Josip Juraj Strossmayer University of Osijek
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SiP 2008

26th International Conference

SCIENCE IN PRACTICE

PROCEEDINGS

Osijek, May 5 – 7, 2008

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PREFACE

Hochschule Bremen, Fachbereich Elektrotechnik, Bremen (Germany) and Faculty of Electrical Engineering in Osijek (Croatia) started from 1984 year with organization a joint scientific colloquium every year. In 1996 Fachhochschule Wiirzburg-Schweinfurt from Germany as well as "Kando Kalman" Polytechnic - Budapest and "Pollack Mihaly" College of Engineering - Pecs from Hungary joined this scientific colloquium, in 2003 Polytechnic Engineering College of Subotica joined the group, too. The main topic of the conference was research, teaching and new technologies in electrical engineering and computer science. In 2008, new university partners joined us.

26th conference held in Osijek and organized by the Faculty of Electrical Engineering, J.J. Strossmayer University of Osijek. The conference provided a platform for researchers and practitioners interested in the theory and practice of electrical engineering, computer science, automation, robotics, as well as interdisciplinary research and applications of the mentioned disciplines with mathematics, physics, mechanical engineering, medicine, etc. Submitted and reviewed papers are fully developed results or on-going work. The general theme of SiP 2008 was “Modern Computer Systems in Engineering Applications”.

At the conference 72 authors, form seven countries, presented 35 papers in the following five sessions: (a) Research and project management, b) Power engineering and electrical drives, (c) Automation, robotics and industrial applications, (d) Computer systems and applications and (e) Computer systems and applications. With presented papers our faculties provided contributions to the development of new technologies and the knowledge economy in our countries which moves to the knowledge society - new civilizational and the development paradigm of European Union.

Osijek, September 2008

Editors

Application of Hydro Power Calculator in Power Engineering Education

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***Abstract* — the subject of this paper is the application of hydro power calculator – a program developed within a diploma paper assignment – in the education of engineers of electric power supply. Energy characteristics of hydro plants are determined on the basis of hydrological characteristics of the flow and hydrological head (head further in the text). An algorithm was developed based on the analysis of the calculation of the parameters of a hydro plant, and software was developed by Java program language. A detail description of the program's use is also given.**

***Keywords* — student educationt, hydro power plant, hydro power calculator, Java)**

I. INTRODUCTION

Program Hydro Power Calculator is used for education, and was created as a product of a diploma paper assignment which was meant to familiarize students with the problems behind producing electric energy in hydro plants. In order to make this program as educational as possible one of the main objectives in making this program was to implement a lot of interactivity of the interface towards the user. This was achieved by an easy-to-survey entry of input-parameters, by their graphic depiction, detailed survey of the calculation, explanation of the selection by pictures and definitions, and by short instructions for the program's use.

Program was made by Java program language because of its ability to facilitate transfer, i.e. its characteristic that once translated Java program can be run on various operational systems without alterations.

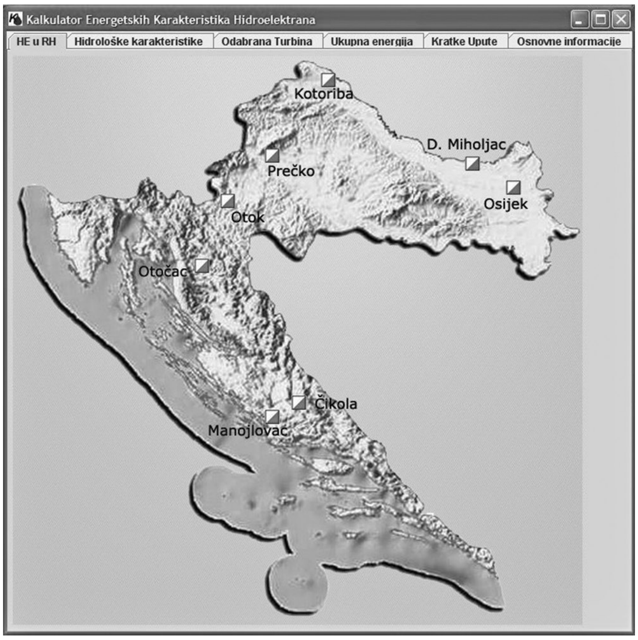
This is made possible by Java Virtual Machine (JVM), a system that interprets Java programs and runs them on the given computer. So a unique program can be run on all computers which have an option for JVM.

