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Matlab simulation of solar panel MSX-64 at the best locations of Kermanshah province using GIS interpolation

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ABSTRACT

Considering that the effective yield of a panel is equal to its total number of hours of solar radiation and temperature, only the effects of temperature and solar radiation intensity at the maximum power point (MPP) are investigated in this article. By collecting temperature data, sun's radiation hours from six synoptic meteorological stations in Kermanshah Province over the course of an eleven-year period (1995-2005), with the use of GIS software, a map of Kermanshah Province's temperature and radiation based on plotted latitude and longitude as well as the establishment of regression, the most suitable location for solar panels is proposed. In this MATLAB software simulation using the characteristics of panel MSX-64, all parameters have been considered and determined by the characteristics of the panel. Throughout the process, the design has been based on four parameters as the primary specifications of the solar panels: I_{sc}, V_{oc}, I_{mp}, V_{mp}. With the ability to simulate other solar panels with temperatures and radiation intensity corresponding to each area, the I-V curve of each custom solar panel can be drawn, making it possible to obtain the maximum power.

Keywords: GIS, Interpolation, MATLAB, Regression, Solar panel Msx-64.

1. Introduction

As a result of population growth and increasing industrialization, the demand for renewable energy is increasing every day [1]. In turn, the importance of "green", environmentally-friendly, non-polluting, renewable energy sources have greatly increased. The sun is, and will remain, our main source of lasting energy for the next 5 billion years [2]. The mass of the sun is 333 thousand times larger than that of the Earth, and is converted into energy at a rate of 4.2 million tons per second [3]. In order to harness the power of solar energy, we must use solar cells which are electronic devices and use photovoltaic phenomenon for conversion of light or photon into electrical current or voltage [4].

If just 0.1% of the Earth's surface was covered with solar panels and had only 10% efficiency, this would be enough energy fulfill all human requirements [5]. Since the efficiency of each solar cell is usually low, combine both series and parallel arrays so as to enrich the ultimate performance and expected power. Due to their efficiency, receiving the highest possible level of

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efficiency in a solar panel is the most important topic in each type. The maximum power point (MPP) [6], and the corresponding current and voltage (V_{mp}, I_{mp}) can determine the performance of a panel and the basic factor for naming it [7]. For example, MSX-64 is a panel with maximum power of 64 watts. Since the non-linear performance characteristics of the *I-V* and *P-V* curves is a function of temperature and radiation [8], it is essential to incorporate these parameters in analysis.

2.Materials and Methods

The List of symbols and terminology used in this article can be observed in Table 1.

2.1. Temperature and radiation maps

By analysing data from a six synoptic station Kermanshah, Kangavar, West Islamabad, Sarpolzohab, Ravansar, and Sararood in the eleven-year period mentioned, the results obtained about temperature range are shown in Table 2.

With the purpose of accessing the radiation map by checking the hours of sunshine data in the range of the six stations mentioned, the results in Table 2 were obtained.

By introducing temperature data obtained from Table 2 and the latitude and longitude, respectively the five level analysis and interpolation by using GIS software in Fig.1a is observed. By introducing sunshine hours' data obtained from Table 2 and the latitude and longitude, respectively the five level analysis and interpolation by using GIS software in Fig.1b is observed.

As Fig.1a shows, the eastern regions are the hottest regions and the western regions with the restricted area of the southern part of Kermanshah are the coldest regions in this province. Then, by observing Fig.1b, it is concluded that, in Kermanshah province, in the eastern regions and some limited areas in the West, the highest part of radiation in the location can be found.

Table 1. List of symbols and terminology

Symbols	Description	Symbols	Description
I_{pv}	The radiation flow	R_s	Series resistance
V_{oc}	Open circuit voltage	R_{sh}	Shunt resistance
I_{sc}	Short circuit current	s	Irradiance
V_{mp}	Maximum power of voltage	k	Boltzmann constant 1.38×10^{23} (joules per kelvin)
I_{mp}	Maximum power of current	q	Electron charge 1.6×10^{19} (colon)
T	Temperature	α	Ideal factor
T_{ref}	Reference temperature	n	Emission factor

Table 2. Average temperature and number of sunshine hours per month by each station in the eleven-year period from 1995 to 2005

Name of station	Temperature (in degrees Celsius)	Average solar radiation (in hours)
Kermanshah	15.48	254.10
West Islamabad	13.87	263.48
Kangavar	13.12	260.15
Ravansar	15.18	259.71
Sarpolzohab	20.20	263.64
Sararood	14.70	253.83

