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TECHNO-ECONOMIC ANALYSIS OF AN OFF-GRID HYBRID ENERGY SYSTEM WITH HOMER PRO

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ABSTRACT

The decrease in fossil-based energy sources and increasing environmental problems increase the tendency to renewable energy sources day by day. The potential of renewable energy sources differs according to the region where the energy will be produced. For this reason, it is crucial to conduct a good feasibility study that deals with the selected systems from a technical and economic point of view before making an investment decision on energy conversion systems based on renewable energy sources.

In this study, the most suitable equipment and capacities were investigated by examining the techno-economic analysis of a hybrid system created with wind-solar renewable energies for a detached house, which is considered off-grid, in a rural area of Tekirdağ province (40º58.7' N, 27º30.7' E). Investigations were carried out using the HOMER Pro (Hybrid Optimization Model for Electric Renewable) program. The wind and solar energy potential of Tekirdağ province were obtained from the NASA renewable energy resources database added to the HOMER Pro program. The daily electricity requirement of the sample house was chosen as 11.27 kWh, and the current peak electrical load was chosen as 2.39 kW. A wind turbine is connected to the AC busbars, solar collectors and battery group connected to the DC busbars, and a converter that converts energy between AC and DC busbars in the energy conversion system. In order to determine the optimum capacities of the system elements, 27486 different simulations were performed by HOMER Pro. The selection of the most suitable system among these was determined according to the lowest net present cost (NPC) value. In addition, the energy production capacities that will occur in the case of different wind speeds were also investigated. Accordingly, the system to be installed with a solar panel with a capacity of 6.25 kW, PV-MPPT with a capacity of 1 kW, 2 wind turbines with a capacity of 1 kW, 8 Lithium-ion batteries with a capacity of 6V-167 Ah, and a converter with a capacity of 2.5 kW has been determined will generate electrical energy of 5433 kWh per year. In addition, it has been determined that 61.8% of this produced energy will be obtained from solar energy and 38.2% from wind energy, and the simple payback period of the investment will be 14 years. It is thought that this study will provide valuable information to researchers and investors.

Keywords: Hybrid energy systems, Renewable energy, Techno-economic analysis, HOMER Pro.

ÖZET

Fosil kökenli enerji kaynaklarının azalmaya başlaması ve artan çevresel sorunlar, yenilenebilir enerji kaynaklarına yönelimi her geçen gün arttırmaktadır. Yenilenebilir enerji kaynaklarının potansiyeli ise enerjinin üretileceği bölgeye göre farklılıklar göstermektedir. Bu nedenle yenilenebilir enerji kaynaklarına bağlı enerji dönüşüm sistemlerine yatırım kararı verilmeden önce seçilen sistemleri teknik ve ekonomik açıdan ele alan iyi bir fizibilite çalışması yapılması çok önemlidir.

Bu çalışmada, Tekirdağ ilinin kırsal bir bölgesinde (40º58,7' K, 27º30,7' D), şebekeden bağımsız olduğu kabul edilen müstakil bir konut için rüzgar-güneş yenilenebilir enerjileri ile oluşturulan hibrit bir sistemin tekno-ekonomik analizleri incelenerek en uygun ekipmanlar ve kapasiteleri araştırılmıştır. İncelemeler HOMER Pro (Hybrid Optimization Model for Electric Renewable) programı kullanılarak gerçekleştirilmiştir. Tekirdağ ilinin rüzgar ve güneş enerjisi potansiyeli, HOMER Pro programına eklenmiş olan NASA yenilenebilir enerji kaynakları veri tabanından elde edilmiştir. Örnek alınan konutun günlük elektrik ihtiyacı 11,27 kWh ve anık en yüksek elektrik yükü (peak) 2,39 kW olarak seçilmiştir. Enerji dönüşüm sisteminde, AC barasına bağlı bir rüzgar türbini, DC barasına bağlı, güneş kolektörleri ve batarya grubu, AC ve DC baraları arasında enerji dönüşümü yapan bir konvertör bulunmaktadır. Sistem elemanlarının optimum kapasitelerinin belirlenebilmesi için HOMER Pro tarafından 27486 farklı simülasyon gerçekleştirilmiştir. Bunlar arasında en uygun olan sistemin seçimi en düşük şimdiki maliyet değerine göre belirlenmiştir. Ayrıca farklı rüzgar hızlarının gerçekleşmesi durumunda meydana gelecek enerji üretim kapasiteleri de araştırılmıştır. Buna göre, 6,25 kW kapasiteli güneş paneli, 1 kW kapasiteli PV-MPPT, 1 kW kapasiteli 2 adet rüzgar türbini, 6V-167 Ah kapasiteli 8 adet Lityum-iyon batarya ve 2,5 kW

