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An Easy Calculation Method for the Electricity Production by Solar Panels and its Applicability in Gaziantep

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Abstract: In this study an easy formulation method has been developed for electrical energy production by solar panels for pre-cost analysis. Moreover, this developed formulation method applied to Gaziantep City in the Southeast Anatolia of Turkey.

Key words: Solar energy, PV, solar formulation

INTRODUCTION

As fossil fuel prices have risen and concerns over greenhouse gases and global climate change have increased, alternative technologies for producing electricity have received greater attention (Darren and Boreland, 2008; Borenstein, 2000; Alanne and Saari, 2006). One of that is solar energy technology. Photovoltaic (PV) electricity is produced by direct conversion from sunlight. Markets for solar photovoltaic (PV) systems are expanding rapidly. World photovoltaic cell and module production increased in 2004 to 1195 MW representing a massive 57% increase on 2003 (716 MW). The PV cell and module production increased 65% to 602 MW in Japan in 2004. European production increased by 49% to 314 MW whilst in the United States production increased 35% to 139 MW. Elsewhere the balance of world production increased 67% to 140 MW (Maycock, 2005).

In Europe, especially in Germany, through generous financial support, has dramatically increased electricity production from renewable technologies. With an estimated share of about 14% of total electricity production in 2007, Germany has already significantly exceeded its minimum target of 12.5% set for 2010 (Frondel *et al*., 2008). In addition to this, 100.000 roofs in Germany and 70.000 roofs in Japan are the applications which plan on enlarging the market and increasing clean energy usage (Bahaj, 2002).

In the study, that was performed by averaging the meteorological observations between the years 1975-2008, the total maximum sunshine time of the months in Gaziantep City is 111.4; the daily maximum sunshine average time is 6.9 h; the intensity of maximum total monthly sunshine time (hour) is 438.03 (kcal m^{-2}) (http://www.dmi.gov.tr/index.aspx). The datasets used for this study were obtained from the archives of the Turkish Meteorological Service. The Gaziantep city located in the Southeast of Turkey has the geographic coordinates of 37°06'N latitude and 27°23'E longitude. Turkey is located between Europe and Asia. This geographical location makes it a natural land bridge connecting Europe to Asia. In 2003, the population of Turkey was 70.8 million, 26% over the 1990 level. The average population growth rate was 1.8% per year between 1990 and 2002, the highest among the International Energy Agency (IEA) member countries (Hamzacebi, 2007). Figure 1 shows Turkey annual average solar radiation map. Figure 2 shows average total monthly sunshine duration (hour/month) and Fig. 3 shows monthly average total solar intensity (cal cm^{-2}) of Gaziantep from 1975-2007.

A sample calculation has been performed with the assistance of this graphical data for a place. By choosing a system voltage of 220 VAC 50 Hz and an inverter with a sufficient power, a charge regulator in order to regulate the voltage between inverter and photovoltaic cell series, an battery in order to correspond the demand of electricity in case of absence of sun light (night or cloudy weather) in parallel with no energy output from photovoltaic modules and the diodes between the system supporter components except that system components, cabling, disconnection components, fuses, grounding components, overcurrent protection components and assemblage components have been used for this design. Figure 4 shows a diagram for a sample solar system. This system has been draft for 2-3 kWh daily energy consumption.

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Fig. 1: Annual average solar radiation in Turkey (http://repa.eie.gov.tr/MyCalculator/Default.aspx)

