Energy Analysis of a High Speed Train Set Supplemented With a Photovoltaic Power System

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Abstract

A photovoltaic power system mounted on the whole outer surfaces of a high speed train set and energy analysis related to the system have been studied in this model. In the considered model, flexible photovoltaic solar modules with high efficiency have been mounted fully on the surface of train set in order to get optimum power from incident sunlight. At the end of this photovoltaic mounting it is expected that the needed energy for lighting and/or air conditioning of the train set can be supplemented fully or partially with this photovoltaic application. As a conclusion energy analysis concerning the amount of Turkey's annual average solar radiation, installation cost and depreciation of the system have been discussed in this work.

Keywords: Energy Analysis, High Speed Train, Solar Energy, Solar Cells

1. Introduction

Solar cells are getting more important day by day and also they are finding new industrial applications. As it is known that electricity from solar energy is provided by only solar cells. Sun is also the main source for these applications. Our country has an important place in the world in terms of average solar power of 290 W/m^2 per year [1]. Meanwhile, significant studies of local and global solar radiation of Turkey have been studied [2,3,4]. Referring to studies in recent years, it is seen that the solar panels have been used in many different areas. These applications varies from electric power plants to vehicle applications. Especially, new trend cars with solar panels or hybrid structure have been seen rarely. It has recently been seen that solar cells have been implemented in a number of vehicles [5,6,7,8]. The application of solar cells for high speed train is a fairly new study. Literature survey shows that solar panels have either been mounted on the ceiling of railway carriages or layed next to railway [9]. But either of them seems as a quite new work. Placing the solar panels with the efficency of 13% on the ceiling of TVS 2000 passenger coaches, energy generation capacity and the units that can be supported such as lighting and also air conditioning systems were examined in an earlier study on this application [10]. In the mentioned study, it has been seen that outer ceiling surface only have been coated by the solar panels. But, a high speed train set has been utilized as a main model instead of TVS 2000 passenger coaches in this study. Whole outer surface area of the train has been coated by the flexible solar panels having 16.44 % efficiency.

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2. Materials and Method

In this work, the performance of solar power system mounted on the high speed train set has been examined in the developed model. In the considered model, outer surface areas of the side walls and the ceiling have been concerned as a whole surface. In the study, the solar panels having 16.44 % efficiency have been utilized, but if solar panels made of GaAs are preferred, the total yield of the photovoltaic system will increase 4% more. However, in this case the installation costs will increase more slightly. The figures given below illustrate the considered high speed train sets with and without the efficient solar panels.

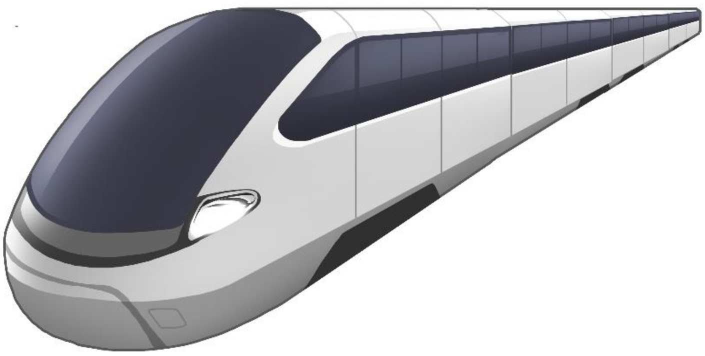

Figure 1. Illustrates a high speed train set considered in the model.

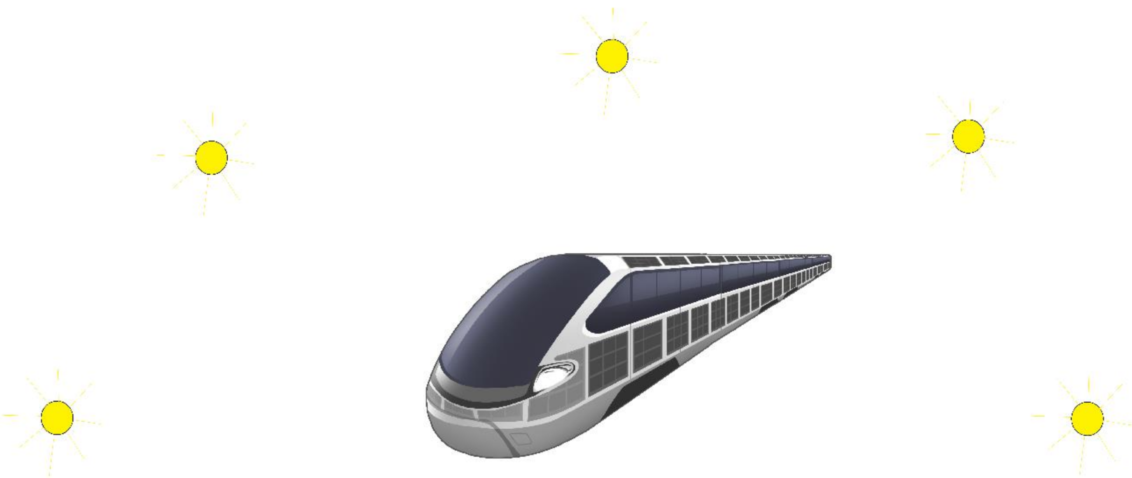

Figure 2. Illustrates a high speed train set mounted by solar panels.

