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ALGORITHM FOR SELECTION OF HEATING DEVICE AND ITS ALTERNATIVE SOURCES OF ENERGY

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The article deals with one part of more complex problem, which is the algorithm for calculation of thermal power needed for specified object, selection of heating device and its alternative energy sources and calculation of its operational expenses for 25 years. In this paper, we assume that we already have the object specified, values for needed thermal power are obtained, and the heating device considered is the electrical cauldron. First part of the article describes the algorithm for selection of proper device and calculation of its expenses, where all the variables are explained, and second part deals with measured results of renewable energy sources and consideration about their usage. Final part is the conclusion and explanation of further steps not presented here due to limited space.

Key words: heating, energy, photovoltaic, algorithm, electrical.

АЛГОРИТМ ВИБОРУ ОБІГРІВАЮЧОГО ПРИСТРОЮ ТА ЙОГО АЛЬТЕРНАТИВНІ ДЖЕРЕЛА ЕНЕРГІЇ

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Висвітлено одну зі складових комплексної проблеми визначення алгоритму обчислення теплової енергії, яка потрібна для обігріву визначеного об’єкту, вибору обігріваючого пристрою та його альтернативних джерел живлення, а також обчислення експлуатаційних витрат на утримання об’єкту в розрахунку на 25 років. Прийнято, що визначено об’єкт обігріву, відомі значення необхідної теплової енергії, оскільки як обігріваючий пристрій обрано електричний котел. У першій частині роботи описується алгоритм вибору обігріваючого пристрою та розрахунок експлуатаційних видатків, коли всі змінні визначено. У другій частині проаналізовано виміряні дані поновлюваних джерел енергії та розглядається можливість їх використання. У кінцевій частині надано висновки та напрям наступних кроків дослідження, не наведених у даній роботі у зв’язку з лімітованим обсягом.

Ключові слова: нагрівання, енергія, фото гальваніка, алгоритм, електрика.

PROBLEM STATEMENT. Selection of proper heating device and calculation of its operating expenses is an uneasy task due to amount of information available for customer. Much of these information are vague and contradictory. The program is an attempt to make things clear and provide user with user friendly and understandable platform for calculating the thermal energy needed for his house, selection of heating devices, calculation of their operating expenses for 25 years and determine whether alternative sources of energy like photovoltaic and wind are viable option for selected device. As mentioned above, due to limited space, only a portion of the program is presented here, the part which calculate and select the electrical cauldron and calculates its alternative sources of energy. It will be assumed, that the previous parts of the program were completed, which means, that the object was specified, thermal resistances of walls were calculated as well as the thermal energy needed for every month.

EXPERIMENTAL PART AND RESULTS OBTAINED. As mentioned above, several algorithms will be presented in this section. First algorithm presented (Fig. 1) is for selection of suitable model of electrical cauldron (similar algorithms not presented here deal with gas cauldron and thermal heat pump). Because the program considers all months of a year, therefore 12 values of needed thermal power Qobj are obtained. Only the values which have positive value are considered, because right now only the heating is considered. Negative thermal energy values are obtained during summer months, which mean that the cooling instead of heating is needed. From these positive Qobj values, maximum Qobjmax has to be found and the cauldron needs to have its thermal power higher than this Qobjmax value. The algorithm goes straight through the database of devices (which because is made in MS Excel can be easily edited by user) and compares the values until it finds the value which meet the condition.

The algorithm then loads few needed variables which are related to the chosen cauldron and needed for further calculations. These variables are the price of the device ($C_{elekkotolN}$), electrical input of the selected device in kWh ($Pr_{Nelekkotol}$), price of electric energy in €/kWh (C_{elek}) and finally the coefficient of electric energy price increase, as we assume, that the price of energy in following years will increase, due to limited fossil fuel sources and rather negative public opinion on nuclear power (K_{elek}).

