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## MODELLING OF METEOROLOGICAL PARAMETERS FOR THE PURPOSE OF SIZING OF THE SOLAR PHOTOVOLTAIC IRRIGATION SYSTEMS

### SUMMARY

Solar photovoltaic (PV) irrigation systems are usually sized by using measured or modelled meteorological data, such as solar radiation, air temperature and precipitation during a year or a certain period. Experiences during sizing, as well as in the use of such systems, have shown certain discrepancies during the year, despite the available data such as annual cloud coverage, number of sunny days, etc. In such cases, the usual statistical parameters as well as trend analysis are not reliable tools for predicting deviations of the PV irrigation system operation.

The justification of using the Rescaled Adjusted Partial Sums (RAPS) method has been researched in his paper, in order to determine the existence of such deviations in the given time series (i.e. their deviations or fluctuations) of the solar radiation intensity, air temperature and precipitation. In this way the existence of certain irregularities of the given time series, i.e. input quantities of solar radiation intensity, air temperature and precipitation amounts were determined. This defined the period of the year in which special attention had to be paid to the operational functioning of the PV irrigation systems. The presented methodology was shown on real examples on several locations in the Republic of Croatia where PV irrigation systems are planned to be built. This methodology will certainly contribute to the achieving of systematic sustainability of the PV irrigation systems.

**Keywords:** Meteorological parameters, RAPS method, Solar photovoltaic energy, Irrigation system, Time series

### INTRODUCTION

Climate changes are highly related to all meteorological parameters. Air temperature and insolation intensity are main input parameters for the sizing of the solar photovoltaic (PV) irrigation system. Additionally, rainfall enriches the natural watercourses or aquifer, and has an impact on the PV irrigation system working parameters. These parameters, i.e. their input values play an important role in sizing that kind of systems. Attention should be focused on the possible seasonal or even weekly value deviations or fluctuations, as well as irregularities in time series of particular input data. The mentioned input parameters have a

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stochastic nature; considering the climate variability, the PV irrigation system could be oversized or undersized.

Most common approaches in the analysis of changes in meteorological parameters are based on defining and analysis of their time series trends. Since meteorological parameters depend on climate changes, time series trends are not reliable and could lead to wrong conclusions about the analyzed characteristic of the parameters. Using the time series analysis, except determining the general time series trend, it is possible to determine more detailed fluctuations within the examined time series (Bonacci, 2010). For that purpose, a RAPS (Rescaled Adjusted Partial Sums) method has been used in this paper (Garbrecht and Fernandez, 1994; Bonacci et al, 2008). The RAPS method has been widely used in hydrological and meteorological parameters analysis. Bonacci, 2010, used the RAPS method for the time series analysis of the average annual air temperature measured at 26 meteorological stations in Croatia. Furthermore, Bonacci et al, (2008) and Bonacci et al (2009), used RAPS method for the analysis of the flow and temperature of the Danube River at Bratislava (Slovakia) and for the analysis of the temperature of the Danube River in Croatia. Lojen et al (2009), used the RAPS method to determine the climate changes impact on the limestone layers at the Krka River (Croatia) basin. The RAPS method is mostly used for the flow analysis of watercourses and analysis of their hydrological regimes. If within the time series of meteorological parameters the presence of subseries is determined, it is easier to focus on a certain part of the original (default) time series. In this way, it is possible to determine the reasons causing the appearance of subseries.

## MATERIAL AND METHODS

### Definition of the RAPS method

The RAPS method is based on the time series analysis by the usage of the deviation sum curve. Graphical presentation of the RAPS method is suitable since it provides overcoming of the small systematical and random changes, errors and variability in the analyzed time series. Graphical presentation of the RAPS method indicates the existence of subseries with similar characteristics, larger number of trends, sudden value changes, irregular fluctuations, existence of periodicity of the analyzed time series, etc. The RAPS method is defined through the following expression:

$$RAPS_k = \sum_{t=1}^k \frac{Y_t - \bar{Y}}{S_y} \quad (1)$$

Where  $\bar{Y}$  is average value of the considered time series,  $S_y$  is standard deviation of the same series,  $n$  is number of data in time series,  $k$  is summation counter ( $k = 1, 2, 3, \dots, n$ ), (Bonacci, 2010). Graphical presentation of the  $RAPS_k$  values obviously and without any doubt points to existence regularities in the analyzed parameters ( $Y_t$ ) fluctuations. When the existence of the subseries

within the main series has been determined, the next step is to determine (as a general rule) the linear trends of the subseries.

