehand set tasks (the hot water consumption, the hot water use schedule, the set warm water temperatures) has the value 1.3 % for the solar heating system for SWH with SC#1.

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Svetska Top Klasa
Energetske Efikasnosti

DVM S je dostigao najveće svetske vrednosti koeficijenata efikasnosti usvajanjem dvostrukih inverterskih kompresora i dvostrukih vijčanih kompresora.

Maksimalan kapacitet:
jedne jedinice 22HP, modula 88HP

DVM S obezbeđuje najveći svetski kapacitet (jedna jedinica 22HP, modul - jedinica 88HP) i ekonomičnost pri instalaciji sa najmanjom površinom osnove i najmanjom težinom.

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