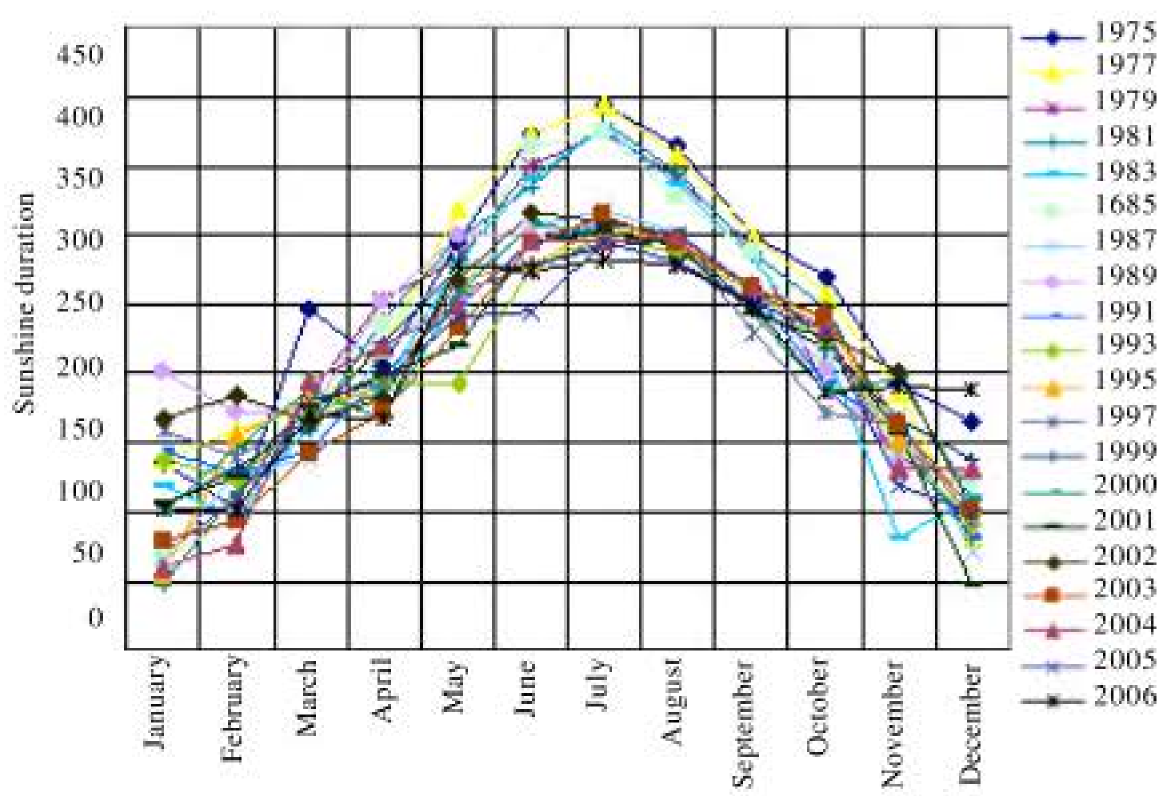

Fig. 2: The average total monthly sunshine duration (hour/month) of Gaziantep from 1975

