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The Method of Selecting the Optimal Variant of Irrigation Systems Driven by PV Energy

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Abstract

Recently there have been increasing trends to use renewable energy sources, especially solar photovoltaic energy for electric energy production for the operation of urban water supply systems. The reason are not only economic requirements, but environmental and social criteria should also be taken into account. Using the example of a local football club "Obreš", located in Sveti Ilija in Croatia, this paper shows the application of the Critical Period Method for the design of hydraulically and energetically sustainable irrigation system. Two variants have been analyzed, Variant I and Variant II, which include solar photovoltaic generator and inverter, pumping station, water reservoir and pipeline. The water needed for irrigation is provided by combining the use of groundwater and rainwater. The difference between the analyzed variants is that Variant I is based on the water tower, while Variant II is based on the use of solar batteries. The selection of the optimal variant is shown by the application of multi-criteria methods Promethee and GAIA.

Keywords: Critical Period Method; GAIA; irrigation; Promethee; solar photovoltaic energy; water pumping.

1. Introduction

The use of solar photovoltaic (PV) cells for the production of electricity for the operation of pumping stations that pump water is a current issue not only due to economic demands, but it is necessary to take into account environmental and social criteria.

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These pumping systems are a well-established and well-known technology, for example [1-4] etc. However, there are still problems related to unreliable operation of such systems, primarily due to the stochastic nature of solar radiation and to the lack of methods and procedures that would annul these problems.

Therefore, this paper presents the application of the Critical Period Method (CPM), a scientifically innovative and, in terms of engineering, applicable method in the case of the irrigation system of the local football club "Obreš" located in Sveti Ilija, near the city of Varaždin in Croatia. The irrigation system consists of solar photovoltaic generator and inverter, pumping station, water reservoir and pipeline. Pumping stations operate on electricity supplied by solar photovoltaic cells, i.e. inverters and pump water from the water reservoir into the pipeline which transports water to the land being irrigated. Two options have also been analyzed, of which one is based on water reservoir and the other on the use of solar battery. The selection of the optimal variant was carried out using the multi-criteria methods Promethee and GAIA.

2. Description of the Observed Irrigation System

Two variants of independent water supply systems were observed, which operate on the principle of using the energy of solar photovoltaic cells. In both variants, the PV generator is used for the conversion of solar radiation into direct current power which is converted by inverters into alternating current. Available insolation *Es*, i.e., electric power of the PV generator $P_{el,PV}$ determines the period of pump operation with uniform rate during daily work period. Figure 1 presents detailed diagrams of the analyzed variants.

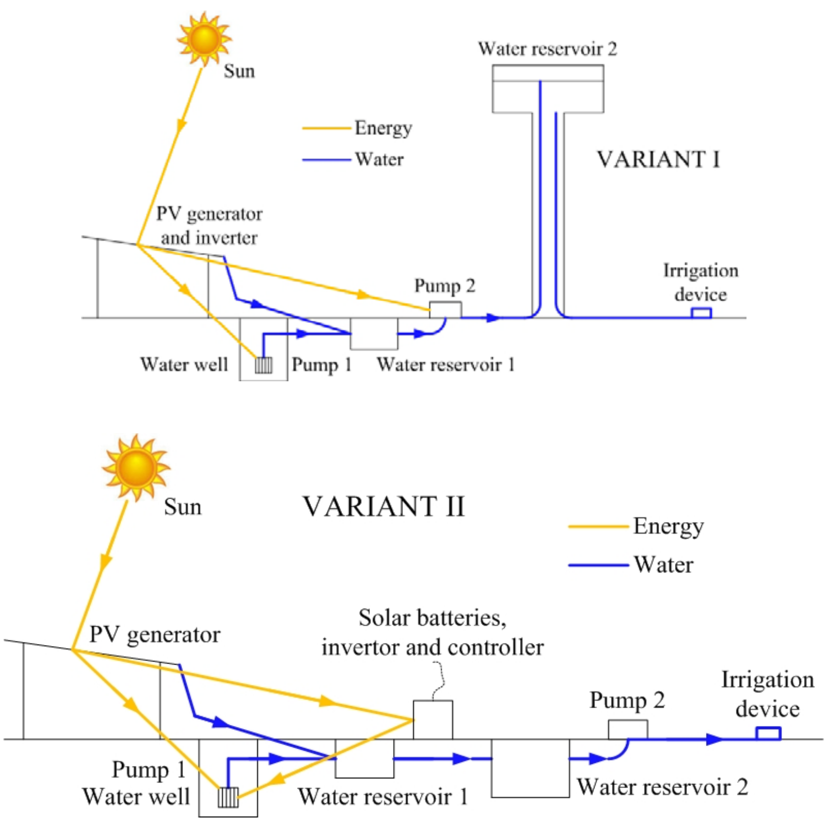

Figure 1: Schematic view of Variant I and Variant II

The difference between these two variants is that in Variant I energy is used to run the pumping station that pumps water into the water reservoir, while Variant II uses solar batteries for this purpose.

The distribution of water in both variants takes place by gravity from water reservoir 1 to reservoir 2 and from reservoir 2 to the irrigation system. The difference is that in Variant I water is stored in the water tower (reservoir 2) and in Variant II it is stored in the reservoir on the ground (in this case also reservoir 2). In Variant II electric energy stored in solar batteries is used for pumping water from the water reservoir to the irrigation system. At least two pumps are necessary for both variants, because pump 1 (pump in the well) is used to pump water from the well to water reservoir 1 where rainwater is collected. Rainwater is collected from the existing roofs and PV cells via grooves for water discharge into water reservoir 1. From reservoir 2, water is collected and distributed to the irrigation device, i.e. to the areas being irrigated [5]. Pump 2 in Variant I is used for superficial pumping of water from reservoir 1 into reservoir 2, where it is collected and later distributed for irrigation of the intended areas. In Variant II the pump is used for distributing water from water reservoir 2 to the irrigation system.