### Case study

In this paper two potential locations for building of the PV irrigation system have been analyzed. Both locations are in the North West area of Croatia. The first location was located in Sveti Ilija, the city of Varaždin; the second was located in Domašinec, Medimurje County. The Sveti Ilija location was planned for building of the irrigation system at the football pitch. The Domašinec location was planned for building of the irrigation system for the family farm holding. RAPS method was applied on time series of the total average daily insolation  $E_S$  on the inclined surface of  $15^\circ$ , oriented to the South (SODA, 2017), average daily air temperature  $T_a$  (DHMZ, 2017a) and total daily precipitation  $P$  for the year 2015 (DHMZ, 2017b). The mentioned parameters with calculated trends are presented in Figure 1-3.

Negligible low values of the coefficient of determination ( $R^2$ ) show that definition of a linear trend (as mostly used trend) was not acceptable (Figure 1-3). From these figures it could be concluded that definition of any trend was not acceptable, due to the stochastic nature of the input parameters. This is a motivation for the application of a new method which could determinate the irregularities i.e. functional dependencies in input time series (like RAPS method).

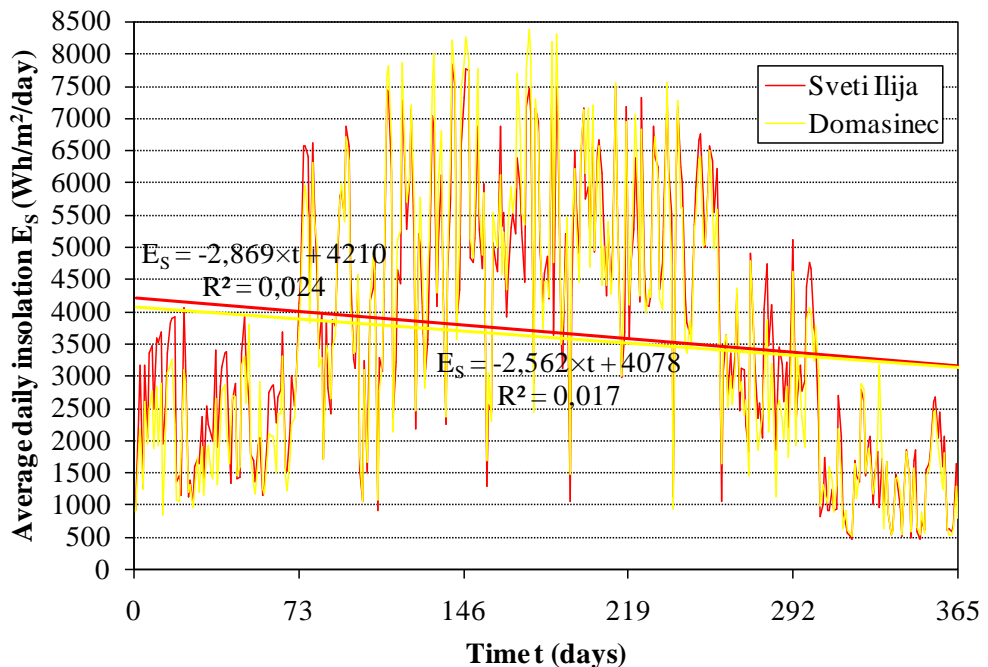


Figure 1. Average daily insolation for the Sveti Ilija and Domašinec.