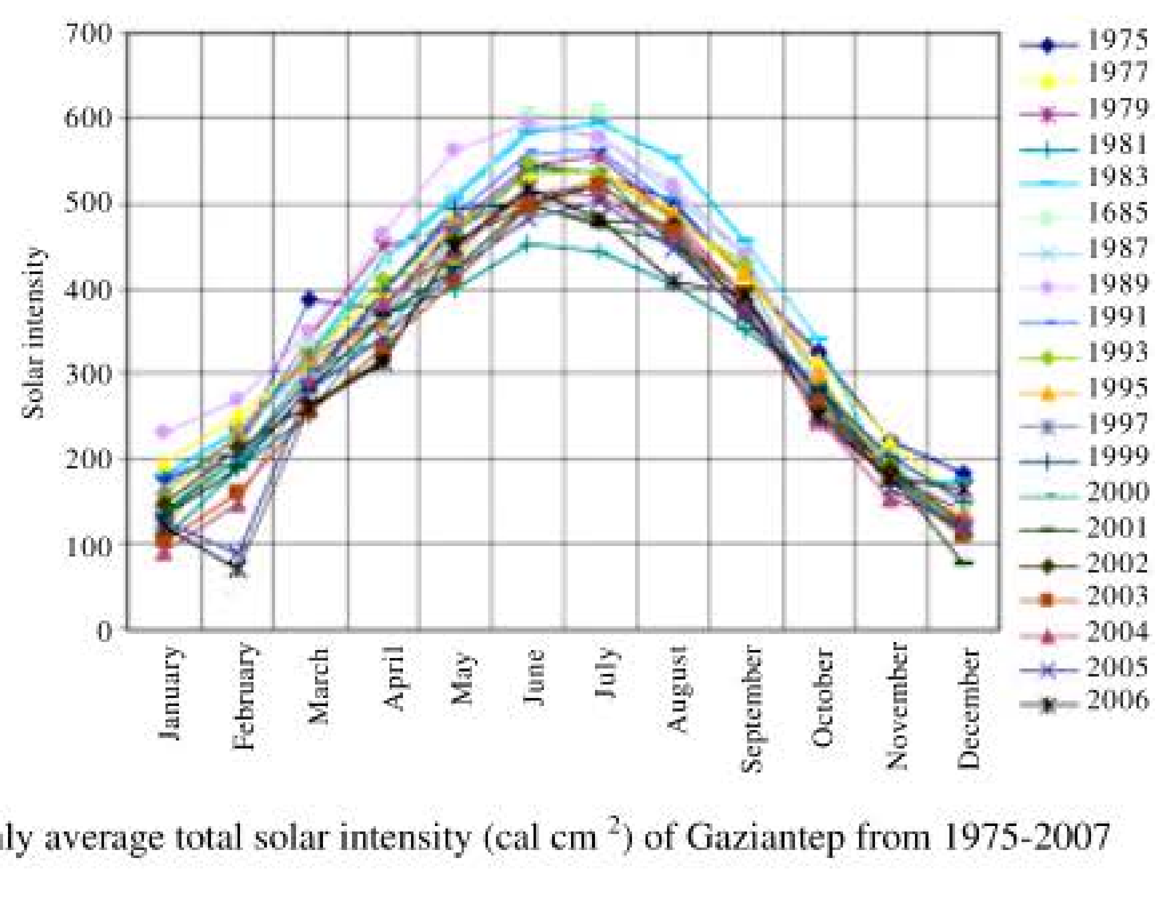

Fig. 3: The monthly average total solar intensity (cal cm ^{2}) of Gaziantep from 1975-2007