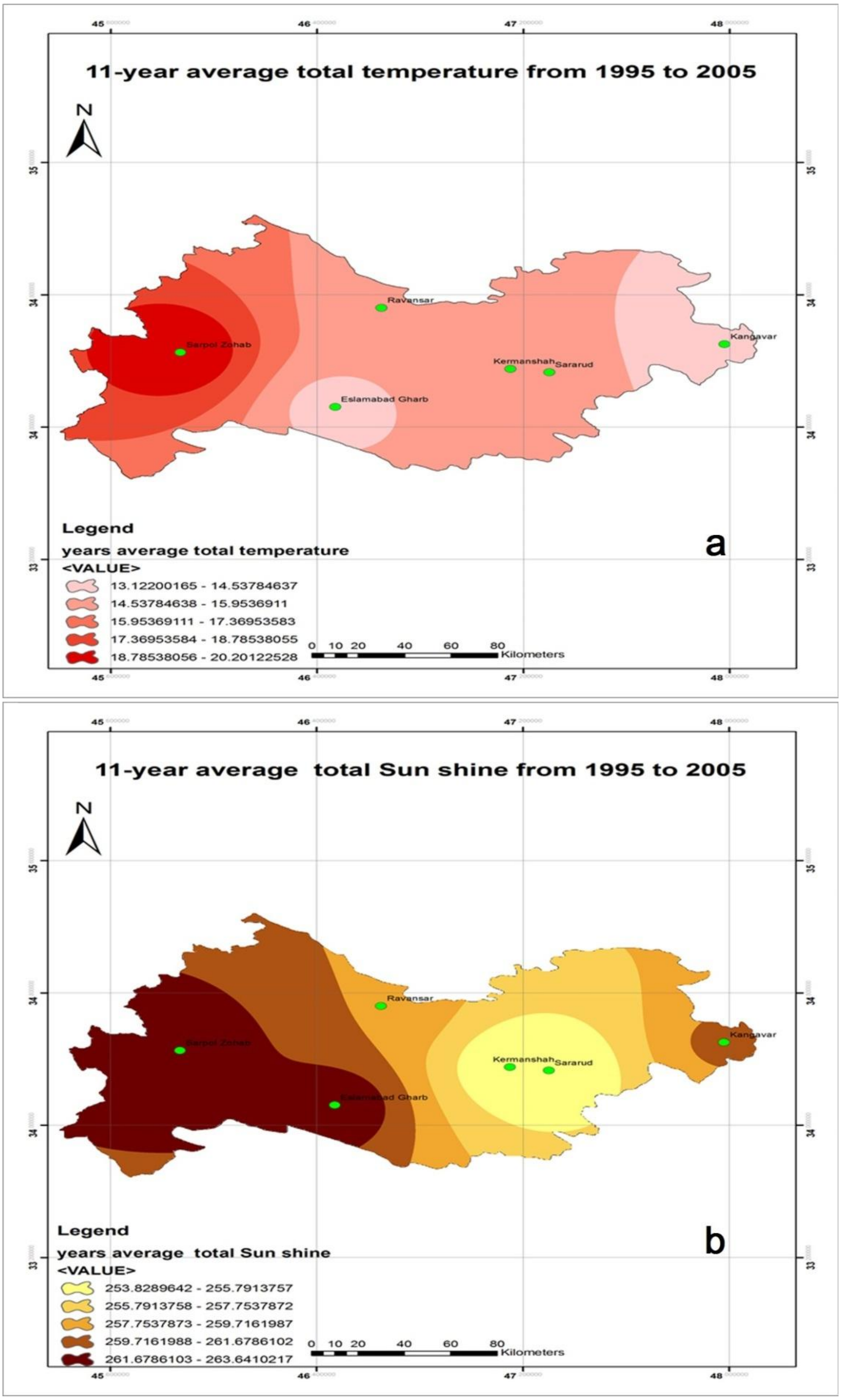

Fig.1. Kermanshah province maps: a) Temperature map in Kermanshah province in the eleven year period from 2005 to 1995; b) Radiation map in Kermanshah province in the eleven year period from 2005 to 1995

2.2. Modeling

In general, because solar cell is based on P-N junction, being exposed to light radiation, it can model a cell with diodes, which uses source flow instead of radiation [12].

In Fig.2a, the equivalent circuit of a polycrystalline silicon solar cell [13] is observed.

The curve *I-V* and *P-V* characteristics and effects series and parallel resistors on the performance of the solar cells [14] in Figure 2b are observed.