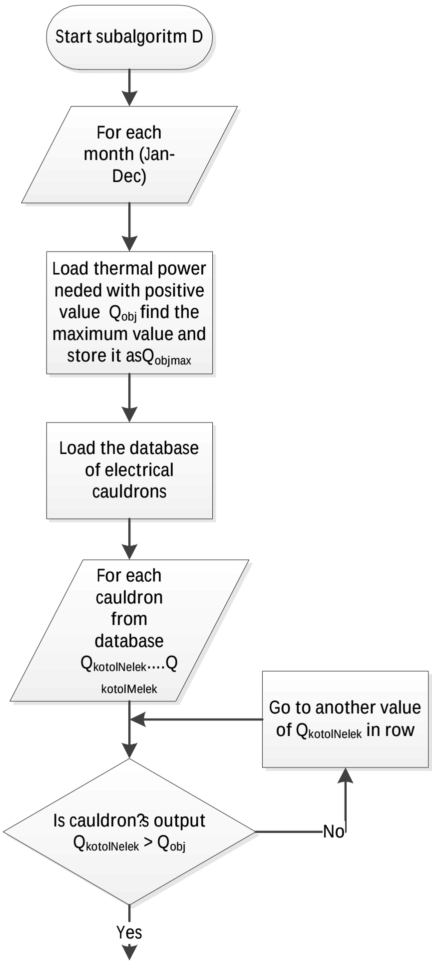
Because the upper mentioned variables are pretty self explanatory, only the coefficient K_{elek} should be explained. This coefficient was calculated from historical prices per kWh of electrical energy, according to Tab. 1.

In order to estimate the future progress based upon historical data the MS Excel FORECAST function was used. The FORECAST (x, known_y's, known_x's) function returns the predicted value of the dependent variable (represented in the data by known_y's) for the specific value, x, of the independent variable (represented in the data by known_x's) by using a best fit (least squares) linear regression to predict y values from x values.

The graphical representation of the data with regression curve is pictured on Fig. 2.

Table 1 – Estimated prices of electrical energy

Year	Eur/kWh	Year	Eur/kWh
1993	0,033	2015	0,099632
1994	0,033	2016	0,10169
1995	0,035	2017	0,103781
1996	0,037	2018	0,105903
1997	0,043	2019	0,108052
1998	0,056	2020	0,110227
1999	0,073	2021	0,112425
2000	0,083	2022	0,114644
2001	0,096	2023	0,116884
2002	0,106	2024	0,119141
2003	0,108	2025	0,121416
2004	0,11	2026	0,123707
2005	0,12	2027	0,126012
2006	0,126	2028	0,128332
2007	0,129	2029	0,130664
2008	0,132	2030	0,133009
2009	0,145	2031	0,135366
2010	0,146	2032	0,137734
2011	0,159	2033	0,140112
2012	0,093702	2034	0,142501
2013	0,095634	2035	0,144899
2014	0,097612		