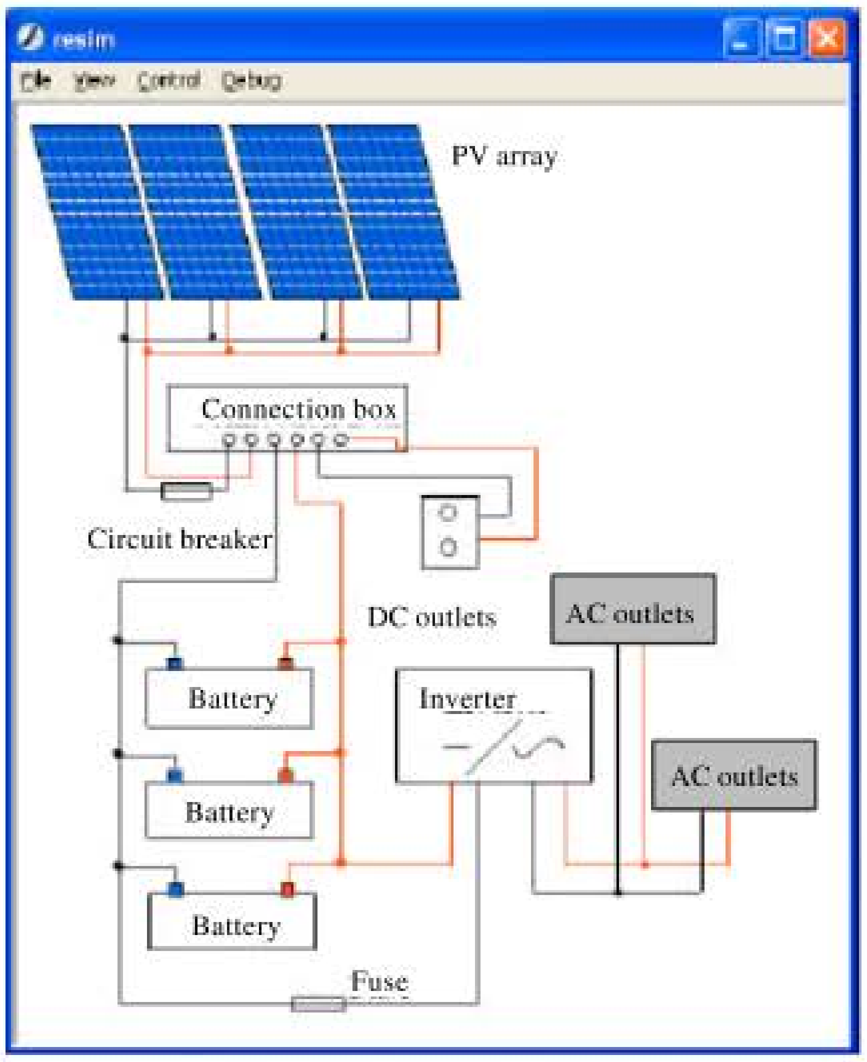

Fig. 4: The block diagram of a sample solar cell system

Solar cells are produced in the structure of monocrystalline, polycrystalline and CIS (copper-indium diselenid). Monocrystalline solar cells have the efficiency capacity of 20%. The production requires time and technique therefore they are expensive. Polycrystalline solar cells have the efficiency of 16%. Even though polycrystalline cells are not as good as monocrystalline ones in terms of quality and efficiency, they are the most-widely produced type because of their low cost and high efficient/cost ratio. The CIS-cells are one of thin layered solar cells. Classical solar cells (mono or polycrystalline thick layered cells) have a thickness of 180-350 μm, CIS ones have a thickness of 5 μm. By the reason of low cost due to the low layer and the efficiency of 10%, it is advantageous on several counts. The CIS is stable even if the presence of bad weather conditions because of its ability to use the bigger part of band with of the light (Chen *et al*., 2006; Ashhab, 2008; Kylie *et al*., 2001). In order to increase the power output a number of solar cells are connected together parallel or serially and they are installed on a surface and this structure is called solar cell module or photovoltaic module. By connecting parallel or serially, the system is formed from a few Watt to Mega Watt.

CALCULATIONS FOR SOLAR CELL

In the early days of photovoltaics, some 50 years ago, the energy required to produce a PV panel was more than the energy the panel could produce during its lifetime. During the last decade, however, due to improvements in the efficiency of the panels and manufacturing methods, the payback times were reduced to 3-5 years, depending on the sunshine available at the installation site. Today the cost of photovoltaics is around $2.5 US per watt peak and the target is to reduce this to about $1 US/W peak by 2020 (Kalogirou, 2009)

Table 1: The product description and technical information of solar cells

Cell type	Monocrystalline	Polycrystalline (PV)	CIS
Size of module (mm)	1202/536	1653/670	1256/656
Weight (kg)	7.60	13.2	13.7
Module type	LX-95 M/125-36 B	AC-150 P	AC-50 CIS
Max. power voltage (V)	100	1000	1000
Nominal power (Wp)	95	150	50
Nominal voltage (V)	19.12	20.18	20
Open circuit voltage (V)	23.40	24.16	26
Nominal current (A)	5.05	7.64	2.60
Short circuit current (A)	5.05	8.14	3.30
Cost ($)	449.00	760.00	200.00

Table 2: The sunshine time and the intensity for Gaziantep city

Sunshine time and intensity	Value
The average total monthly maximum sunshine duration (h)	111.40
Average daily sunshine duration hour (h)	6.90
Average monthly sunshine intensity (kcal m^{-2})	438.03

Solar cells are sold in the market considering their efficiency and quality. As to their sale price, it directly affects the redemption period and the energy quantity that can be obtained in a specific time period. In order to have many selections and a correct calculation, it has been calculated profiting from the average values of the solar panels of monocrystalline, polycrystalline and CIS. Table 1 shows the technical features of three different types of solar panels.