In practice the program is applied in laboratory practice for the subject "Energetski procesi i elektrane" (energy processes and energy plants), which, amongst other things, deals with production of electric energy in hydro plants.

II. DESCRIPTION OF THE PROGRAM FOR THE CALCULATION OF HYDRO PLANT'S PARAMETERS

When the program is run, a window for entering user account and password appears (picture 2.1.). After the user has entered the right data, program's working window, which is made of six tabs that guide the user through the calculation of hydro plant's parameters, appears

Picture 2.1. User account and password window



Picture 2.2. Hydro energy potential of Croatia's water flows

A map of Croatia with hydro energy potential of Croatia's water flows which is in program's data base is depicted in the program's first tab (picture 2.2.). Next tab is opened by selecting any of the offered locations.

TABLE 2.1.
Characteristics of Croatia's water flows

Month	*Drava Manojlovac m^3/s*	*Drava Osijek m^3/s*	*Krka Manojlovac2 m^3/s*	*Krka Čikola2 m3/s*	*Kupa Otok m^3/s*	*Lika Otočac m^3/s*	*Mura Kotoriba m^3/s*	*Sava Prečko m^3/s*
January	*394,6*	*423,5*	*24,7*	*10,0*	*72,7*	*30,1*	*111,9*	*301,9*
February	*379,6*	*408,9*	*23,6*	*9,1*	*73,9*	*26,4*	*113,0*	*295,1*
March	*473,8*	*497,3*	*25,5*	*10,3*	*89,1*	*31,2*	*153,7*	*400,4*
April	*552,9*	*574,0*	*26,5*	*11,2*	*85,1*	*29,0*	*204,6*	*376,8*
May	*724,9*	*735,4*	*24,5*	*9,1*	*68,7*	*21,2*	*273,1*	*369,9*
June	*821,7*	*826,9*	*20,1*	*7,0*	*39,7*	*8,7*	*261,7*	*310,8*
July	*684,5*	*699,5*	*14,6*	*2,5*	*26,7*	*3,4*	*205,0*	*241,9*
August	*575,5*	*596,8*	*10,4*	*0,5*	*21,5*	*1,5*	*181,5*	*189,0*
September	*490,4*	*513,6*	*10,2*	*1,0*	*47,9*	*2,6*	*154,5*	*235,6*
October	*478,4*	*502,0*	*14,8*	*4,6*	*91,5*	*14,5*	*148,4*	*354,9*
November	*566,4*	*582,5*	*28,2*	*11,8*	*116,3*	*32,9*	*164,6*	*509,4*
December	*457,5*	*484,8*	*28,3*	*13,7*	*103,8*	*33,7*	*134,1*	*384,8*
Annual average	*550,0*	*570,4*	*21,0*	*7,6*	*69,7*	*19,6*	*175,5*	*330,9*