3. Methodology (Critical Period Method)

Critical Period Method (CPM) [6, 7, 8] includes design elements of the solution: PV system, pump station and water reservoir based on the critical period of operation of each one. The balancing period of water pumping and water reservoir water balance, t_b, is usually at least one day and may be several days, usually no more than five, (t_b = 1 till 5 days). Based on the obtained values, the minimum required size of the PV system is determined, which provides the necessary inflow of water in the critical period. Due to the scope and purpose of this paper, the required equations and procedures for the calculation of the individual irrigation system parts size will not be listed and explained because they are well known since it is already a proven technology, but they can be found in [5, 6, 8, 9, 10]. The minimum required $P_{el,PV}$ is determined from established differences $\Delta V_{tb,i}$:

$$\Delta V_{tb,i} = V_{PS,tb,i} - V_{daily,tb,i} \quad (1)$$

The critical day/period for PV generator design is determined by statistical minimization, where $\Delta V_{tb,i}$ is a difference which is typically equal to 0:

$$\min \Delta V_{tb,i} \Rightarrow t^*_{Pel,PV,tb,i} \quad (2)$$

The required volume of water reservoir 2, V_{op}, is obtained using the common sizing procedures [10]. In general, the critical day/period for the design of volume reservoir is the day with maximum water demand and the shortest duration of solar radiation suitable for pump station operation, providing that on the available day insolation $E_s(i)$ is sufficiently high. A critical day/period for the pump station also coincides with this critical day. Based on the above mentioned, the required volume for each alternative tb is obtained using statistical maximization, with the associated critical day:

$$V^*_{tb,i} \geq max V_{tb,i} \Rightarrow t^*_{V,tb,i} \quad (3)$$

As a rule, the critical day refers to the day in which the daily duration of solar radiation Ts, which is suitable for pumping, is shortest during the analyzed year. The same situation applies to the capacity of pump stations:

$$Q_{PS}^{*} \geq max\, Q_{PS} => t_{PS,tb,i}^{*} \qquad (4)$$

4. Multicriteria Methods Promethee and GAIA

4.1 Promethee

Promethee is an outranking method for a finite set of alternative actions to be ranked and selected among criteria, which are often conflicting. Promethee is also a quite simple ranking method in conception and application compared with the other methods for multi-criteria analysis [11]. Alternatives are evaluated according to different criteria, which have to be maximized or minimized. Determination of the weights is an important step in most multi-criteria methods. It is assumed that the decision-maker is able to weigh the criteria appropriately, at least when the number of criteria is not too large [12]. For each criterion, the preference function translates the difference between the evaluations obtained by two alternatives into a preference degree ranging from zero to one. The following three segments are characterized for the PROMETHEE method:

- Scope of criteria

The design of preferences of the decision maker will be modified by observing six possible scopes (preference function) for each criterion, based on the intensity of preferences. Some of them allow intransitivity of indifference, while others offer a smooth transition from indifference to strict preference.

- Estimated relation of "higher-rank"

The use of criteria as defined in the previous paragraph allows the construction of the estimated relation of "higher-rank". This relationship will be less sensitive to small changes of parameters and its interpretation will be simple.

- Using the relation of "higher-ranking"

This concept will discuss the specific use of the estimated relation of "higher-rank", especially when actions must be ranked from the best to the worst. Method Promethee I allows partial ranking of actions. Full ranking is obtained by the method Promethee II. The scope of criteria is based on the introduction of the preference function which gives preference to the decision maker for action a in relation to action b. This function will be defined for each criterion separately; its value will range between 0 and 1. The lower the value of the function, the greater the indifference of the decision maker; when this value is closer to 1, the preference is greater. In the case of strict preference, the value of the preference function will be equal to 1 [13].

Let f be a certain criterion, and *a* and *b* two actions (alternatives) from the set of actions *A*. The associated preference function *P(a,b)* of a in relation to b will be defined as:

$$P(a,b)= \begin{cases} 0, & \text{if } f(a) \leq f(b) \\ p[f(a), f(b)] & \text{if } f(a) > f(b) \end{cases} \qquad (5)$$

For concrete cases functions type *p* should be chosen

$$p[f(a), f(b)] = p[f(a)-f(b)] \qquad (6)$$

where *p* depends on the difference between values *f(a)* and *f(b)*. Indifference zone d in environment *f(b)* is defined by:

$$d = f(a) - f(b) \qquad (7)$$

Equation (8) presents function *H(d)* (Figure 2):

$$Hd= \begin{cases} P(a,b), \text{if } d \geq 0 \\ P(a,b), \text{if } d \leq 0 \end{cases} \qquad (8)$$

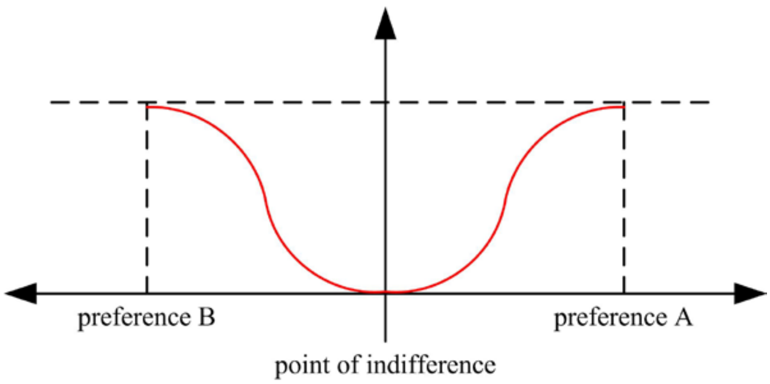

Figure 2: Function *H(d)*

According to [13] and [14], six criteria are defined: common criterion, quasi criterion ("U" shaped preference function *p*), criterion with linear preference ("V" shaped preference function *p*), the criterion of levels, criterion with linear preference function and indifference zone and Gaussian criterion. Each of them is different with regard to defining/setting and selection of the threshold (parameter) for a decision.