As shown in Fig.2b, increasing the series resistance adversely affects maximum power; therefore, a resistance of the lowest possible value (close to zero) is optimal [15]. The opposite is true for parallel resistance, whereby its reduction lowers the maximum power point; therefore, the greatest possible value of parallel resistance (close to ∞) is ideal [16]. According to what was mentioned in the introduction, the Maximum Power Point (MPP) dependence on temperature will be demonstrated in this simulation.

The MSX-64 solar panel is an upgrade of the basic MSX-60 model. Its functional improvements [17], as presented in Table 3, along with its associated costs in relation to other panels, are fundamental considerations for its selection.

The correlations between the maximum voltage point, V_{mp}, and intensity of the radiation, s, as well as ambient temperature, T, was established based on [18], [19]

$$V_{mp} = f(s, T). \tag{1}$$

Because the objective is to achieve the maximum values of the voltage and current (V_{mp} and I_{mp}) as based on Fig.2b and Table 3, relation

$$I_{pv} = I - I_0\left(e^{\frac{q(V+IR_S)}{\alpha kT}} - 1\right) \tag{2}$$

is derived.

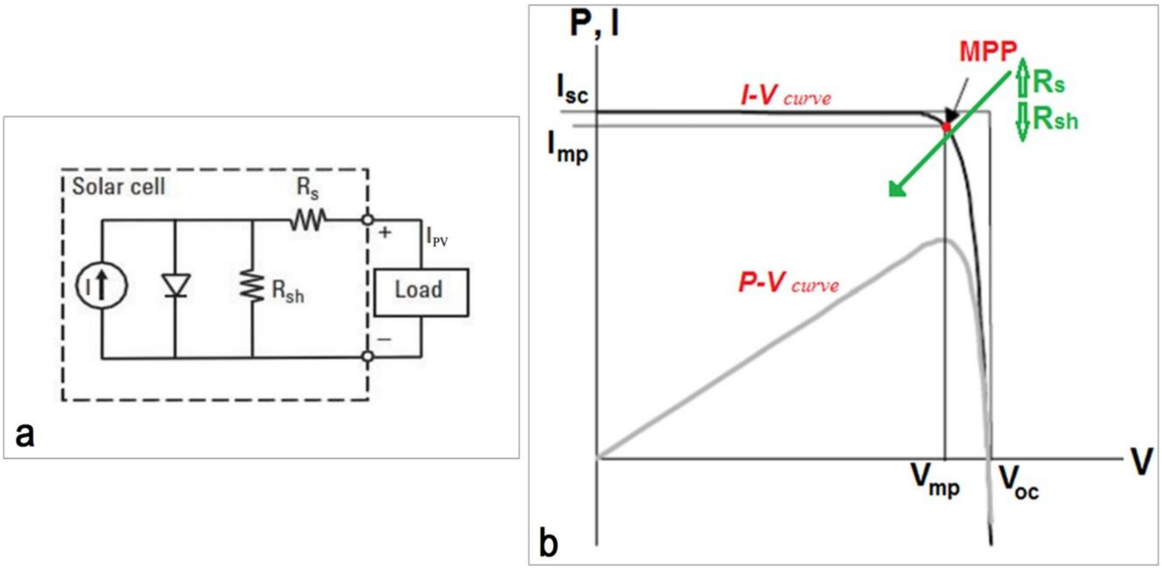

Fig. 2. Solar cell: a) equivalent circuit of a solar cell; b) I-V and P-V characteristic curves of a solar cell

Table 3. Characteristics of solar panel MSX-64

Data	value
Maximum power (P_{max})	64 W
Maximum voltage (V_{pm})	17.5 V
Maximum current (I_{pm})	3.66 A
Short circuit current (I_{sc})	4 A
Open circuit voltage (V_{oc})	21.3 V

Equation (2) [20] shows that the ideal output of a photovoltaic cell, denoted I_0, is the reverse saturation current of the diode. In applying Eqs. (1) and (2), a simulated model of the temperature and radiation is created. Note that D_I, C_1, C_2, and V_R are defined quantities used to simplify the final equation. That is

$$C_2 = \frac{\frac{V_{mp}}{V_{oc}} - 1}{Ln(1 - \frac{I_{mp}}{I_{sc}})} \tag{3}$$

$$C_1 = (1 - \frac{I_{mp}}{I_{sc}})(e^{\frac{-V_{mp}}{C_2 V_{oc}}}) \tag{4}$$

$$D_I = s\alpha(T - T_{ref}) + I_{sc}(s-1) \tag{5}$$

$$V_R = V_{pv} + \beta(T - T_{ref}) + R_s D_I \tag{6}$$

Coefficients α and β are defined according to the following equations:

$$\alpha = I_{sc} \times 0.0012 \tag{7}$$

$$\beta = V_{oc} \times 0.005 \tag{8}$$

Applying Eqs. (3), (4), (5) and (6) in tandem generates the conclusive equation:

$$I_{pv} = I_{sc}\,(1 - [C_1(e^{\frac{V_R}{C_2 V_{oc}}}) - 1]) + D_I \tag{9}$$

The simulation of the resulting system of equations is illustrated in the figure below.

