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TECHNICAL AND ECONOMIC ANALYSIS OF SOLAR PANELS USED VERTICALLY AND AT AN ANGLE IN AGRICULTURAL FENCING APPLICATIONS

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Abstract

Turkey is more advantageous than many countries in terms of solar radiation intensity and sunbathing time due to its location. However, costs such as land, transportation, security, etc. required for the establishment of solar power plants increase the total cost. For this reason, the use of solar panels as a fencing system in agricultural areas offers some advantages. The vertical or angled positioning of the solar panels according to the terrain conditions has a significant effect on both the investment cost and the amount of electricity generated. In this study, the technical and economic analysis of the solar panels to be used as a fence on the border of the Faculty of Engineering campus of Trakya University with 90° and 32° angles is investigated using the PV sol software. The investment cost of the fencing application was determined to be 3.726.000TL depending on the installed power of the designed solar energy system, the characteristics of the system components, and the location. Analyzing the simulation results, the payback period is 7 years if the solar panels are positioned at 90° and 6.2 years if the tilt angle of the solar panels is 32°. It can therefore be seen that the tilt angle of the solar panels in the location where they are installed in agricultural fencing applications is effective in terms of the amount of energy produced and the payback period.

Keywords: energy, solar panel, fence, technical analysis

INTRODUCTION

Energy is one of the most basic needs of society. From the past to the present, the use of carbon-based fuels such as fossil oil and natural gas has continued. It is well known that the increased use of these fossil fuels worldwide has led to a decrease in fossil resources and an increase in pollutant emissions into the environment. In addition, the increasing demand for energy as the population grows is causing economic problems. As a result, interest in energy diversity and renewable energy is growing in many countries. However, in the installation of solar power plants, the performance of the system varies depending on the climatic characteristics, design features, and operating conditions depending on the geographical location. On the other hand, large areas are needed to install solar power plants at a level that reduces fossil fuel consumption [1-3]. The energy conversion efficiency to be achieved by solar power plants varies depending on the environmental conditions and the design features of the system [4-7]. As there is a limit to the impact of any energy source and renewable energy production, energy efficiency becomes more important depending on the system installation. For this reason, it is of great benefit to carry out analyses such as initial investment cost, energy production, and payback period before installing solar power systems.

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Recently, the use of fencing with photovoltaic panels as solar power plants has become trendy due to the reduction in land costs required for installation; In order to determine the applicability of fence-based solar panels across the USA, analyses were performed using the Python program to determine the number of PV modules between vertical fence posts according to wind loads. The results were used to determine the pole spacing required for agri-voltaics in areas where sheep, goats, pigs, and cows are present [8]. A study carried out in Europe on the reduction of environmental impacts in an agricultural PV application scenario found that environmental impacts can be reduced both in terms of electricity production and in some categories. It was also emphasized that further studies are needed and that it is important to investigate the hot spots in the module in PV production [9].

In another study, the power output of vertically positioned bifacial PV panels using reflective mirrors was investigated. The PVsyst simulation software was used to analyze the increase in power generation over one year. It was observed that the reflected radiation on the PV modules increased by a factor of 10 with the mirrors used in this application. For a 10 kW bifacial system using reflective mirrors, a 51% increase in power output was achieved. With this approach, it is stated that reflective mirrors can be used to increase the power generation capacity of vertical PV modules in fence-type applications [10].

In this study, unlike the literature, the effects of vertical positioning of PV panels with 90° and 32° angles in the fencing application to be applied at the border of the campus of Trakya University Engineering Faculty have been compared. By determining the design parameters, the aim is to analyze the electrical energy production and payback period of the system using the PV Sol program.

EXPOSITION

On the campus of Trakya University's Faculty of Engineering, the location of which is shown in Figure 1, a solar panel fence is to be used to both generate electricity and define the boundaries of the site. The solar panels to be used in the fence design are of the CW energy brand and consist of 66 monocrystalline cells. The technical specifications of the solar panel and inverter to be used in the system are shown in Table 1-2. According to the site information available for the design, the solar panels are firstly applied vertically and then the ideal PV panel tilt angle for Edirne province is 32°. The investment cost, electrical energy production amount and payback period of the system to be installed are analyzed in the PV sol simulation program.

Fig. 1. *Location*

The fence application, comprising solar panels, was modeled on the boundary area delineated by a yellow line on the land depicted in Figure 1.

Table. 1. *PV Module Data Sheet.*

Manufacturer	CW Energy Eng. Trade and Industry Ltd. Şti.
PV Module:	CWT690-132TNB12-V (v1)
Cell Type	Si monocrystalline
Cell Count	66
MPP Voltage	39.9 V
MPP Current	17.29 A
Open Circuit Voltage	46.5 V
Short-Circuit Current	18.37 A
Voltage in MPP at Part Load	37.71 V
Current in MPP at Part Load	3.46 A
Open Circuit Voltage (Part Load)	41.86 V
Short Circuit Current at Part Load	3.67 A
Width	1303 mm
Height	2384 mm
Depth	35 mm
Frame Width	30 mm
Weight	34.5 kg

The technical specifications of the photovoltaic panel selected in the fence design are given in Table 1.

Table. 2. *Inverter Data Sheet.*

Manufacturer	Huawei Technologies
Model	SUN2000-36KTL-M3
DC nominal output	40.65 kW
Max. DC Power	73.2 kW
Nom. DC Voltage	600 V
Max. Input Voltage	1100 V
Max. Input Current	104 A
Max. short circuit current	104 A
Number of DC Inlets	8
AC Power Rating	36 kW
Max. AC Power	40 kVA
Nom. AC Voltage	230 V
Number of Phases	3
With Transformer	No
Max. Input Current	26 A
Max. short circuit current	26 A
Max. Input Power	18.3 kW
Min. MPP Voltage	200 V
Max. MPP Voltage	1000 V

The specifications of the inverter to be used in the system installation are given in Table 2 in detail.