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kapasiteli konvertör ile kurulacak sistemden yıllık 5433 kWh elektrik enerjisi üretileceği tespit edilmiştir. Ayrıca, üretilen bu enerjinin %61,8'nin güneş enerjisinden, %38,2'sinin ise rüzgar enerjisinden elde edileceği ve yapılan yatırımın basit geri ödeme süresinin 14 yıl olacağı tespit edilmiştir. Bu çalışma ile araştırmacılara ve yatırımcılara faydalı bilgiler sunulacağı düşünülmektedir.

Anahtar Kelimeler: Hibrit enerji sistemleri, Yenilenebilir enerji, Tekno-ekonomik analiz, HOMER Pro.

INTRODUCTION

With the Industrial Revolution, the ever-increasing need for energy drives engineers and researchers to look for technologies that will make as much use of renewable energy sources as possible. Among the leading causes of this phenomenon is the risk of decimating fossil energy sources and their negative impact on the environment. As there is no risk of depletion or extinction of renewable energy sources, many renewable energy sources worldwide can be reached homogenously and are highly preferred due to their environmental friendliness (Engin, 2010). The combination of renewable energy sources in a hybrid system has positive characteristics in many decks (Türkdoğan, Mercan, & Çatal, 2020). For example, since solar energy is only available during daylight hours, the wind is not continuous, The Independent use of these systems is restricted, or energy storage can be achieved by installing high-capacity energy systems (Yılmaz, 2012). In this regard, much research is currently being done on hybrid energy systems, where several energy sources are used together Dec. In a study conducted by Türkdoğan and colleagues, technical and economic analyses of various hybrid energy systems were conducted to meet the needs of a community of 160 people with 40 digits of electricity and thermal loads independently of the grid. The HOMER (Hybrid Optimization Model for Electric Renewable) program was used to meet the needs of an average electricity load of 320 kWh/d and a thermal load of 142.47 kWh/d, and to find the unit price of energy that will be generated by the energy systems that will be installed for this purpose is close to reality (Türkdoğan, Mercan, & Çatal, 2020). In a study conducted by Çakmak and colleagues, an economic analysis-based optimization study was conducted to meet the electrical energy needs of Bilecik Şeyh Edebali University Faculty of Engineering with a hybrid system. They used HOMER software to ensure that the system created in a computer environment is as realistic as possible and to study the effect of time-varying magnitudes such as electric charge, wind speed, and solar radiation (Çakmak, Kurban, & Dokur, 2020). In a study conducted by Stefan, research was conducted to provide part of the electricity needs of a large sports facility in Falun, Sweden, with renewable energy sources. In the study, the system design was carried out using HOMER simulation programs developed by PVsyst and the National Renewable Energy Laboratory (NREL). Wind system technology and PV system technology are compared economically (Stefan, 2011).

This study examined the situation of meeting the electricity needs of an off-grid (grid-independent) residence with hybrid wind and solar energy system from a techno-economic and environmental point of view; HOMER Pro (HOMER Energy, 2021) software was used in the research.

MATERIALS AND METHODS

The housing, which is independent of the network, is located in the Süleymanpaşa District of Tekirdağ province (40º58.7' N, 27º30.7' E). The average daily electrical energy requirement was 11.27 kWh/d and the peak load value during the day was 2.39 kW. Hourly, seasonal and annual electrical load changes of the residence are presented in Figure 1.