Circuit blocks B, C, D, E, and F in Fig.3 of the simulated model are subsystems of the solar panel (Fig.3; block A). In this simulation, the input values are temperature and radiation intensity (Fig. 3; block A), and directly influence the I_{PV} output value (Eq.(9); Fig. 3; block F).

As previously mentioned, a change in the values of the four basic parameters I_{SC}, V_{OC}, I_{MP}, and V_{MP} will alter simulation results for each other panel (Fig. 3; block B). The values in effect for the MSX-64 panel simulation are listed in Table 3.

The simulation was executed with temperature values of 25 and 50 degrees Celsius and a radiation intensity of s=1 (1000 w/m^2). Once again the simulation was conducted, with a variation in radiation intensity, at values of s=0.5 and s=1 (500 and 1000 w/m^2 respectively) and a temperature of 25°C.

As seen through Eq.(1), temperature directly influences the performance of the

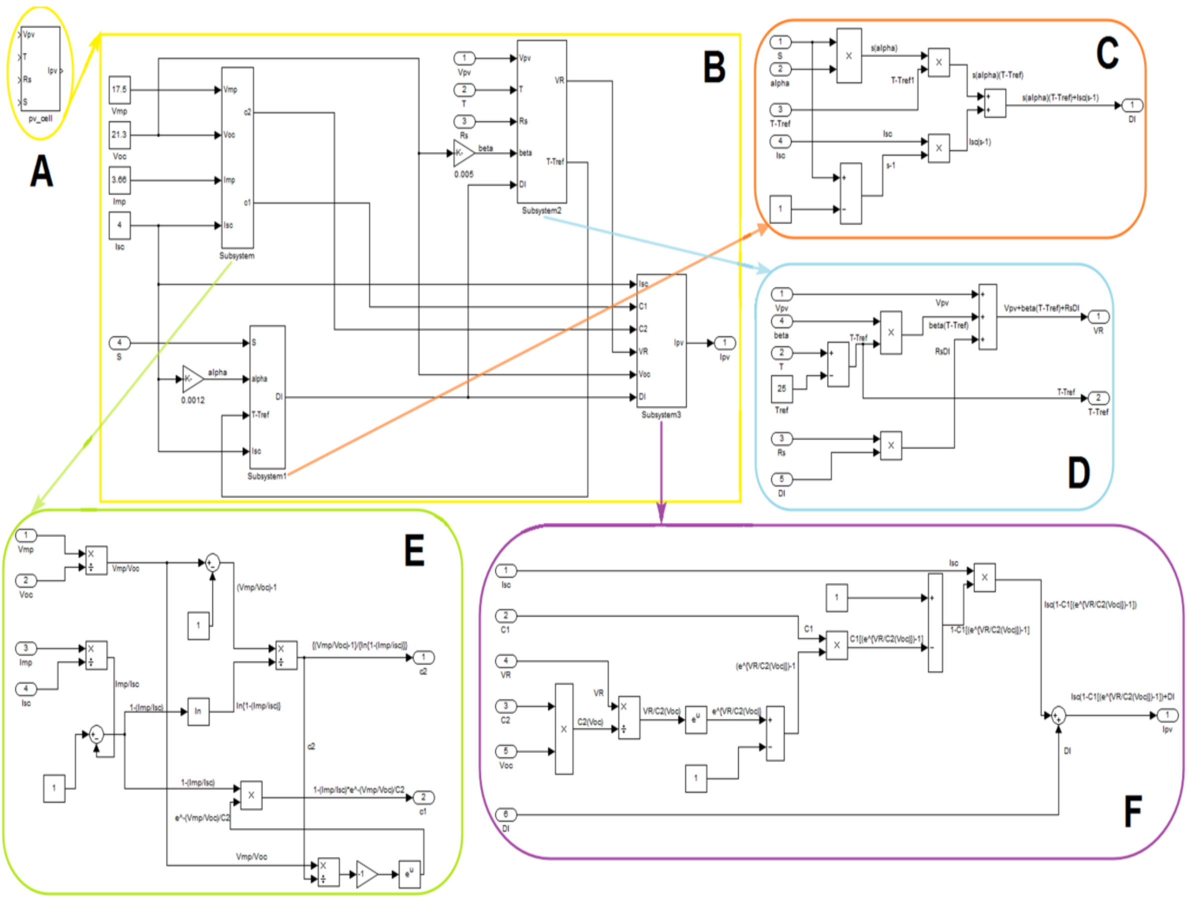

Fig. 3. Solar panel simulation using MATLAB software

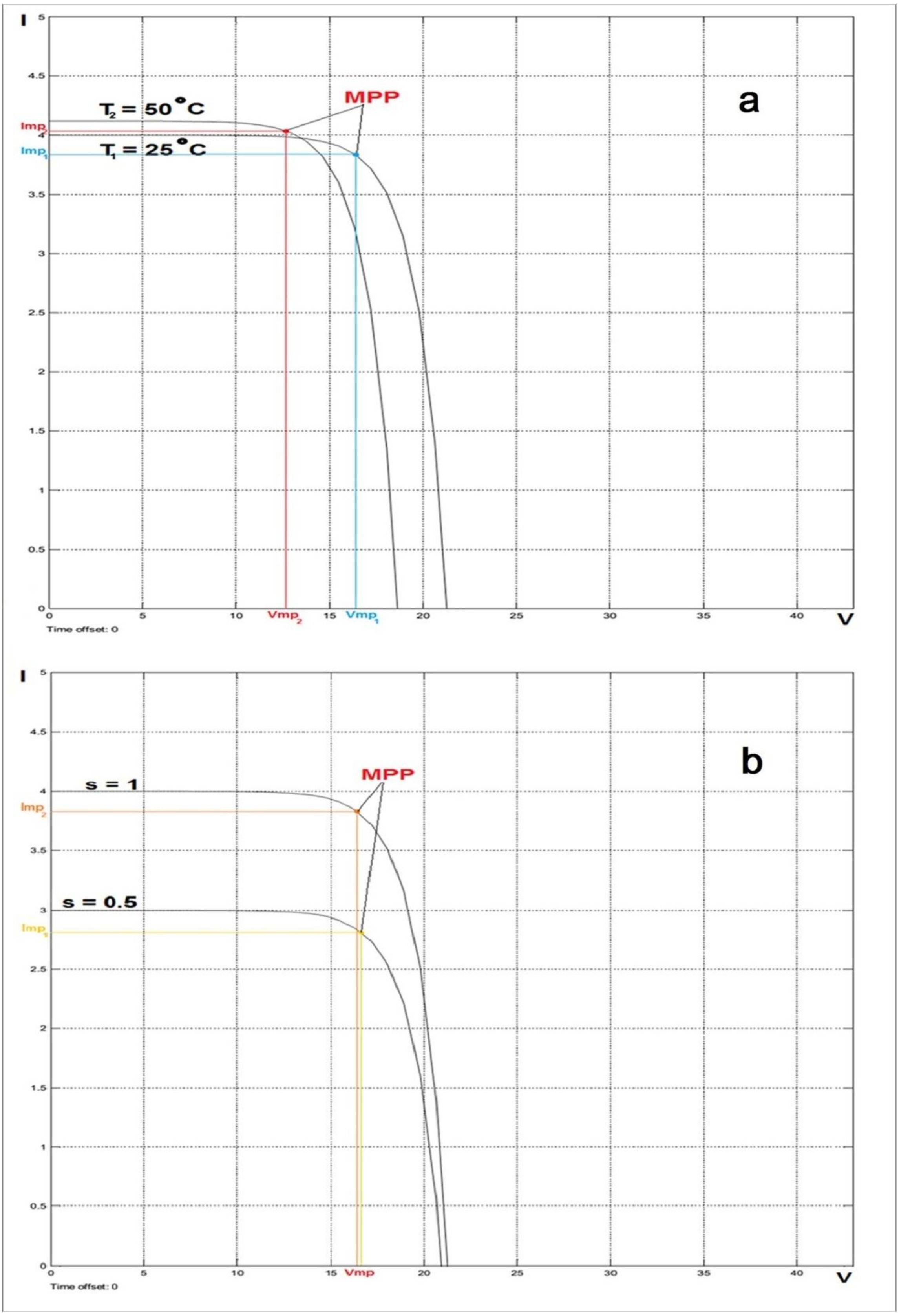

Fig. 4. Solar panel simulation: a) results at temperatures of 25°C and 50°C; b) results of simulated solar radiation at 500 and 1000 watts per square meter

solar panel. We expected that a temperature change would cause slight variations in I_{MP}, and substantial changes in V_{MP}. The end goal is to determine the peak performance level of the solar panel, which according to Fig.4a, is achieved at a lower temperature.