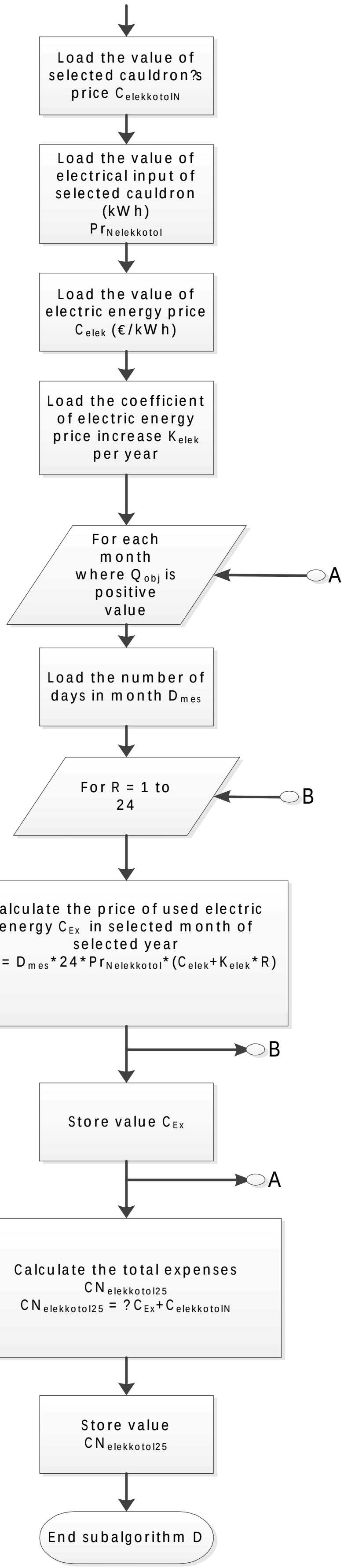


Figure 1 – Algorithm for cauldron selection

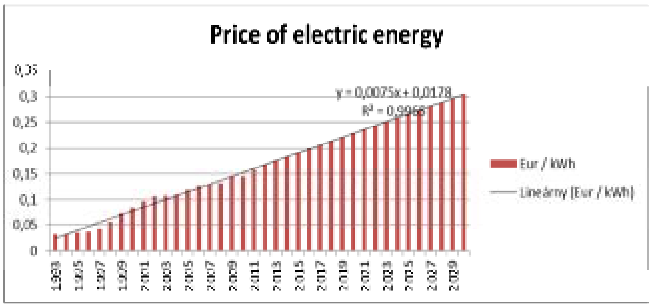


Figure 2 – Graphic representation of prices

As can be observed the increase is the linear, and when the regression curve y = 0,0075x + 0,0178 is derived, the resulting K_{elek} = 0,0075, which is the coefficient used for calculations.

The R variable which is used in calculation represents the year, from 1 to 24 and is multiplied by coefficient of price increase in order to reflect the rising prices of energy and for more precise results.

Because it is impossible to calculate the exact expenses, for the future, we can only consider the worst case scenario when the cauldron is running at its nominal power by 24 hours every day during the months when the heating is needed (months with positive Qobj) value. The resulting number can be then compared with results obtained with analogical method used for gas cauldron and/or thermal heat pump.

It is obvious that, the electrical cauldron has very high electric input, therefore the resulting operating expenses will be very high, therefore, there is a question whether known alternative sources of energy like the photovoltaic and/or wind energy can provide power to the cauldron (or heat pump). It is very important to note, that the calculations and measurements were made for Kosice region, which unfortunately has unfavorable conditions for wind energy and photovoltaic's during winter months.

In order to better photovoltaic understanding, the V-A (Fig.3) characteristics of module are needed to be explained a bit.

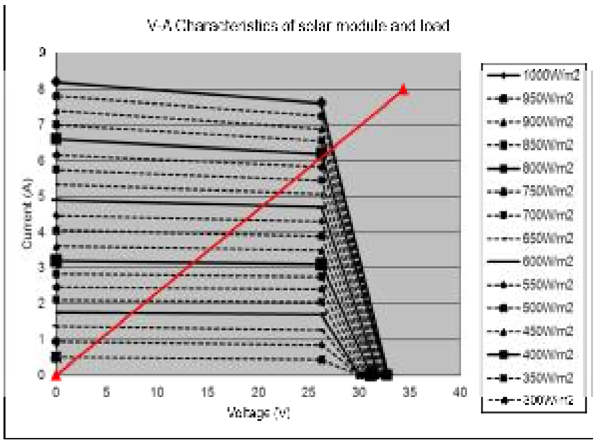


Figure 3 – V-A characteristics of photovoltaic module

This V-A characteristics clearly shows that the maximum power is directly proportional to the intensity of sunlight. When the intensity decreases, the maximum obtainable power decreases as well. It is worth noting the few key values for every datasheet. The rated power for the module which was measured was P_{max} at 200W. Voltage at P_{max} is 26,3 V. This voltage is referred as V_{mp}. The V-A characteristics shows that the V_{mp} value is the same regardless of sunlight intensity. This is the value of voltage when the maximum power can be obtained. Current at P_{max} is 7,61A. This current is referred as I_{mp}. Short-circuit current (I_{SC}) is 8,12 A and open-circuit voltage (V_{oc}) is 33,4 V for intensity of 1000W/m^2 of sunlight.