In this study, high efficient, flexible and a commercial solar cell has been chosen for the surface application of a high speed train set. The electrical parameters of the solar cell chosen for this study are given as follows [11] ;

Electrical production parameters of the solar panel:

V P (V) = 18.56
The P (A) = 8.16
P (watts) = 151.45
VCA (v) = 20.80
ICC (I) = 8:45
Efficiency = 16.44 %

Two important cases are emerging with the implementation of solar panels to high-speed trains. The first one is the change of the incident angle of solar radiation according to the seasons and second one is also the change in the effective projection area of the train surface. Calculations related to the outer surface area of the train were done according to the assumption, the related values are as follows;

Outer surface area of a wall without window of the train set: 550 m^2,
Outer ceiling surface area of the train set: 460 m^2,
Total outer surface area (ceiling+a wall): 1100 m^2,
Effective surface area of the train (ceiling+ a wall) according to incident solar light flux: 811 m^2

The considered assumption depends on the situation of the side walls and the ceiling which are perpendicular to each other and also on the position of the sun in motion. Another important point in the calculation to be considered is that the whole surface of the panels must be kept clean during the study. Because the performance of the panels is affected negatively by the surface contamination.

3. Results

Turkey is the best country in Europe in terms of the average amount of solar radiation. The amount of the solar radiation increases towards the South. A map showing Turkey's solar energy potential is given in Figure 3.

Figure 3. Illustrates the map of Turkey's solar energy potential [12].

Monthly solar energy values of Turkey's different cities are also given in Table 1. As seen from Table 1, the values vary considerably from city to city.

Table 1. Monthly solar energy values related to Isparta, Erzincan, Yozgat, Balıkesir and Ankara [12].

Months	Isparta (Wh/m²)	Erzincan Wh/m²)	Ankara Wh/m²)	Balıkesir Wh/m²)	Yozgat Wh/m²)
January	1541	2582	1460	1588	1317,616
February	1759	3567	2412	1801,45	1881,111
March	2060	4398	3724	3228,87	3514,4
April	3825	4710	4789	4708,32	3980,427
May	4035	6121	6280	6348,24	5166,213
June	7726	7685	6964	7424,47	5132,015
July	7708	8005	7124	7366,15	5265,12
Agustos	7003	6263	6287	6869,68	5505,827
September	5870	5110	4538	4817,82	5230,232
October	3731	3911	3095	3189,50	2790,659
November	2436	2611	2179	2006,32	3047,264
December	1973	1617	1241	1226,73	1022,485
TOTAL	49,667	56580	50093	50575,5	39853,36

At the same time, Turkey's Total Annual Regional Distribution of Solar Energy Potential is given in Table 2. Meanwhile, when Table 2 is carefully examined it has been seen that not only amount of total solar energy is increasing, but also sunshine duration is increasing significantly from North to South.

Table 2. Turkey's Total Annual Regional Distribution of Solar Energy Potential [13].

Regions	Total Solar Energy (kWh/m^2-year)	Sunshine Duration (hours/years)
Southeastern Anatolia	1460	2993
Mediterranean	1390	2956
East Anatolia	1365	2664
Central Anatolia	1314	2628
Aegeon	1304	2738
Marmara	1168	2409
Black Sea	1120	1971

Taking into the consideration of the data given in Table 2, some significant values related to performances of the system were estimated in Table 3. In the calculation, 1kwh electricity was regarded as 0.4 TL and also the efficiency of the solar panels given before which is η: 16.44%.

Table 3. The performance and gain values of the system mounted on the fast train which will run in the seven different regions in Turkey.

Regions	Total effective surface area of the train (m^2)	The amount of solar energy received by whole surface area of the train (kWh/year)	Gain (Euro)
Southeastern Anatolia	811	1.184.060	25.954
Mediterranean	811	1.127.290	24.710
East Anatolia	811	1.107.015	24.265
Central Anatolia	811	1.065.654	23.359
Aegeon	811	1.057.544	23.181
Marmara	811	947.248	20.763
Black Sea	811	908.320	19.910

The position of sun in motion and also weather status are very important to get optimum power from the system.

4. Discussion

In this study, a solar cell application on the whole surface of a high speed train set has been considered in a model. According to this model, this application causes a capacity of 147 kW and also leads to 793000 Euro installation cost. At the end of this study, it is expected that all of the energy required for the entire lighting system and majority of the energy required for air conditioning system of the high speed train will be provided by the solar panels. If the train runs in the region of South Eastern Anatolia, the system will provide 30.000 Euros gain, if it runs in the region of Black Sea, it will provide about 20.000 Euros gain in a year as well. Because the current solar cells are still quite expensive, the depreciation of the system will take some time.

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