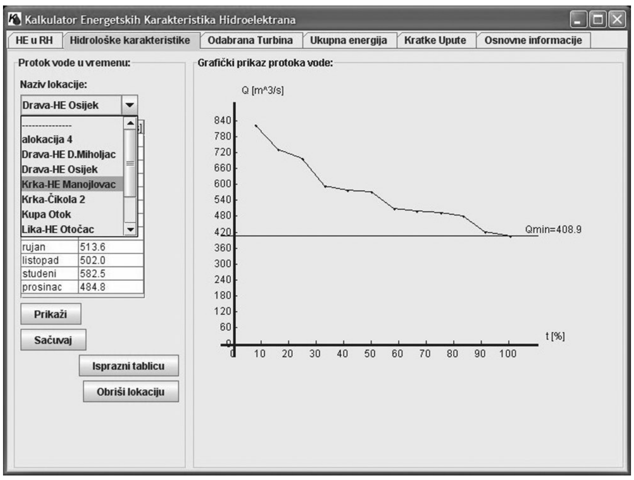
Offered locations are those for which the characteristics, taken from available hydro energy studies, are stored in the data base. Table 2.1. brings middle average values of the flow taken in the period of 40 years, this hydrological stream is also in the data base of the program.

A. Hydrological characteristics and calculation data

After a location on the map is chosen, second tab of the user interface opens (picture 2.3.). This tab is used for alteration of choice or forming hydrological characteristics and entering input data for the calculation of the hydro plant's parameters.

1. Selection of the flow's duration curve

User can once again select one of offered water flows, and the existing data can be altered directly by entering values into table's fields.Altered data needs to be confirmed by pressing the "Prikaži" (show, display) button. Upon this the flow's duration curve appears on the graph designed for the purpose.

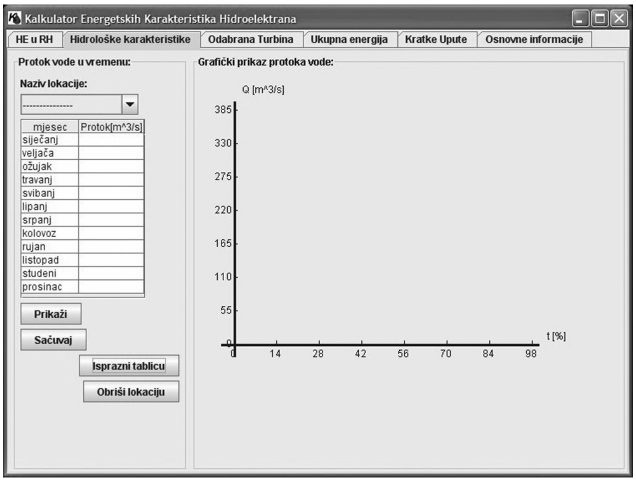


Picture 2.3. User interface with hydro plant selection

Entered data can be saved in the data base by pressing the "Sačuvaj" (save) button. Saved location can be deleted by pressing the "Obriši lokaciju" (delete the location) button. Data on hydrological characteristics of Croatia's water flows are protected from deleting.

2. Forming flow duration curve

One of eminent functions of this program is the possibility of forming flow's duration curve by the user.



Picture 2.4. User interface for forming the flow's duration curve

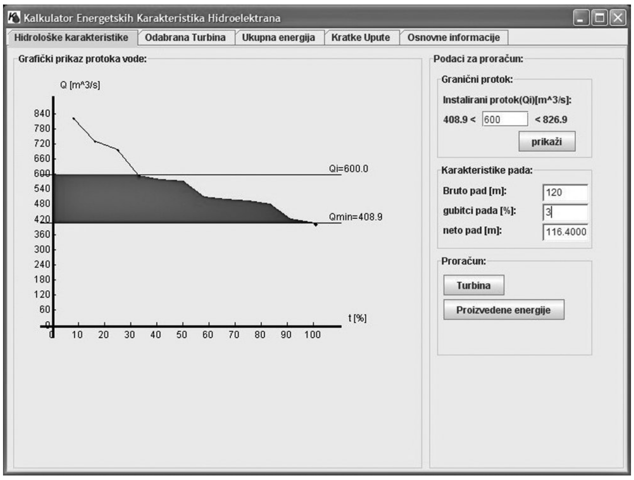
By pressing the "Isprazni tablicu" (clear table) button all the values are set to zero. (Picture 2.4.). Desired data is entered directly into table's fields, taking into consideration that (average monthly) flows are entered by months.