Table 2 shows the sunshine time fort he region that will be used in the calculations and the sunshine intensity that will determine the efficiency.

Firstly, it is necessary to calculate the installed power in order to determine the panel intensity and the region as well.

The average 2500 Wh energy demand of a house which is supposed to have a fridge, a washing machine, a dish washer, a computer, an iron, a toaster, a blower fan, a TV, a stereo and a hair dryer, can be calculated considering the weekly consumptions. After calculation of average power, the number of PV module and converter capacity can be calculated:

$$N_{Module} = \left(\frac{DED}{\eta_{System} \times \text{Module Power} \times H} \right) \tag{1}$$

$$N_{Module} = \left(\frac{2500\ \text{Wh}}{0.85 \times 150\,\text{W} \times 6.9\ \text{h}} \right) = 2.84 \cong 3\text{Polycristalline Module}$$

$$N_{Batt} = \left(\frac{DED}{\eta_{Batt} \times V_{Batt} \times C_{Batt}}\right) \quad (2)$$

$$N_{Batt} = \left(\frac{2500Wh}{0.90 \times 12V \times 190Ah}\right) = 1.21 \cong 2$$

$$C_{Converter} = \left(\frac{DED}{\eta_{Converter} \times H}\right) \quad (3)$$

$$C_{Converter} = \left(\frac{2500Wh}{0.90 \times 6.9h}\right) = 402.57VA$$

where, DED is daily energy demand, η is efficiency, V_{Batt} is battery voltage, C is capacity, N is number of unit and H are the average daily sunshine duration hours.

System converter loss is 10% of converter capacity; pollution loss is 3% for Turkey. Table 3 shows average cast analysis.

Where:

$$\sum Loss = (C_{Converter} \times 0.1) + (\text{Panel Power x } 0.03 \times N_{Module}) \quad (4)$$

$$\sum Loss = (402.57 \times 0.1) + (150 \times 0.03 \times 3) = 53.757W$$

Solar panels are the materials that can stand 20 years (Medvedovski *et al*., 2008). In cost analysis, installation cost is added to total twenty years costs. The approximate electrical energy that will be produced in those twenty years is determined. As a result, if the costs are divided by energy then unit cost is reached. If we make a cost calculation considering only the hours with sunlight then in that region which face the sunlight daily total 6.9 h:

$$\sum Cost = InstallationCost+BatteryCost+Maintenance \quad (5)$$

$$\sum Cost = 3186 + (4 \times 135) + (20 \times 10) = 3926\$$$

The approximate total energy in 20 years = Daily energy×365×No. of years

The approximate total energy in 20 years = 2500 Wh×365×20 = 18250 KWh

$$\text{Unit cost} = \frac{\text{Expenses}}{\sum \text{Productions}} \quad (6)$$

$$\text{Unit cost for monocrystalline panel} = \frac{3926}{18250} = 0.21\$$$

$$\text{Unit cost for polycrystalline panel} = \frac{3968}{18250} = 0.217\$$$

$$\text{Unit cost for CIS panel} = \frac{3926}{18250} = 0.18\$$$

Table 3: Average cost analysis

Equipment name	Monokristalin	Polikristalin	CIS
Solar panel	5 unit 2245 $	3 unit 2280 $	9 unit 1800 $
Battery	2 unit 135 $	2 unit 135 $	2 unit 135 $
Converter	1 unit 110 $	1 unit 110 $	1 unit 110 $
Battery charger	1 unit 165 $	1 unit 165 $	1 unit 165 $
Installation account	531 $	538 $	442 $
Total	3186 $	3228 $	2652 $

Table 4: TEDA^s yearly tariff prices (TL/kWh) and the increment per cent during the year (http://www.tedas.gov.tr/17,Tarifeler_Index.html)