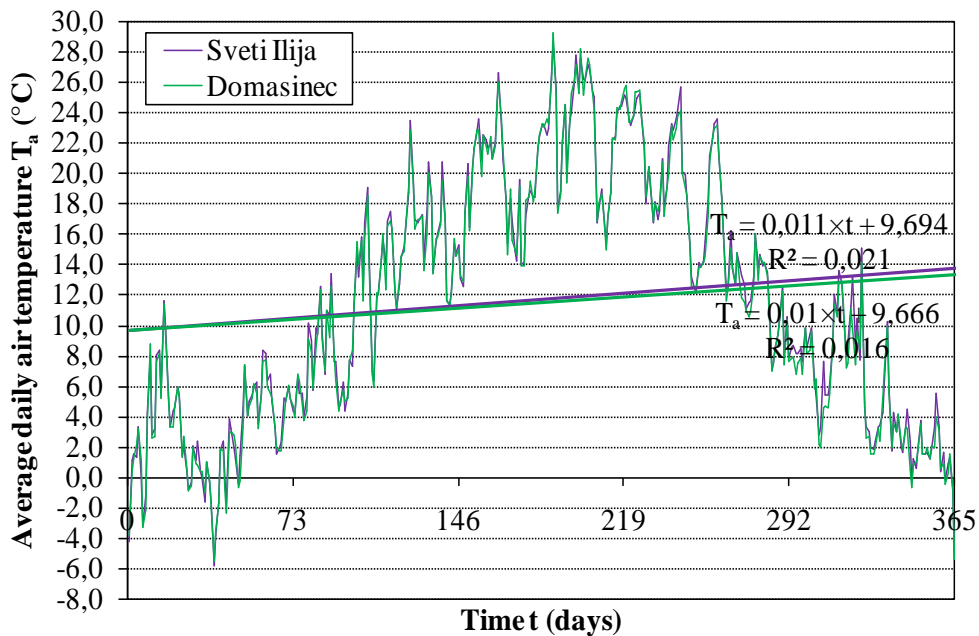


Figure 2. Average daily air temperature for the Sveti Ilija and Domašinec.

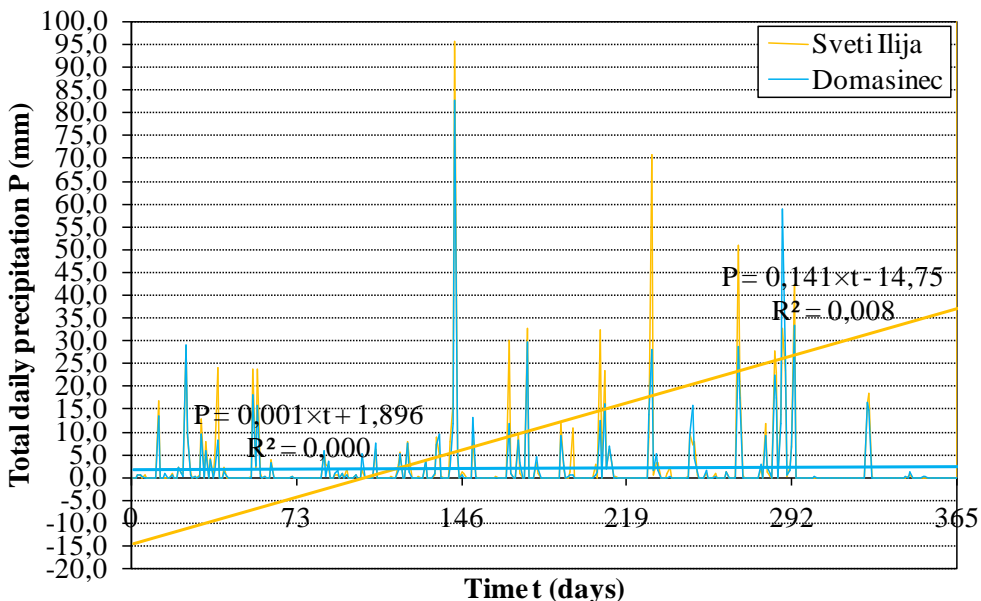


Figure 3. Total daily precipitation for the Sveti Ilija and Domašinec.

## RESULTS AND DISCUSSION

Figure 4 presents RAPS values obtained by using Eq. 1 in the example of the average daily insolation  $E_S$  series.