After finishing the input, and pressing the "Prikaži" (show, display) button, flow's duration curve is graphically displayed, in the same manner as the offered curve, arranged by size, not chronologically by months, because if it was given chronologically it would represent flow's curve.

Entered data can be saved in the data base by pressing the "Sačuvaj" (save) button, and a saved location can be deleted by pressing the "Obriši lokaciju" (delete the location) button.

B. Calculation data

After a flow's duration curve is formed, the program enables user to enter data necessary for the calculation (picture 2.5.): installed flow of the turbine Qi (m3/s), and the characteristics of the head (gross head Hb in meters and the loss of head Hg in percentages of Hb)



Picture 2.5. Calculation data entry user interface

This allows processing real or fictional water flow. User can, by changing the shape and the size of the water flow, monitor the influence on the selection of the turbine and possible annual generation of electric energy.

$$Q_{\min} < Q_i < Q_{\max}$$

1. Instalirani protok

Installed flow is set by entering data in the field designed for the purpose. Value of the installed flow can be within borders: i.e. between minimal Q_{min} (m^3/s) and maximal flow Q_{max} (m^3/s) which are determined by the flow's duration curve.

If the user should enter a value that is outside the given borders, the program signalizes illogical entry of parameters.

Once the user has entered the installed flow, and pressed the "Prikaži" (show, display) button a work area determined by the minimal and maximal flow is shown on the flow's duration curve.

2. Head's Characteristics

Second parameter for the calculation of the turbine are the head's characteristics. The program enables direct entry of net head H_n or gross head H_b and loss of head H_g that leads to the calculation of net head.

Fields designed for that purpose require entry of gross head H_b in meters. Value of gross head is limited to:

$$H_{b\max} = 2000 \text{ m}$$

After this the entry of head's loss, which represent a measure for the loss of power, is required. Program has a field designed for the entry of total loss in percentages. The loss is then calculated as:

$$H_g = H_b \frac{H_{g\%}}{100} \qquad \textbf{(2-1)}$$

H_b stands for gross head in meters, $H_{g\%}$ stands for total loss of fall in percentages and H_g total loss of head in meters. Loss of head is limited to

$$H_{g\max} = 20\%$$

Net head equals gross head if the head's loss has not been entered. In contrary net head is calculated by:

$$H_n = H_b - H_g \qquad \textbf{(2-2)}$$

Maximal value of net fall is also limited:

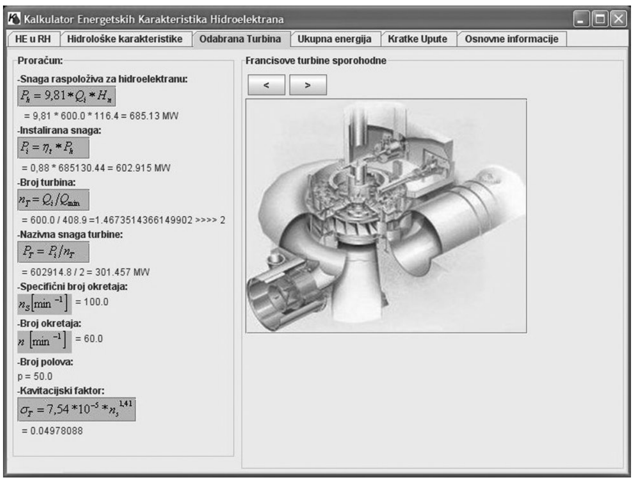
$$H_{n\max} = 1800 \text{ m}$$

If any of the entered head's characteristics is bigger than the maximum value, the program informs that the entered data should be altered.

Once the user has entered the installed flow and net head, the program calculates turbine's parameters. Should the data be illogical the program will warn the user to alter the calculation data

C. Parameters Calculation and the Selection of the Turbine

Parameters necessary for the selction of the water turbine are calculated based on the data on installed flow and head which were entered on the previous tab. Parameters calculation and the choice of turbine based on the specific number of rotations is shown on the third tab of program's user interface.