The red line represents the load which was used for measurement. The load was resistor with the value of 4,3 Ω, therefore the linear line. The results from measurements were only values on the red line, however as can be seen from the V-A characteristics (Fig. 2) with properly dimensioned load, the maximum power for every value of intensity can be obtained.

Program EasyLog was used for measurement of voltage. This voltage was measured every day in minute intervals. With such intervals 1440 values of voltage per every day of year were measured and stored to file. Because the value was known, the current was calculated using Ohm's law:

$$I = U/R. \qquad (1)$$

With the voltage and load known, the obtained power could be easily calculated using the equation for power in DC circuits which is:

$$P = U^2/R. \qquad (2)$$

As can be seen from the V-A characteristics (Fig. 3), especially in case of lower intensities, the values of current and power were quite low, however this was caused by the load which was chosen. It is important to look at P_{max} values at V_{mp} (26,3V) because these are the value which can be obtained.

With the known currents, next step was the determination of maximum obtainable power. As can be seen from the picture, although the power can be calculated as:

$$P = UI. \qquad (3)$$

In order to obtain the real values the calculated current has to be lowered by a specified amount, because the line is not straight, but with increased voltage it is decreasing. This decrease is more significant in higher intensities, as can be seen.

This decrease of current for V_{mp} voltage was calculated as:

$$K = I_{mp}/I_{sc.} \qquad (4)$$

For the intensity of 1000W/m^2 this decrease is K = 7,61/8,12 = 0,94.

Therefore the maximum obtainable power is calculated as:

$$P_{max} = V_{mp}\, I 0{,}94. \qquad (5)$$

Upper mentioned equation (5) is valid for currents from range 6,6 to 8,12 A, which are for range band 800-1000 W/m^2. The same procedures were made for every remaining range bands (800-600 W/m^2, 600-400 W/m^2, 400-200 W/m^2, 200-0 W/m^2).

The level of decrease is different in every range band, in the last 200-0 W/m^2 the coefficient of decrease was only 0,97.

One of the goals of the work is to evaluate the performance of photovoltaic panel especially during winter months, as the question is, whether it can provide enough energy for domestic heating system, which can be for example electrical cauldron or thermal heat pump, which is much better option, despite higher initial investment.

Fig. 4 and 5 represents the graphical representation of average daily values of obtained power and obtainable power P_{max}.