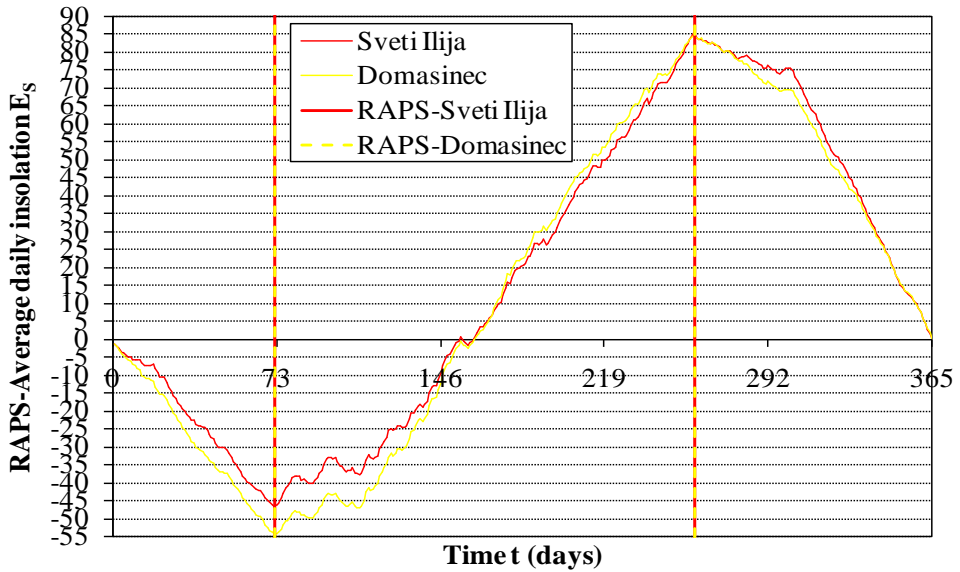


Figure 4. RAPS values for the average daily insolation.

Since Figure 3 shows the absence of continuity of the total daily precipitation for both sites (given the large number of days without any recorded precipitation), the application of the RAPS method is not acceptable due to discontinuity on both locations. Figures 5 and 6 present a calculated subseries for the average daily insolation  $E_s$  and average daily air temperature  $T_a$ .

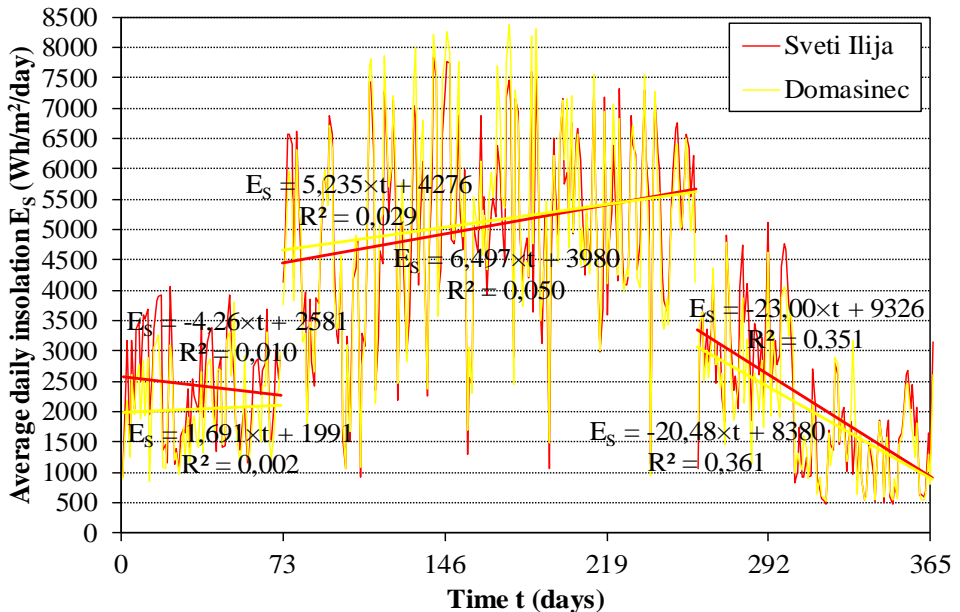


Figure 5. Subseries for the average daily insolation for the Sveti Ilija and Domašinec.