Equation (1) suggests that a change in radiation intensity has a major impact on the performance of a solar panel. Figure 4b shows that while these changes have no effect on V_{MP}, they greatly affect I_{MP}, which is the more influential variable on the maximum power point. Therefore, greater radiation intensity results in the improved performance of the solar panel.

2.3. Regression

While the temperature and radiation maps of Kermanshah and the results of the simulation as well as sunshine hours are major factors in the intensity of the radiation, with the establishment of the regression between temperature and the sunshine hours by using IDRISI software, the temperature can be calculated on the basis of the sunshine hours and the best location for the placement of solar panels can be determined in Kermanshah and run the simulation there.

Regression based on the regression Eq.(10) has been performed in Fig.5. In this regard, R represents the multiple correlation coefficients between the dependent variable and the independent variables. The value of apparent R in the regression equation is equal to 0.73 and R^2 which shows the variability of the dependent variable based on the independent variables, 54 percent of the station's temperature is demonstrated by the independent variable. The adjusted R and R^2 represent the amount of corrective effects related to the number of variables; these coefficients show modified complexity of the model. After adjusting the effects of the regression equation according to the number of variables, a significant change in the values of R and R2 cannot be seen.

In this regression equation, the following critical values to check significant review of the equation have been used. The regression coefficient has the F-statistic equal to 127765.53 at a significant level of 99% with degrees of freedom 3.0173= 105748, which suggests this equation is significant at 99% level.

T-test and ANOVA table are also in Fig. 5 where they can be observed. T-statistic and F-statistic combine the most common type of test to estimate the relative success of the model and the possibility to add or delete independent variables in the regression model. Coefficients indicate the separated effects of each independent variable over the dependent variables. The meanings of coefficients are expressed in the T-test. T-test reveals that each significative independent variable moves from zero (no effect) in the separated regression table where 72244 degrees of

Multiple Regression Results:

Regression Equation :

Temperature = 0.1167 + 0.5219* **Sun shine**

Regression Statistics :

Apparent R = 0.739692 Apparent R square = 0.547144
Adjusted R = 0.739692 Adjusted R square = 0.547144
F (1, 105748) = 127765.539063

ANOVA Regression Table

Source	apparent degrees of freedom	sum of squares	mean square
Regression	1	73458.62	73458.62
Residual	105748	60799.67	0.57
Total	105749	134258.28	

Individual Regression Coefficients

	Coefficient	t_test (105748)
Intercept	0.116748	38.275967
Temperature	0.521936	357.443054

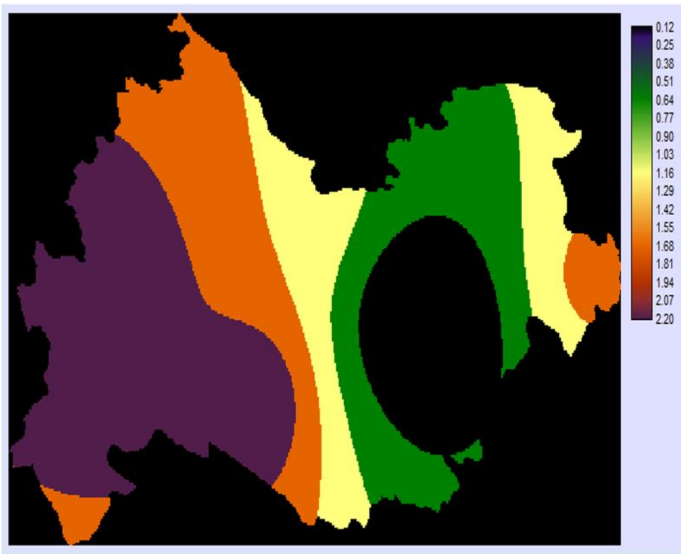

Fig. 5. Results of regression

freedom are listed. In this regression equation, the following critical values to check significative reviews of the equation were used. It has a significant level of 99% accuracy with 2.326= 105748 degree of freedom.