Years	Unit price (TL/kWH)	Accrual (%)
1998	13,090 (0.14 $)	
1999	20,730	58
2000	37,430	80
2001	52,060	40
2002	129,750	149
2003	182,025	40
2004	217,900	19
2005	127,800	58
2006	172,000	34
2007	216,100	25
2008	272,500 (0.18 $)	26
Exchange ratio	--------	2000 for Turkish Liras

The result derived over here belongs to only the daily energy gained under sun light. In fact, in a real implementation, it has been observed that even at times deprived of sun light, panels can produce energy with an efficiency of 30%. Especially, in summer which has long lasted days, the significant raise on energy quantity produced is unavoidable. The unit cost of this calculated region will be highest 0,21 $. Besides, it is predicted that in 10 years there will be important decreases on thin film solar panel unit cost production (Darren and Boreland, 2008). If this prediction becomes real, solar panel will take up an important place in electrical production. In order to realize whether that result is available or not, we are in a state to examine the tariff applications of TURKIYE ELEKTRIK DAGITIM A.S. (TEDAS) by years and compare the obtained result. Table 4 shows the yearly tariff prices according to the abodes and the increment percent during the whole year.

If we consider the prices from European currency unit, we will conclude that the unit prices of panels are higher at the present time. But, if we take the price increase through the years and the energy consumption of the panels beyond daily sunshine into consideration, it can be seen that even the developing solar panel systems are advantageous. Besides, a further very important advantageous of this system is its being unaffected from markups and energy cuts.

CONCLUSION

In this study an easy calculation method improved for generate electrical energy from PV. The method apply to Gaziantep suggests that correctly accounting for the electricity production of solar panels. It is suitable result obtained from the calculation. This calculation shows Gaziantep is suitable cities for solar energy implementations.

In relation to the redemption calculation, considering the rises in the future the solar cells with 20 year life time, can depreciate the whole investment in 10 years and it occurs to be a profitable investment for 10 years. This is important and easy method that from a practical approach, the PV system efficient and cost analysis.

REFERENCES

Alanne, K. and A. Saari, 2006. Distributed energy generation and sustainable development. Renewable Sustainable Energy Rev., 10: 539-558.

Ashhab, M.S.S., 2008. Optimization and modeling of a photovoltaic solar integrated system by neural networks. Energy Convers. Manage., 49: 3349-3355.

Bahaj, A.S., 2002. Means of enhancing and promoting the use of solar energy. Renewable Energy, 27: 97-105.

Borenstein, S., 2000. Understanding competitive pricing and market power in wholesale electricity markets. Electricity J., 13: 49-57.

Chen, Z., Y. Tang, L. Zhang and L. Luo, 2006. Electrodeposited nanoporous ZnO films exhibiting enhanced performance in dye-sensitized solar cells. Electrochimica Acta, 51: 5870-5875.

Darren, M.B. and M. Boreland, 2008. Photovoltaic technologies. Energy Policy, 36: 4390-4396.

Frondel, M., N. Ritter and C.M. Schmidt, 2008. Germanys solar cell promotion: Dark clouds on the horizon. Energy Policy, 36: 4198-4204.

Hamzacebi, C., 2007. Forecasting of Turkeys net electricity energy consumption on sectoral bases. Energy Policy, 35: 2009-2011.

Kalogirou, S.A., 2009. Solar Energy Engineering Processes and Systems. 1st Edn., Academic Press of Elsevier, USA., ISBN: 978-0-12-374501-9.

Kylie, R.C., J.M. Michelle, K.J. Weber and A.W. Blakers, 2001. A review of thin-film crystalline silicon for solar cell applications. Part 2: Foreign substrates. Solar Energy Mater. Solar Cells, 68: 173-215.

Maycock, P.D., 2005. PV review: World solar PV market continues explosive growth. Refocus, 6: 18-22.

Medvedovski, E., N. Alvarez, O. Yankov and M.K. Olsson, 2008. Advanced indium-tin oxide ceramics for sputtering targets. Ceramics Int., 34: 1173-1182.