Picture 2.6. Turbine's parameters calculation user interface

5. Turbine's parameters calculation

Disposable power for a turbine is calculated by relation

$$P_h = 9,81 \cdot Q_i \cdot H_n \quad [\mathrm{kW}] \qquad (2\text{-}3)$$

Disposable power is in kilowatts (kW) for installed flow Q_i in m^3/s and net head H_n in meters.

Installed power is calculated by:

$$P_i = \eta_t \cdot P_h \quad [\mathrm{kW}] \qquad (2\text{-}4)$$

by which the degree of efficiency is always

$$\eta_t = 0,88$$

Number of turbines n_T is determined by the ratio of installed and minimal flow with the presumption that the minimal flow is covered by a single's turbine production:

$$n_T = \frac{Q_i}{Q_{\min}} = \frac{P_i}{P_{\min}} \qquad (2\text{-}5)$$

by which n_T is rounded to the first bigger whole number.

Nominal power of the turbine is calculated as:

$$P_T = \frac{P_i}{n_T} \quad [\mathrm{kW}] \qquad (2\text{-}6)$$

In further calculation power calculated as (2-6) is used, and not the first bigger standardized value from catalogue data of real turbines.

6. Selection of the turbine considering the specific rotation number

Specific rotation number is determined as a given net head H_n as given in table 2.2. so that:

$$H_{n1} < H_n < H_{n2}$$

Specific rotation number is determined from equation:

$$n_s = n_{s1} + \frac{n_{s2} - n_{s1}}{H_{n2} - H_{n1}} \left(H_n - H_{n1} \right) \qquad (2\text{-}7)$$

Where H_{n1} and H_{n2} determine area of head in which the net head is located, and n_{s1} and n_{s2} are lowest and highest boundaries of specific rotation number from table 2.2

TABLE 2.2. Specific rotation number N_S of the hydro turbine and approximate value of net head H_N

Type of turbine	n_s, min^{-1}	H_n, m
Peltonove turbine s jednim mlaznikom	*4 do 30*	*1800 do 300*
Peltonove turbine s dva mlaznika	*25 do 50*	*800 do 100*
Peltonove turbine s tri mlaznika	*50 do 72*	*400 do 100*
Francisove turbine vrlo sporohodne	*55 do 70*	*400 do 200*
Francisove turbine sporohodne	*70 do 120*	*200 do 100*
Francisove turbine normalne	*120 do 200*	*100 do 50*
Francisove turbine brzohodne	*200 do 300*	*50 do 25*
Francisove turbine ekspresne	*300 do 500*	*25 do 15*
Kaplanove turbine sporohodne	*320 do 500*	*80 do 20*
Kaplanove turbine normalne	*500 do 700*	*20 do 14*
Kaplanove turbine brzohodne	*700 do 850*	*14 do 10*
Kaplanove turbine ekspresne	*850 do 1000*	*10 do 5*

Overlap of more turbines for the same area of head is possible according to table 2.2. Specific rotation number is calculated for every type and a turbine with bigger ns is selected

Real rotation number is calculated as:

$$n = n_s \cdot \frac{H_n \cdot \sqrt[4]{H_n}}{1,16\sqrt{P_T\,[kW]}} \quad \left[\min^{-1}\right] \qquad (2\text{-}8)$$

and is then synchronized with standard values for hydro generator's speeds according to table 2.3. *n* is taken as such that it makes difference between calculated and standard value is minimal. Number of pairs of polarities is taken from the same table according to the chosen number of rotations.