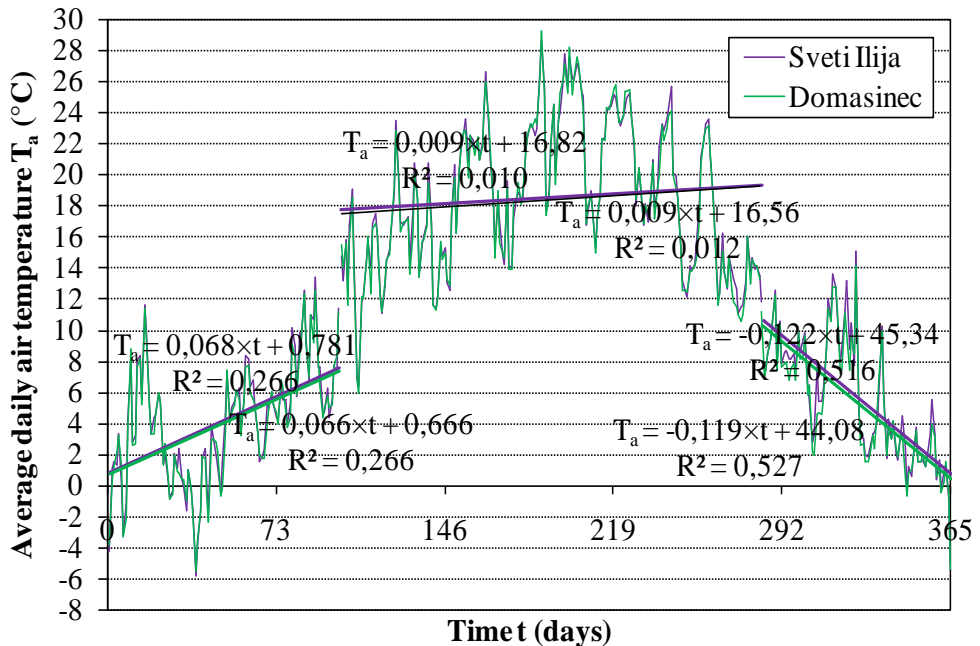


Figure 6. Subseries for the average daily air temperature for the Sveti Ilija and Domašinec.

In Figures 5 and 6, three characteristic periods (three new subseries) can be seen, bordered by the beginning and the ending of a summer season, for both locations. Due to the proximity of both sites, the subseries show strong overlapping. Even though the coefficients of the determination had low values with no significant functional dependence, there are regularities in series deviations.

This shows that in summer time (higher insolation, more water demand) a focus should be on the reliability of a PV irrigation system operational work. In this period of the year deviations in insolation and temperature are higher, compared to winter and spring time.

The PV irrigation system operational work directly depends on this. To increase the efficiency of the PV irrigation system, it is recommended to store water into the reservoirs or to use generators for producing electric energy, to use solar batteries, and to connect to classical electric energy grid.

The input parameters should be considered within the summer period, independently from the sizing method used. This is also supported by the unequal distribution of precipitation, shown in Figure 4, where there are visible extremes in the form of minimum but also maximum precipitation for both locations. Additionally, uneven precipitation distribution (Figure 4), i.e. maximums or minimums support the previous statement for both locations.

## CONCLUSIONS

The RAPS method was employed to analyze the time series of the climate input parameters for sizing the PV irrigation systems. It was possible to determine the subseries where deviations were determined. During sizing of the PV irrigation systems it is necessary to focus on specific (or characteristic) time period according to possible deviations and fluctuations in system operational work. This is the result of stochastic and unpredictable nature of the input climate parameters.

RAPS method should be used in the long time period (ten years or more), as well for every particular year, due to a large number of usable data. This preliminary investigation presents an important base, but also a motivation for further investigation related to this interesting and up-to-date issue in irrigation.

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