The next step is to assess the relation of "higher-ranking". For each pair of actions *a*, *b*∈*A*, first the multi-criteria index of preferences is defined for a in relation to b for all criteria. It is assumed that each criterion is identified as a type of the discussed criteria, so that the preference functions *Pj(a,b)* are defined for each *j* = 1,2, ..., *k*. Multi-criteria index of preference *Π (a, b)* is defined by the following expression:

$$\prod(a,b) = \frac{1}{k}\sum_{j=1}^{k} P_j(a,b) \qquad (9)$$

where k is the number of criteria.

If it is assumed that the preference function $Pj(a,b))$ and criterion weights Wj are specified for each criterion j = 1, ..., k, the multi-criteria preference index $\Pi(a,b)$ for $\forall a, b \in A$ is defined as:

$$\prod(a,b) = \frac{\sum_{j=1}^{k} W_j P_j(a,b)}{\sum_{j=1}^{k} W_j} \qquad (10)$$

where Wj is the criterion weight.

If the decision maker wants to rank actions from A from best to the worst, it is the issue of ranking. If the decision maker must choose the best actions from A, it is the issue of choice. Since the multi-criteria issue generally does not yield the best solution, the problem will consist of determining a set of good actions from A.For this purpose two techniques to solve the problem of ranking will be used, where at ranking can result in a set of good actions as a solution to the problem of choice. These are the PROMETHEE methods, i.e. Promethee I and Promethee II.

In the Promethee method I the actions are ranked in partial order. If the estimated relation of "higher rank" for each node a is defined, based on multi-criteria preference index for each $a \in A$, the following flows are obtained:

- Output flow:

$$\Phi^{+}(a) = \frac{1}{n-1}\sum_{x \in A} \prod(a,x) \qquad (11)$$

- Input flow:

$$\Phi^{-}(a) = \frac{1}{n-1}\sum_{x \in A} \prod(x,a) \qquad (12)$$

When the output flow is greater, a dominates over other actions from A; with lower input flow fewer actions dominate over a. Some actions will be comparable, and some incomparable so that the method Promethee I gives partial relations, i.e. estimated relation of "higher-rank" that gives important information to the decision maker about the relations between actions.

In the method Promethee II actions are ranked in complete order (full ranking without incomparability). For every action a∈A the resulting (net) flow is observed:

$$\Phi(a) = \Phi+(a) - \Phi-(a) \qquad (13)$$

which is used in ranking of actions:

- *a* has a higher rank than b *(aP(2)b) if Φ(a) > Φ(b)*;
- *a* is indifferent to b *(aI(2)b) if Φ(a) = Φ(b).*

The method Promethee II defines the complete relation where all the action from A are fully ranked, noting that in this relation part of information is lost, due to the balancing effects between the output and the input flow, which results in a higher degree of abstraction [13].

4.2 GAIA

Method GAIA (Geometrical Analysis for Interactive Aid) gives a geometric presentation of the results of PROMETHEE method, or methods PROMETHEE I and PROMETHEE II. The idea underlying the programme is the reduction of a multidimensional problem to a two-dimensional one to enable planar presentation. The dimension of multi-criteria analysis is determined by the number of criteria (each criterion determines one of the vectors in such space), and if a geometric presentation is desired, the problem should be reduced to a two-dimensional image (a possible three-dimensional image would be confusing). In this reduction of dimension a loss of information regarding the problem is inevitable. To minimize this loss as much as possible, the plane in which the geometrical presentation is given is determined by the two largest values typical for covariance matrix. GAIA provides data on the percentage of information given by such presentation. With the exception of an extremely unfavorable problem structure, the geometric presentation provides sufficiently high percentage of information for analyzing the problem. It is also possible to connect GAIA method with the method PROMETHEE II. PROMETHEE II requires that a certain weight W_j be allocated to each criterion and that complete order in set A be defined. The weights can also be displayed in the (u, v) plane by using the so-called decision vectors which are aimed towards the highest ranking activities. In this way, by interactive changing of weights, it is possible to observe changes in rank, acquired by the method PROMETHEE II [13].

The described method of selecting the plane for geometric presentation of a multi-criteria problem enables minimal loss of information (in the sense of the least squares method), which means that (with certain losses necessary in the process of reducing the problem dimension) "mutual relations" of the criteria are preserved, as well as the importance of each criterion in relation to the others. In this presentation the conflicting criteria will take a significantly different direction (small covariance among the criteria causes small value of scalar product of vectors which present them) and mutually concordant criteria are presented with vectors of similar direction [13].

The importance of the decision making criteria is geometrically represented with the vector length, so that dominant criteria correspond to the vectors of greater absolute values. Summing the vectors that present the criteria leads to a summary vector whose direction and value describe the resulting action of the criteria. If the summary vector of criteria is of small absolute value in relation to the summary vector of another individual criterion, this indicates the conflict of criteria. It can be concluded that geometrical presentation of multi-criteria analysis is a very powerful "tool" and provides substantial assistance with problems characterized by partially or totally conflicting criteria, which is unfortunately frequent in the decision-making processes [13].