Table 2.3.
Standard values for hydro generators' speeds

Number of pari pole p	*4*	*5*	*6*	*8*	*10*	*12*
rpm n, min-1	*750*	*600*	*500*	*375*	*300*	*250*

14	*16*	*18*	*20*	*24*	*30*	*34*	*40*	*50*	*60*
214,3	*187,5*	*166,7*	*150*	*125*	*100*	*88,2*	*75*	*60*	*50*

After this specific rotation number is calculated again but according to selected number of rotations:

$$n_S = \frac{1,16 \cdot n \cdot \sqrt{P_T}}{H_n \cdot \sqrt[4]{H_n}} \quad \left[\min^{-1}\right] \qquad (2\text{-}9)$$

this serves as a check for turbine's selection. Specific rotation number is checked to confirm that it is within area:

$$n_{S1} < n_S < n_{S2}$$

In case the above given requirement is met, the program will show the chosen turbine. If the requirement has not been met the program will calculate with other values of specific rotation number.

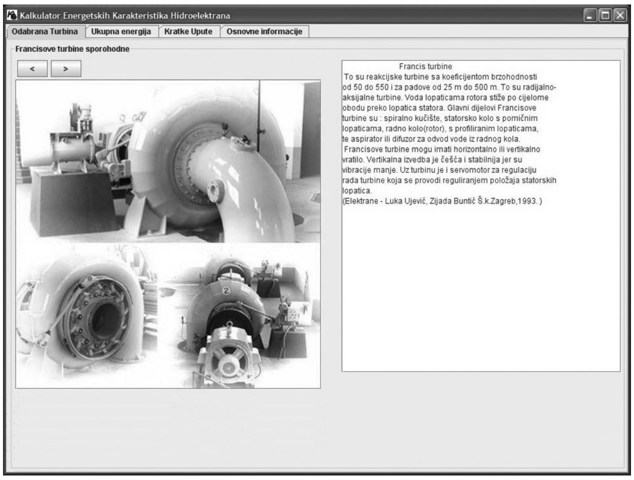
Cavitation factor is calculated for Francis' and Kaplan's turbine while Pelton's turbine has no cavitation.

Francis: $s_T = 7{,}54 \cdot 10^{-5} \cdot n_s^{1{,}41}$ ***(2-10)***

Kaplan: $s_T = 6{,}40 \cdot 10^{-5} \cdot n_s^{1{,}46}$ ***(2-11)***

After the turbine's parameters are set the program will show a detailed calculation of the turbine (Picture 2.6)

Suggested turbine is illustrated in pictures and a short description is also given (Picture 2.7) Pictures of turbines can be changed by pressing the arrows above the picture. Sketches, cross-sections, parts and photographs of each turbine can be seen.



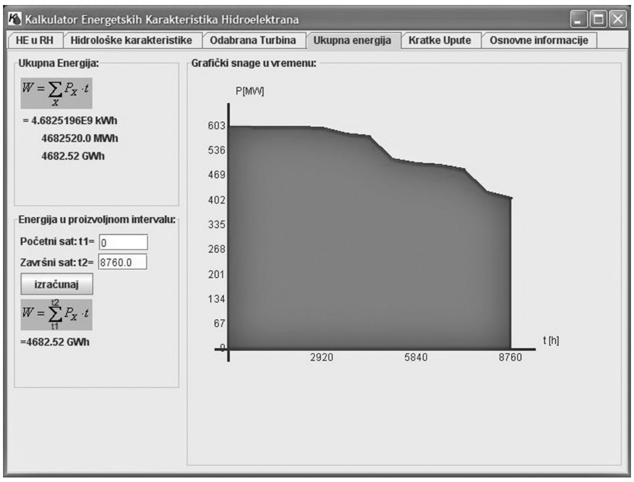
Picture 2.7. program's interface with description and picture of the turbine

D. Possible hydro plant's production

Main calculation of the program is the possible annual electric energy production for a given flow's duration curve with specific area of working flow, net head and optimal turbine.