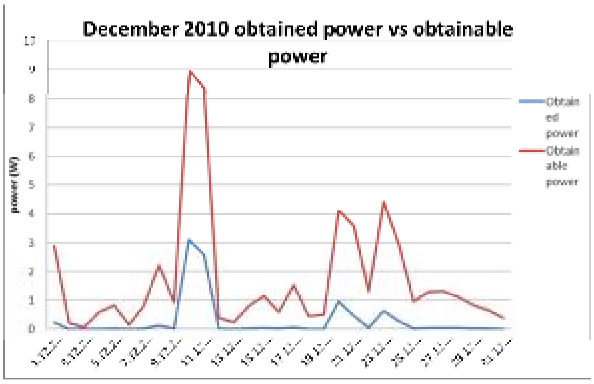


Figure 4 – December 2010 power graph

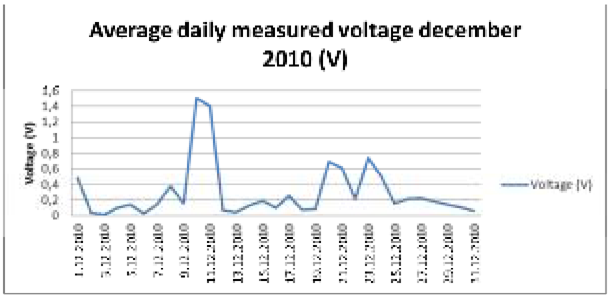


Figure 5 – December 2010 average daily voltage

The graphs show clearly that in the month of December, when the amount of solar energy is lowest in year, the photovoltaic panel measured in Košice region is absolutely useless. However it is fair to note, that this statement is completely true only for December 2010, because the weather cannot be exactly predicted, December 2011 was different, weather in December 2012 can be/won't be different.

Fig. 6 and 7 show the results for January 2011. The situation in January is getting better towards the end of the month, however if 200W rated panel for 300€ can provide only 15 watts of power (which cannot be granted because are subject to weather), the result is unsatisfactory. The measurements prove that especially during winter months photovoltaic is unreliable source of energy and cannot be considered as a primary source in the Košice region.

Wind energy can be very effective source of energy when the right conditions are met. Small wind turbines with diameter about 2 meters can provide 500-1500 W of power for a very reasonable price, comparable with photovoltaic panels. These turbines are small enough to be mounted on houses and widely used. They generate alternating current and need charging regulator to prevent from overcharging of batteries.

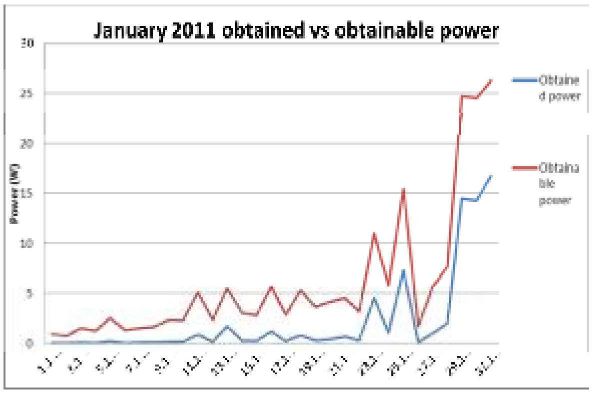


Figure 6 – January 2011 power graph

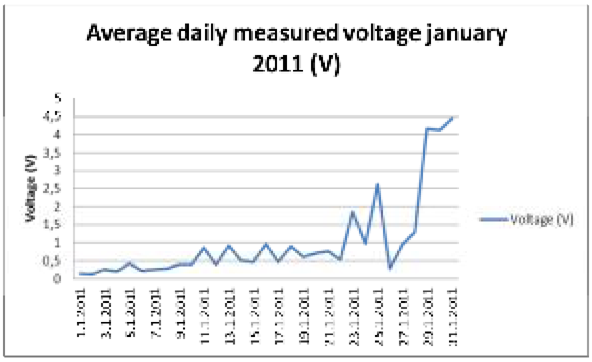


Figure 7 – January 2011 average daily voltage

In order to be effective they need to be mounted high, at least 10 meters above ground and more importantly, they need the specified wind speed to operate effectively. For better understanding, the power curve of the typical (HAWT – horizontal axis wind turbine) turbine is pictured in figure (Fig. 8).

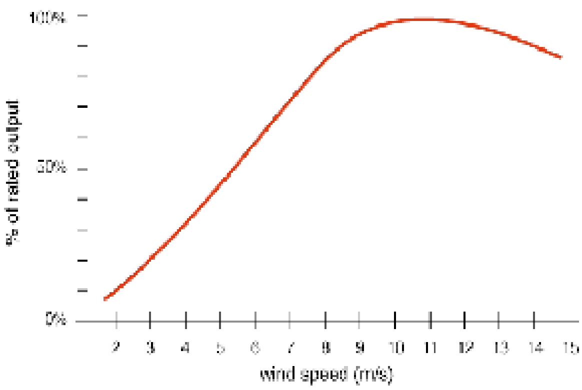


Figure 8 – Power curve of typical HAWT turbine

For most turbines the cut-in speed which is the speed when wind turbine begins to generate energy is 2-3 m/s. The nominal wind speed, when the turbine reaches its nominal power output is mostly 10-14 m/s based upon turbine type. Shut off speed is about 18-20 m/s and more, this is speed, when there is danger of physical damage, therefore the turbine locks itself using the brakes.