Let (A_1, A_2,..., A_i,..., A_n) be the projections of the *n* points representing the alternatives and let (C_1,C_2,...,C_j,...,C_k) be the projections of the *k* unit vectors of the coordinates axes of IR^k representing the criteria. We then obtain a GAIA plane of the following type [11]:

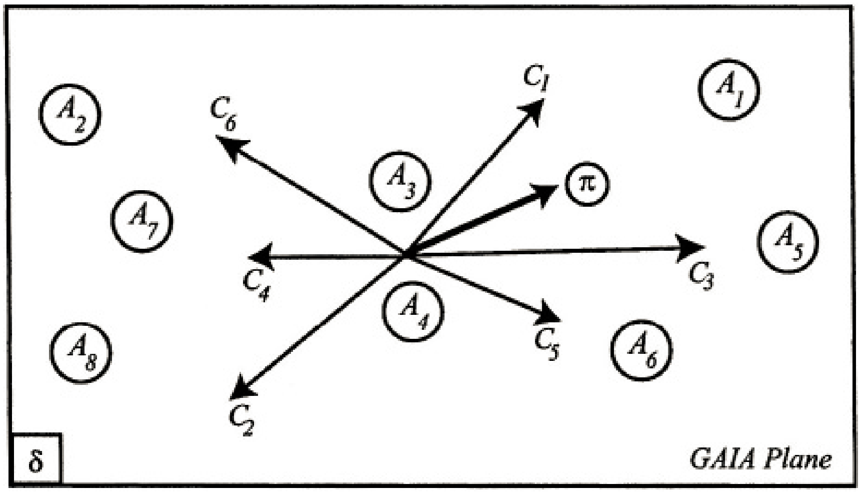

Figure 3: Alternatives and criteria in the GAIA plane

Then the following properties hold provided that δ is sufficiently high [11]:

- The longer a criterion axis in the GAIA plane, the more discriminating this criterion.
- Criteria expressing similar preferences are represented by axes oriented in approximatively the same direction.
- Criteria expressing conflicting preferences are oriented in opposite directions.
- Criteria that are not related to each others in terms of preferences are represented by orthogonal axes.
- Similar alternatives are represented by points located close to each other.
- Alternatives being good on a particular criterion are represented by points located in the direction of the corresponding criterion axis.

On the example of Figure 3 we observe [11]:

- That the criteria g_1(.) and g_3(.) are expressing similar preferences and that the alternatives a_1 and a_5 are rather good on these criteria.
- That the criteria g_6(.) and g_4(.) are also expressing similar preferences and that the alternatives a_2, a_7 and a_8 are rather good on them.

- That the criteria $g_2(.)$ and $g_5(.)$ are rather independent
- That the criteria $g_1(.)$ and $g_3(.)$ are strongly conflicting with the criteria $g_4(.)$ and $g_2(.)$
- That the alternatives a_1, a_2 and a_6 are rather good on the criteria $g_1(.)$, $g_3(.)$ and $g_5(.)$
- That the alternatives a_2, a_7 and a_8 are rather good on the criteria $g_6(.)$, $g_4(.)$ and $g_2(.)$
- That the alternatives a_3 and a_4 are never good, never bad on all the criteria.

Although the GAIA plane includes only a percentage δ of the total information, it provides a powerful graphical visualisation tool for the analysis of a multicriteria problem. The discriminating power of the criteria, the conflicting aspects, as well as the "quality" of each alternative on the different criteria are becoming particularly clear [11].

5. Case Study

5.1 Location and Site Description

Case study will be analyzed and presented on example of the local football club "Obreš" which is located in Croatia near Varaždin, in the municipality of Sveti Ilija, Figure 4, (modified from [15]). According to the recommendations [16] and the position of the available area, the azimuth of the PV generator is in the south direction (Figure 5), while the angle of inclination is equal to 15°. Figure 5 also shows the location of all elements of the analyzed system of Variants I and II.

Figure 4: The ground plan of the location of Sveti Ilija

Figure 5: Schematic ground plan view of the football pitch irrigation for Variants I and II

5.2 Input Values

Due to actual needs and recommendations [17], for daily constant water need (consumption) V_{daily} from May to August adopted value is equal to 30 m^3, Figure 6.

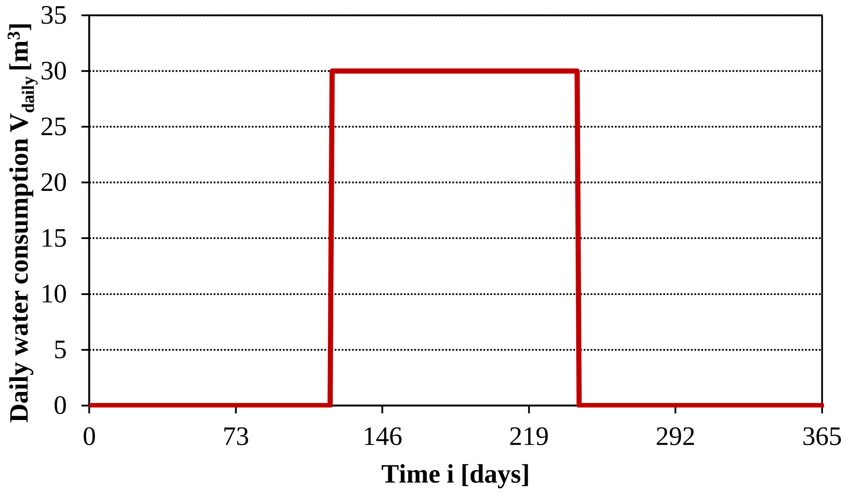

Figure 6: Daily constant water need (consumption) V_{daily} from May to August of the characteristic year

There are two daily regimes of water consumption, i.e. water inflow and outfall (input/output) of water reservoir, Figure 7.