7. Produced energy calculation

Forth tab provides the calculation of possible overall produced energy as well as chart diagram of hydro plant's strain (Picture 2.8)



Picture 2.8. Programs interface with possible energy production calculation

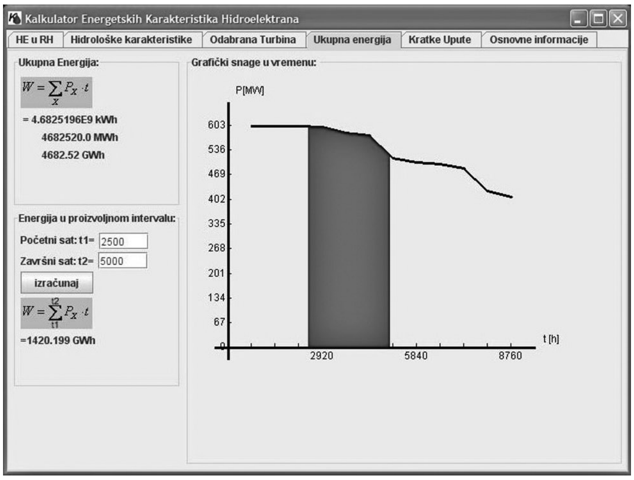
Possible overall produced energy is calculated as the sum of contributions of all portions of surface under the curve on the hydro plant's strain diagram:

$$W = \sum_{x=0}^{8760} P_x \cdot \Delta t \qquad \textbf{(2-12)}$$

This is how we get the possible production of energy follows the flow's duration curve and takes in consideration reduction of efficiency of the turbine due to reduction of flow.

Further calculation of possible energy production in an arbitrary interval t1 to t2 given by the user is possible on the fourth tab (Picture 2.9). This calculation is used because in real life a hydro plant can not be operational throughout the year.

Calculation of energy's production in an arbitrary interval is done so that the useful area of the flow's duration curve gets divided into smaller, equal sections and individual section's contribution to energy production is calculated.



Picture 2.9. Program's interface with an example of calculation of energy of an arbitrary interval

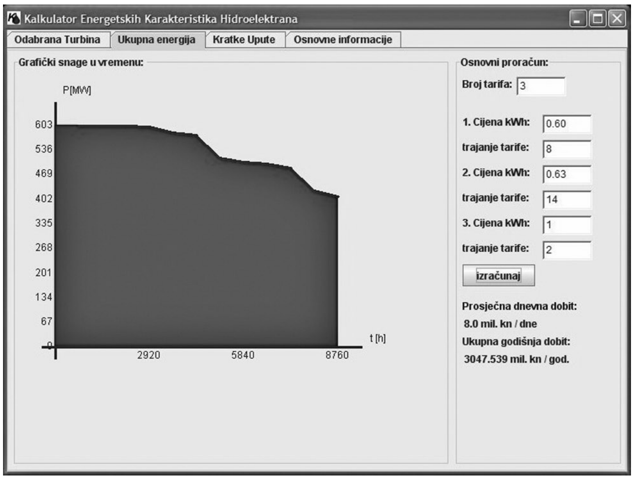
Energy of an arbitrary interval is calculated as:

$$W = \sum_{x=t_1}^{t_2} P_x \cdot \Delta t$$

which represents the sum of contributions of all sections of the surface bellow the power in time curve within t_1 to t_2 interval

8. Financial calculation

The program provides, for a given number of tariffs and the cost of electric energy in each tariff (set by the user), a calculation of daily and annual influx of financial resources from electric energy sale (Picture 2.10). When setting duration for each tariff it should be taken into consideration that the sum of all tariffs must be 24.



Picture 2.10. Program's interface with an example of daily and annual influx of financial resources from electric energy sale calculation.