Fig. 8 clearly shows that in order to get at least 50% power from the turbine, constant wind speed at least 5-6 m/s is needed. This wind speed is common in coastal areas where the turbines are mostly used.

Fig. 9 shows the average monthly wind speed in Košice city in years 2009–2011.

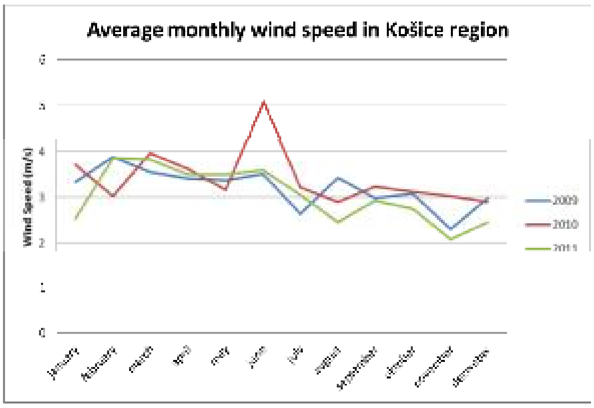


Figure 9 – Average monthly wind speed in Košice

The graph (Fig. 9) clearly shows that the monthly average wind speed is about only 3 m/s which is barely the cut-in speed for most of the small HAWT turbines. With such speed, maybe 10-15% of nominal power is obtained, which is again very low to consider as a primary source of electric power. Unfortunately only few areas of Slovak Republic are suitable for utilizing wind energy, where the wind energy reaches high speeds constantly. Another problem, which prevents the wider usage in cities is the amount of wind blasts between block of flats, turbulences and wind tunnels because of which the turbine must be mounted high, which is often not possible.

CONCLUSIONS. The results of measurements indicate that in current state of technology, the renewable energy sources are not suitable for utilization in Košice region. The wind energy would be interesting to consider in case, that the new turbine with lower nominal wind speed requirement can be manufactured. Measurement of photovoltaic panel proves that the panels are more suitable for different region with where the Sun's intensity is higher. On the other hand, the panels were considered for the winter months, which are mostly cloudy, therefore low power output is expected. During the summer months, the panel provided 70-80% of its nominal power, therefore the question of accumulating energy and its proper storage for utilization during winter months is still valid and worth considering.

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АЛГОРИТМ ВЫБОРА ОБОГРЕВАЮЩЕГО УСТРОЙСТВА И ЕГО АЛЬТЕРНАТИВНЫЕ ИСТОЧНИКИ ЭНЕРГИИ

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Освещена одна из составляющих комплексной проблемы определения алгоритма расчёта тепловой энергии, необходимой для обогрева определённого объекта, выбора обогревающего устройства и его альтернативных источников энергии, а также расчёта эксплуатационных расходов на содержание объекта в расчёте на 25 лет. Принято, что определён обогреваемый объект, известны значения необходимой тепловой энергии, и в качестве обогревающего устройства выбран электрический котёл. В первой части работы описывается алгоритм выбора обогревающего устройства и расчёт эксплуатационных расходов при всех известных переменных. Во второй – выполнен анализ измеренных данных возобновляемых источников энергии и рассмотрена возможность их использования. В последней части приведены выводы и направление дальнейших исследований, не приведённых в данной работе ввиду ограниченного объёма.

Ключевые слова: нагрев, энергия, фотогальваника, алгоритм, электрика.

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