Table. 3. *Set-up of the System*

Type of System	Grid-connected PV System
Location	Edirne, TUR (2001 - 2020)
Manufacturer	CW Energy Eng. Trade and Industry Ltd. Şti.
PV Modules	180 x CWT690-132TNB12-V (v1)
Values source	Meteonorm 8.2(i)
Resolution of the data	1 h
Diffuse Irradiation onto Horizontal Plane	Hofmann
Irradiance onto tilted surface	Hay & Davies
Inclination	90° and 32°
Orientation	South 200°
Installation Type	Mounted - Open Space
PV Generator Surface	559.1 m²

The technical details used in the system setup and simulation software are given in Table 3.

RESULTS

After the details of all system components required in the fence application design are entered into the PV sol software, the results obtained are presented in tables and graphs. The results obtained when the tilt angle of the photovoltaic panels is applied as 90° and 32° are given in Table 4.

Table. 4. *Simulation Results.*

Inclination	**90°**	**32°**
PV Generator Output (kWp)	124.20	124.20
Spec. Annual Yield (kWh/kWp)	958.70	1489.20
Performance Ratio (PR)	62.14	86.12
Grid Export (%)	119143	185030
Grid Export in the first year (incl. module degradation) (kWh/Year)	119143	185030
Standby Consumption (Inverter) (kWh/Year)	72	71
CO_2 Emissions avoided (kg/year)	55963	86931

When Table 4 is examined, it is seen that better results are obtained if the PV panel tilt angle is 32°.

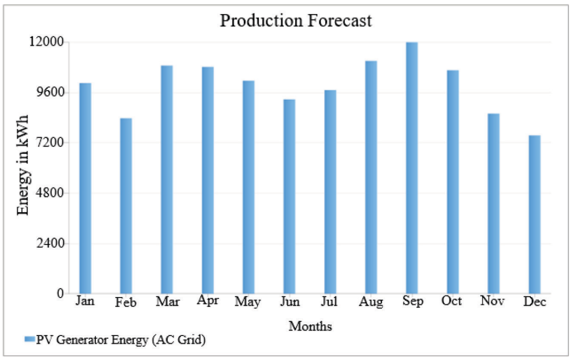

Fig 2. *Monthly energy production forecasts when the tilt angle of the photovoltaic panels is 90°.*

When Figure 2 is examined, it is seen that the highest energy production occurs in September if the photovoltaic panels are applied with a tilt angle of 90° in the fence design. When the simulation results are analyzed, a maximum of 12.000 kWh of energy production is predicted in September.

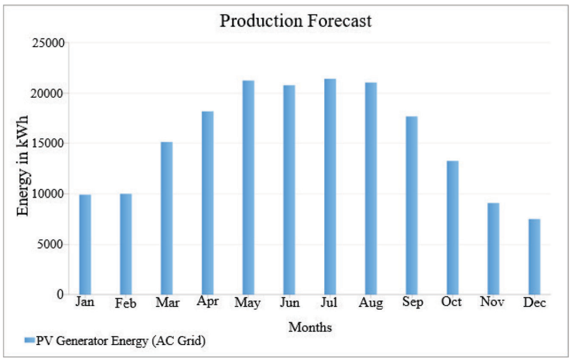

Fig 3. *Monthly energy production forecasts when the tilt angle of the photovoltaic panels is 32°*

Analyzing Figure 2, it can be seen that the use of photovoltaic panels in the fence design with a tilt angle of 32° gives much better results than the energy production values obtained with a tilt angle of 90°. On the other hand, in the application of the photovoltaic panel tilt angle of 90°, a maximum of 12.000 kWh energy is obtained, while when the tilt angle is 32°, it is seen that energy production will be over 15.000 kWh in March, April, May, June, July, and August. In addition, when the tilt angle is 32°, a maximum of 20.000 kWh of energy is produced in July and August.

The results of the financial analysis based on the simulation results are presented in Table 5.

Table. 5. *Financial Analysis.*

Inclination	**90°**	**32°**
Grid Export in the first year (incl. module degradation) (kWh/Year)	119143	185030
PV Generator Output (kWp)	124.2	124.2
Start of Operation of the System	1.07.2024	1.07.2024
Assessment Period (Years)	20	20
Internal Rate of Return (IRR) (%)	66,24	71.21
Amortization Period (Years)	7	6.2
Electricity Production Costs (₺/kWh)	1.7341	1.1163
Investment Costs (₺)	3 726 000	3 726 000
Total Payment from Utility in First Year (₺/Year)	31 186.95	48 975.61

When analyzing Table 5, it can be seen that the 32° tilt angle of the photovoltaic panel in the fencing application provides a significant increase in energy production and cash flow. According to the data obtained from the simulation results, it is clear that photovoltaic panels should not be used in the vertical (90°) position in the fence design under the current conditions.

CONCLUSION

In this study, the technical and economic analysis of the solar panels to be used as 90° and 32° angled fence on the boundary of Trakya University Engineering Faculty campus has been completed. The investment cost of the designed solar fence application was determined to be 3.726.000TL When analyzing the simulation results, it is found that the payback period is 7 years when the solar panels are positioned at 90°, while the payback period is 6.2 years when an inclination angle of 32° is applied. On the other hand, considering that the evaluation period and lifetime of the system is 20 years, it can be seen that the tilt angle at the location where the solar panels are installed in agricultural fencing applications is effective in terms of the amount of energy produced and the payback period.

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