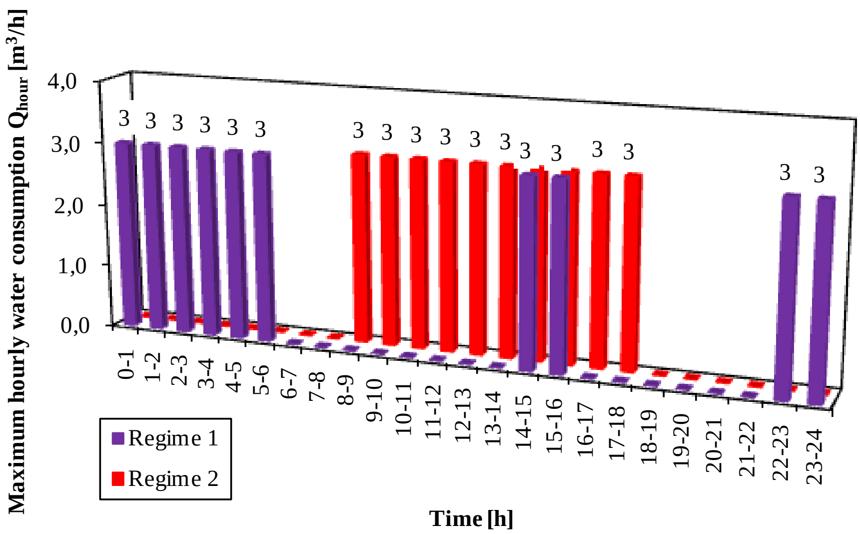

Figure 7: Daily regimes of water consumption of the characteristic year

Regime I is from 10 PM till 6 AM and lather from 2 PM till 4 PM. Regime II is from 8 AM till 6 PM. Regime 1 is more favorable if the pitch is busy during the day, and also it is more suitable for the grass if irrigation takes place during the night. Regime 2 is more practical considering the possibility of theft of the irrigation equipment (Regime 1). Figure 8, 9 and 10 shows average daily insolation intensity, peak hours' period, average daily air temperature, solar cell temperature and mean of the maximum monthly value of measured precipitation height from May till August are taken/calculated from [18] and [19]. The data from [19] are expressed as mean values for the duration of 10 years, i.e. for the period from 2004. to 2013. Also, the data from [18] was available and expressed as a mean values only for the duration of two years, 2004. and 2005.

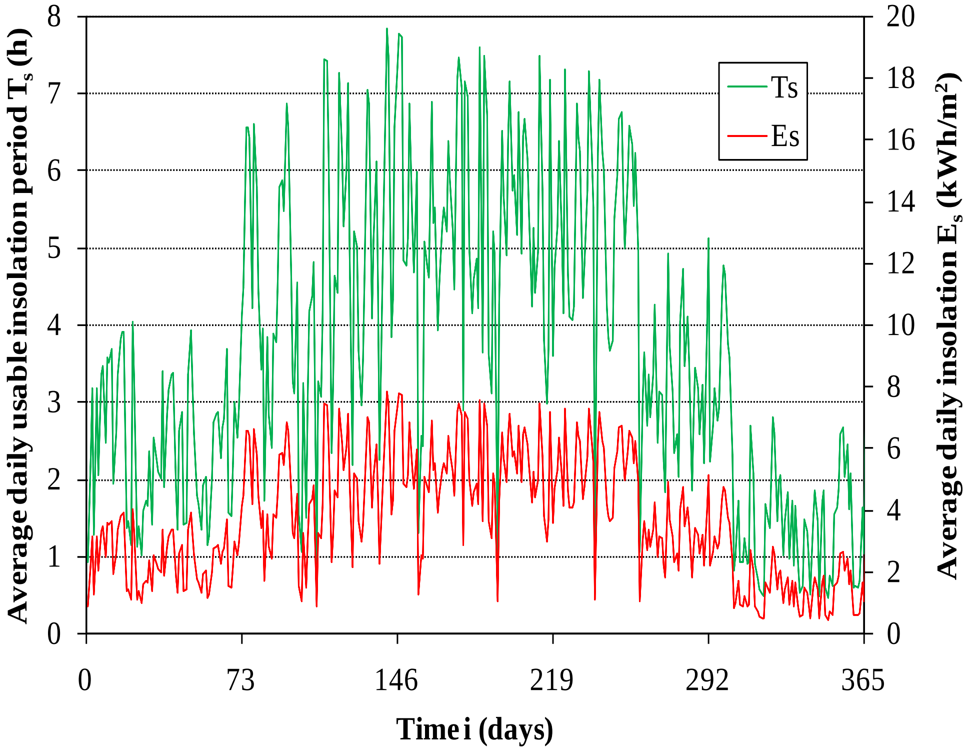

Figure 8: Average daily insolation intensity from May till August from 2004. to 2013.