Annual financial resources from electric energy sale influx is calculated as the sum for each tariff as follows:

$$K_{god}=\sum_{n} h_n \cdot 0{,}04167 \cdot kn_n \cdot W \quad [\text{kn/god}] \qquad \textit{(2-14)}$$

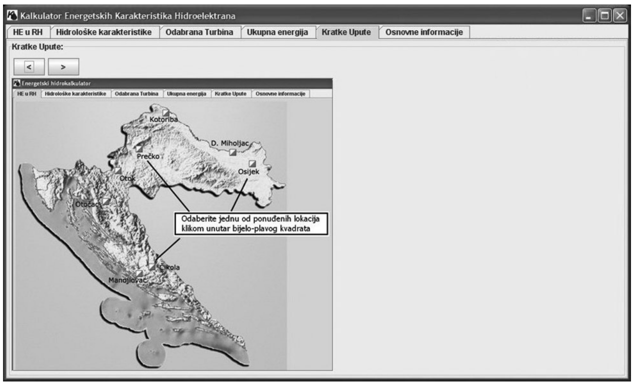
Where h_n is duration of a tariff in hours and kn_n is tariff's price in kilowatt-hours per kuna (kWh/kn)

Daily financial influx is calculated by dividing annual influx with the number of days in a year:

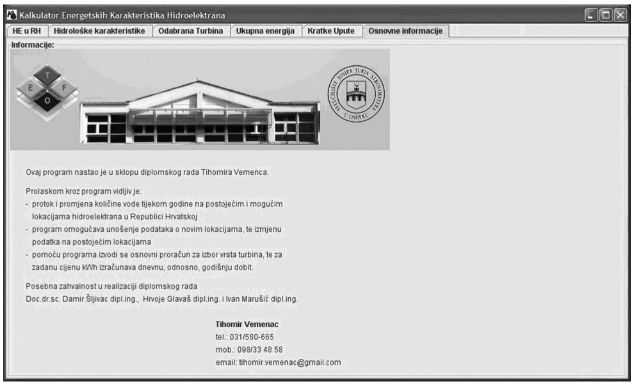
$$K_{dne}=\frac{K_{god}}{365} \quad [\text{kn/dne}] \qquad \textit{(2-15)}$$

E. Short instructions and basic information on the program

Last two tabs of the interface provide short instructions for using the program (Picture 2.11) and some basic information on the program (Picture 2.12)



Picture 2.11. Program's interface with short instructions



Picture 2.12. Program's interface with basic information on the program

III. CONCLUSION

Program Hydro Plant's Characteristics Calculator was made as a work of a student and grow into help for others with the goal of deeper understanding and harnessing water potential. Concept of the program allows for future improvement i.e. it for an example allows the user to choose on his own one of the selected turbines for the given head when there is an overlap of work areas. An algorithm for selection of turbine by work curves of standardized turbines could also be implemented. When determining possible production of a hydro plant one could take into consideration the influence of changeable degree of turbines activity.

The List of Scientific Conferences "Science to Practice"

1984............ I. Colloquium in Bremen

1985............ II. Colloquium in Osijek

1986............ III. Colloquium in Bremen

1987............ IV. Colloquium in Osijek

1988. ...... V. Colloquium in Bremen

1989............ VI. Colloquium in Osijek

1990............ VII. Colloquium in Bremen

1991............ VIII. Colloquium in Bremen

1992............ IX. Colloquium in Bremen

1993............ X. Colloquium in Osijek (Because of the war chain of events and dangers in Osijek - Conference has not been kept)

1994............ XI. Colloquium Budapest

1995............ Because of the war chain of events and dangers – Conference has not been kept

1996............ XII. Conference in Osijek and Pecs

1997............ XIII. Conference in Schwemfurt

1998............ XIV. Conference in Osijek

1999............ XV. Conference in Bremen

2000............ XVI. Conference in Budapest,

2001............ XVII. Conference in Schweinfurt

2002............ XVIII. Conference in Pecs

2003............ XIX. Conference in Osijek

2004............ XX Conference in Subotica

2005............ XXII Conference in Budapest

2006............ XXIII Conference in Pecs

2007............ XXIV Conference in Bremen

2007............ XXV Conference in Schweinfurt

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