ANOVA table is used to show the acceptability of the model in statistical terms. Regression line in the ANOVA table shows the information about change in the model. Column mean square shows parts explained by the regression. These amounts are obtained from subtracting the sum of remaining squares out of the total sum of squares. Residual analysis could help us to feature the model which is identified in a specific area. Remnants of the positive value of the regression equation show that the model can predict values of temperature lower than the actual amount. That is

$$\textit{Temperature} = 0.1167 + 0.5219\ (\textit{Sun shine}). \quad (10)$$

3.Results and Discussion

Considering the regression results and the simulation outcomes, the most appropriate location for the placement of the solar panels are proposed.

Figure 6 indicates that prime locations for the solar panels are in Kangavar and West Islamabad. Based on Fig.7a and the results from Fig.7b, the environmental conditions of the prime locations have been investigated. The maximum power value of the MSX-64 panel is compared with the reference values in Table 3.

The average monthly temperature of the most favorable panel locations taken over the eleven-year period is 13.87 degrees Celsius, with minimum radiation intensity (yearly average during winter solstice) of 861 watts per square meter. The final results are displayed in Fig.7.

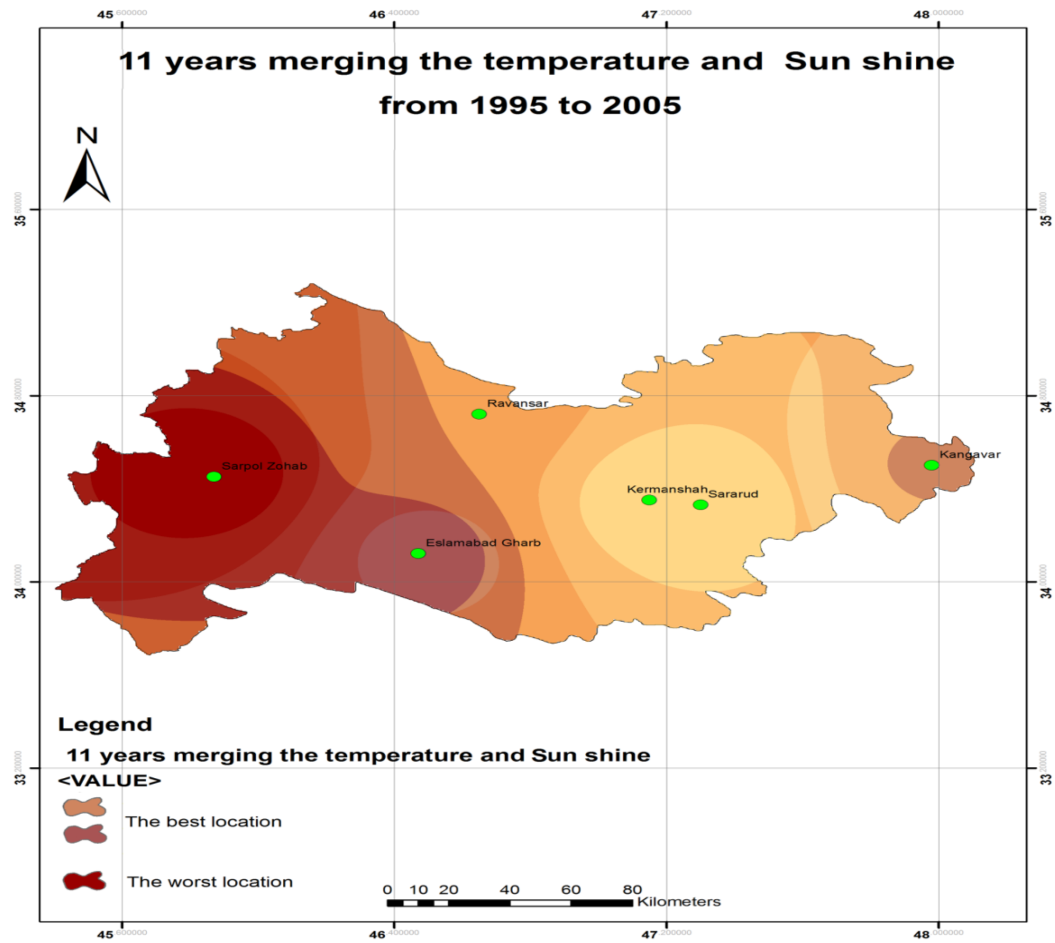

Fig. 6. Indicating the best geographical location for solar panels

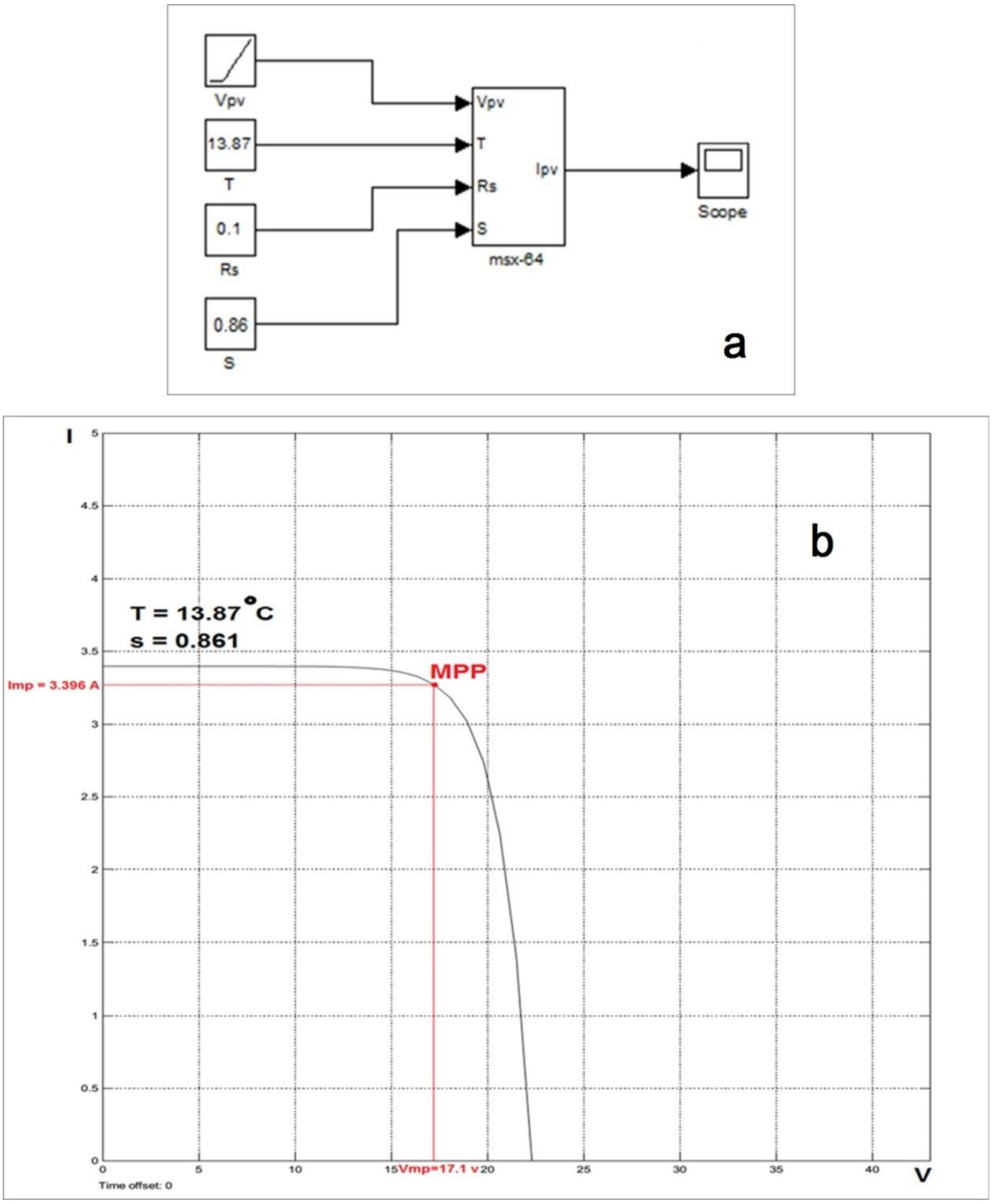

Fig. 7. Simulation: a) simulation of MSX-64 solar panel; b) I-V curves for maximum performance of the MSX-64 panel at the optimal location in Kermanshah Province

According to the *I-V* curve in Fig.7b, the maximum power point (MPP), established as the point of maximum voltage and current, was obtained at a V_{MP} of 17.1 volts, I_{MP} of 3.396 amperes and P_{MAX} of 58 watts.

4.Conclusions

The final result in terms of maximum power differs slightly from the 64 watt MSX-64 panel. Please note that the factor of greatest significance in regards to the decrease in power is the low level of radiation in the province of Kermanshah during winter solstice. We may get the better results if we have more parameters, for example, number of clear days, cloudy hours, or else. If any more parameters are added to the regression equation, it is subject to change and it will be better. We only have the permission to access two kinds of data during periods 1995 to 2005. Therefore, we were forced to choose specific temperature and sunshine hours for this research.

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