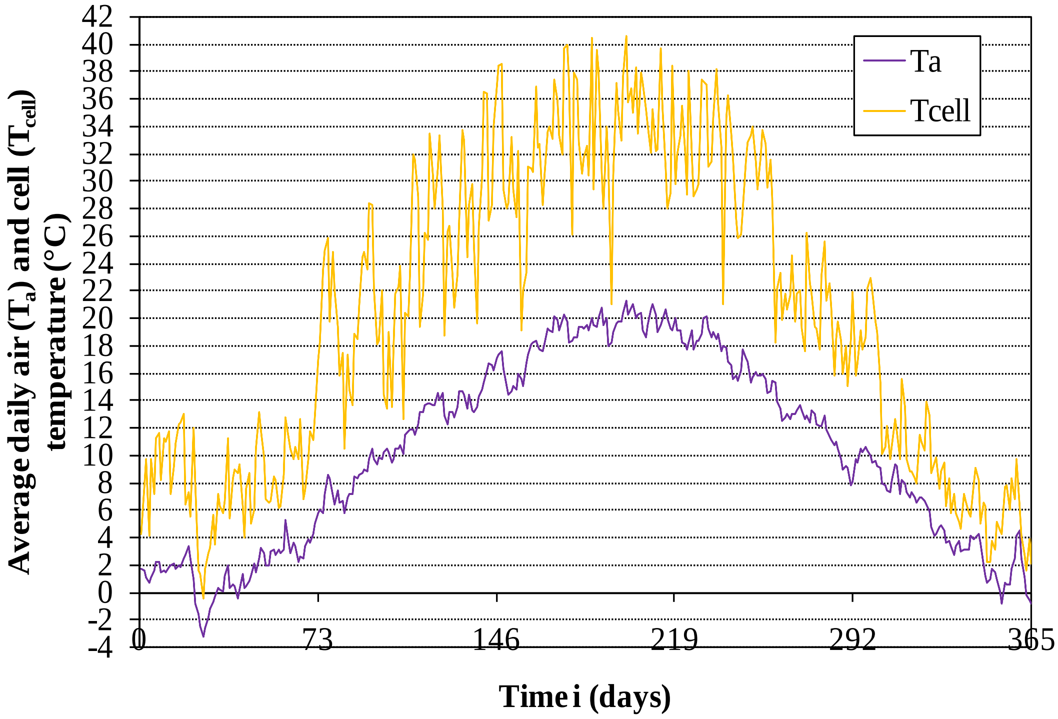

Figure 9: Average daily air temperature, solar cell temperature from May till August from 2004. to 2013.

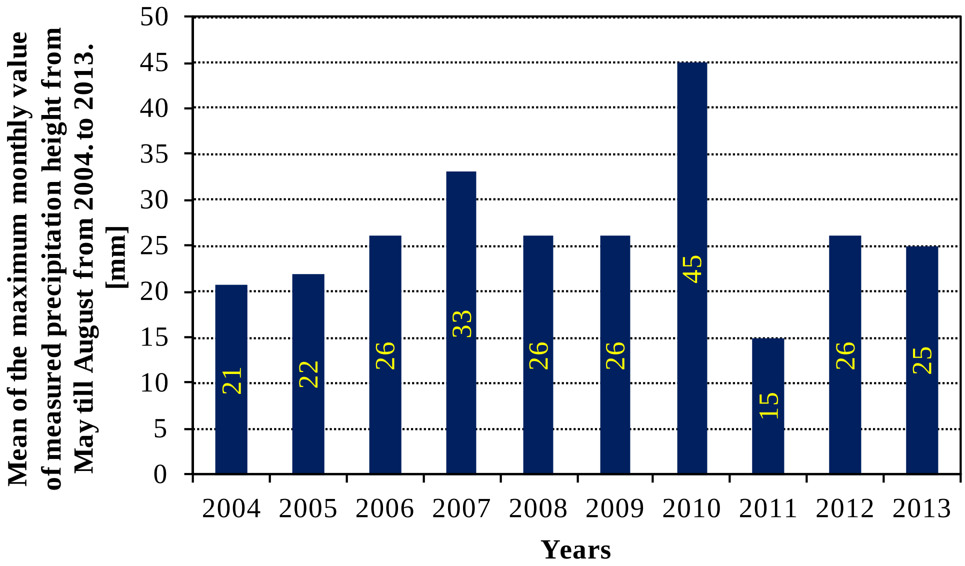

Figure 10: Mean of the maximum monthly value of measured precipitation height from May till August from 2004. to 2013.

6. Obtained Results and Discussion

For this case, the mentioned sizing procedure Critical Period Method, will be carried out for the period of balancing one day only (t_b = 1 day). Critical days for sizing of all parts of the subsystem are the same, according to the equations (2-4); for the subsystem PV: $t^*_{Pel,PV,tb,i}$ = 239th day, for the subsystem V: $t^*_{V,tb,i}$ = 239th day and also for the subsystem PS: $t^*_{PS,tb,i}$ = 239th day. Typically, critical days differ, [6, 8]. Overlapping of the critical periods in this case is explained with fact that water consumption regime is constant.

Taking into account the estimated total pressure losses in all the pipelines, secured height to prevent cavitation, as well as the required pressure of 3.5 bar for operation of the irrigation device [17], the adopted height of the water reservoir is 50 m, with the adopted pipeline diameter of 5 cm (as well as all pipelines) to the water reservoir.

The total calculated/adopted manometer height of a submersible well pump (with total pressure losses included, as well as secured height to prevent cavitation) is 10 m. Water is delivered from water reservoir 1 to water reservoir 2 by gravity, and if this is not possible, delivering is ensured by using of ‘’booster pump’’ (re-pumping).

The minimum or maximum speed range for water flow in inlet pipelines in both water reservoirs ranges from 0.5 m/s up to 2 m/s with respect to minimum (3.75 m^3/h) and maximum (15 m^3/h) hourly input water flow values to reservoirs 1 and 2.

This means that the adopted capacity for both pumps is 15 m^3/h. Considering the mean values, sizes and capital costs (with VAT) of all irrigation system elements for both variants, based on equations (1-4) and the available references [6, 20 - 23], are calculated and shown in Table 1.

Table 1: Sizes and capital costs of individual irrigation system parts for Variants I and II

Subsystem	**Unit price**	**Size**	**Price (€)**
PV generator (I, II)	1.5 €/W	7800	11700
PV invertor (I, II)	0.5 €/W	7800	3900
Pump station 1 (I, II)	1 €/W	700	700
Pump station 2 (I, II)	1 €/W	3500	3500
Water reservoir 1 (I, II)	-	11	1000
Water reservoir 2 (I, II)	-	24	2700
Water reservoir tower (I)	-	-	53500
Well (I)	-	-	2000
Solar batteries (II)	2 €/Ah	3250	6500
Controller (II)	-	-	1320
Irrigation device with pipes (I, II)	-	-	2000
Pipes (I, II)	2 €/m’	100 (I); 10 (II)	200 (I); 20 (II)

Water reservoir 1 capacity is adopted based on the mean of the maximum monthly value of measured precipitation height for May till August month within the observed period of 10 years (from 2004. to 2013.), which is 26.4 mm [19]. Since the water is collected from available roof areas (350 m^2) and area of PV generator (52 m^2), the estimated quantity of storm water that may occur is 11 m^3.

The required capacity of solar battery C_B is obtained based on procedure described in [9], where C_B is 3250 Ah. As a rule, it should be taken into account the complete analysis LCC (Life Cycle Costs). In other words, besides capital costs, it should be taken into account, the costs of replacement and the costs of the operation and maintenance.

However, such economic analysis was not conducted due to the scope of this paper. As an approximate value, for similar systems [6, 8] it has been adopted that the share of capital costs is about two thirds of the amount of LCC. The total capital costs for Variant I amount to 81200 € and for Variant II 33340 €. Therefore, the variant with water reservoir is approximately 2.5 times more expensive than the variant with solar batteries. It is evident that the price of tower is dominant in Variant I.

7. Multicriteria Analysis by Using of Methods Promethee and GAIA

7.1 Hierarchical structure of the objectives

Multicriterian analysis is carried out by using of multicriteria method Promethee, or using the software package Visual PROMETHEE Academic Edition 1.4© [14]. Figure 11 shows the hierarchical structure of the objectives and criteria that define the multicriteria analysis of ranking and the final decision between Variants I and II.

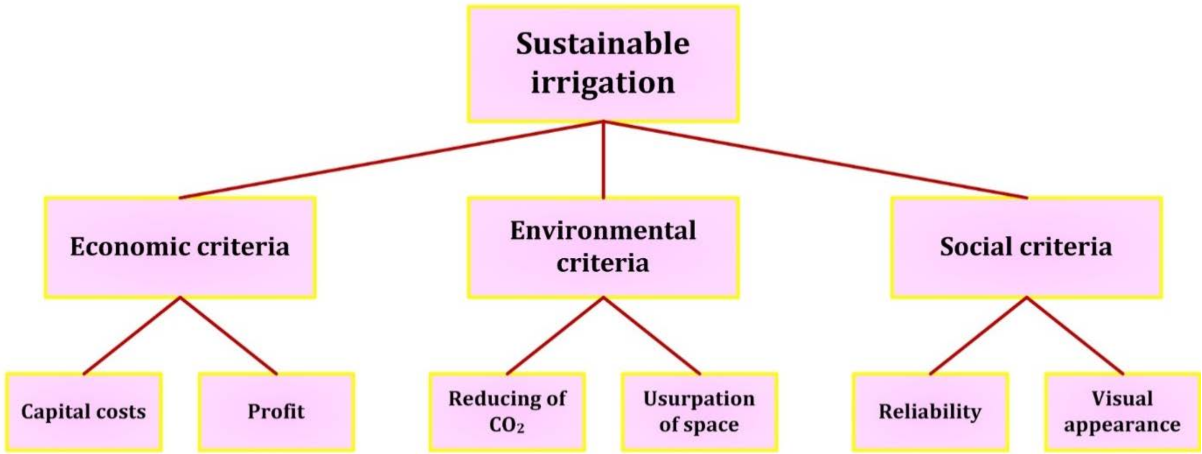

Figure 11: Structure of the analyzed problem

It is adopted that all criteria has equal importance i.e. equal weight. Economic and environmental criteria are described quantitatively, while social criteria are described qualitatively.

7.2 Economic, Environmental and Social Objectives

From economic point of view, profit from sale of the energy surplus from Variant I and II amounts annually 613 €. Environmental criteria in this paper are defined by the amount of CO_2 that would not be released if PV energy was used instead of classical electric energy produced by using fossil fuels, which is 0.95 kg/kWh [6]. According to [19], the annual number of operating hours of the PV subsystem is 1348 hours. The fact that the produced electric energy is 10514 kWh means that with the use of PV energy, 9988 kg of CO_2 was not released into the atmosphere on annual basis. The area occupied by the PV cells is taken as one of the environmental criteria, which in this case is 52 m^2. This is important in case of urban areas where the above mentioned represents usurpation of space. Regarding social criteria, they include reliability of the irrigation system, as well as visual identity for both analyzed variants. Variant I is suitable for urban areas, while Variant 2 is suitable for lowland rural areas. The evaluation of the appearance is based on visual integration into the landscape/environment. Since this is a highly subjective criterion, equal qualitative rating will be adopted. It will be assumed that both variants have good reliability of operation.

7.3 Ranking and Selection of Variants by Using the Promethee and GAIA Method

By using the equations (11-13) i.e. software package Visual PROMETHEE Academic Edition 1.4.© [14] it has been obtained that Variant I ranked higher compared to Variant II with regard to the indicator □ which is 0.1667 for Variant I, and □ = -0.1667 for Variant II (Scenario 1). However, if the same problem were analyzed for an urban environment, or if the existing (built) elevation were used instead of a tower, Variant II would be better (□ = 0.333) compared to Variant I (□ = -0333) (Scenario 2). It is obvious that the price of a tower has great significance in relation to other criteria. Figure 12 shows results obtained by using of method GAIA (which is included within Visual Promethee) for Scenario 1, while Figure 13 shows results for Scenario 2.

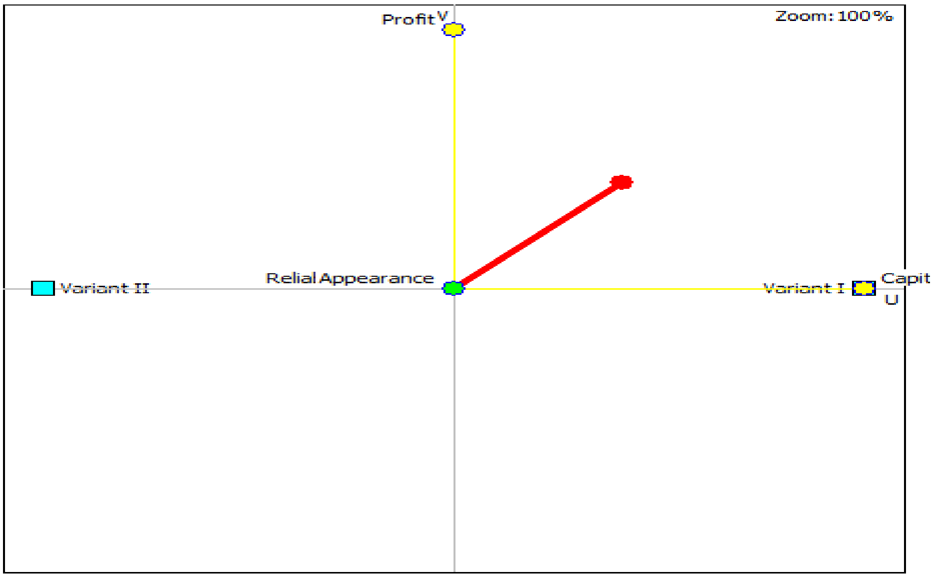

Figure 12: Results obtained by using of the method GAIA for Scenario 1

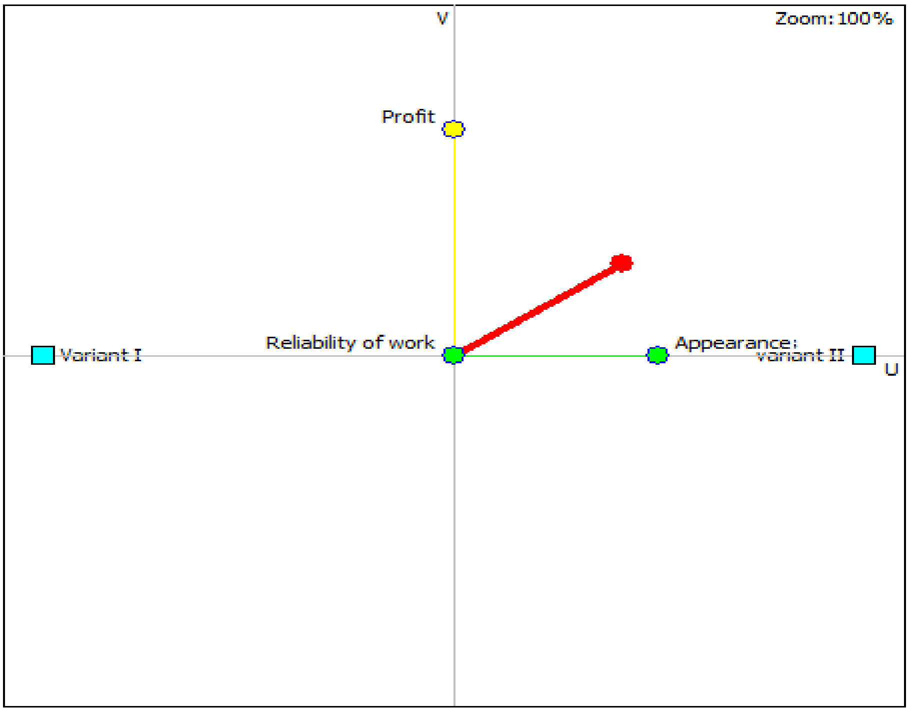

Figure 13: Results obtained by using of the method GAIA for Scenario 2

As previously stated, the importance of criteria for making decisions on the analysis results using the GAIA method is represented by the length of the vector, so that vectors of larger absolute values correspond to dominant criteria. Figures 12 and 13 shows the results of the analysis, where the suitability of the analyzed variants with regard to the two scenarios is shown by the sum of the vectors of the presented criteria. The optimality of the analyzed variants can be concluded according to the proximity of the perpendicular drawn from the point that is a geometrical presentation of Variant I and decision vector, as well as the proximity of the decision vector and the perpendicular of the geometrical presentation of Variant II. Given that in Scenario I (Figure 12) the perpendicular drawn from the point that presents Variant I is closer to the top of the decision vector in relation to the perpendicular from the point presenting Variant II, it can be concluded that Variant I is the optimal choice. Analogous to Scenario 2 (Figure 13), according to the proximity of the perpendiculars drawn from the points presenting the analyzed variants and decision vector, it can be concluded that in this case Variant II is the optimal choice. The results obtained using the GAIA method confirms the results obtained using the Promethee method.

8. Conclusions and Guidelines for Further Research

By using of Critical Period Method, real picture of possible sustainable using of water and energy for irrigation in rural, as well as urban areas has been presented. Proposed concept of the system for irrigation of the football field is in accordance with the world and European legislation, directives and strategies related to the negative impacts of climate changes and greenhouse gas emissions [24, 25]. The resulting solution is conservatively sized enabling high reliability of irrigation system. It also allows the use of surplus generated electricity for other purposes. Further research would consist of more accurate determination of available quantities of storm water with regard to return periods and probability of occurrence. There is also a plan for further sizing of the irrigation system for the balancing periods longer than one day. Furthermore, presented variants of possible solutions have been analyzed by using of multicriteria methods Promethee and GAIA. Apropos, other criteria were taken into the account, i.e. economic, environmental and social criteria, all for the purpose of selecting the optimal solution.

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