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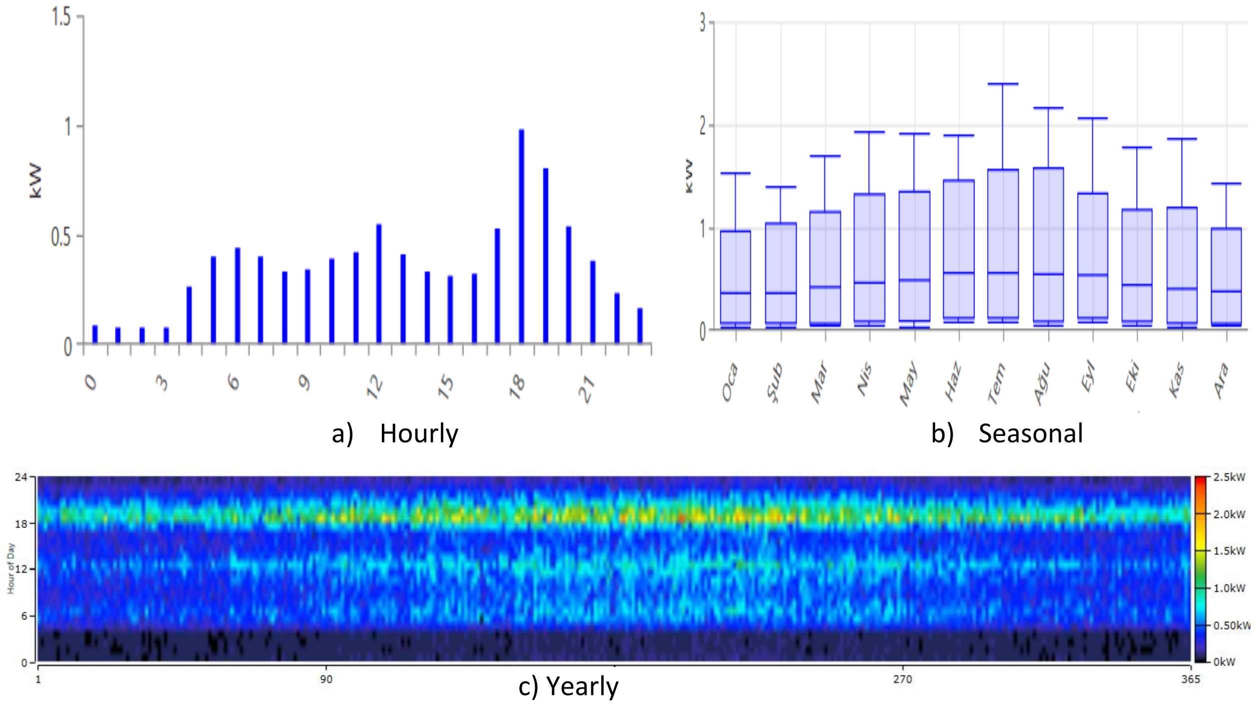

Figure 1. a) Hourly, b) Seasonal and c) Yearly energy load change of the examined house (HOMER Energy, 2021)

Daily horizontal solar radiation values and wind potential of the region were obtained from the NASA Meteorological database integrated into HOMER Pro software. April – September is the most common sean period of solar radiation. The seasons with the highest wind speed are the autumn and winter months. Data on the potential of solar and wind energy in the studied region are presented in Table 1.

Table 1. Solar and wind energy data of the studied region

Months	Clearness Index	Daily Radiation (kWh/m^2/day)	Wind Speed (m/s)
January	0.408	1.660	5.680
February	0.443	2.430	7.630
March	0.482	3.610	6.660
April	0.505	4.820	5.280
May	0.557	6.130	4.570
June	0.604	7.000	4.610
July	0.626	7.060	4.650
August	0.621	6.250	4.390
September	0.593	4.850	4.610
October	0.500	3.030	7.060
November	0.429	1.880	5.660
December	0.376	1.370	5.960
Average	0.512	4.170	5.560

The circuit assembly formed by system equipment that will provide electrical energy off-grid is schematically shown in Figure 2.

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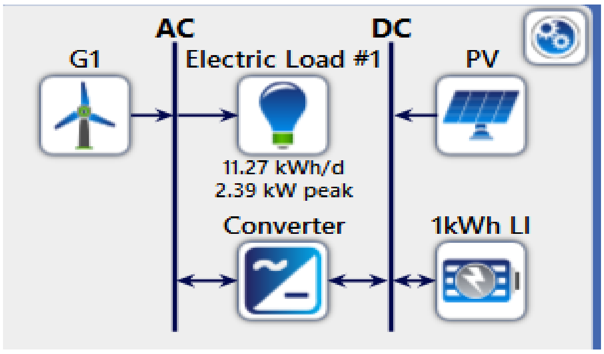

Figure 2. Hybrid system model

When these equipment are examined,

PV PANELS

In the reviews, generic brand flat PV panels with a capacity of 0.25 kW were used. For the sensitivity analysis of the system, analysis of the PV system with a December of 0.25 kW and an estimated capacity of up to 7 kW was performed. The efficiency of PV panels is 95%. A graph of the output power of PV panels is presented in Figure 3. In addition, a maximum power point tracking system with a capacity of 1 kW has been added to the system.

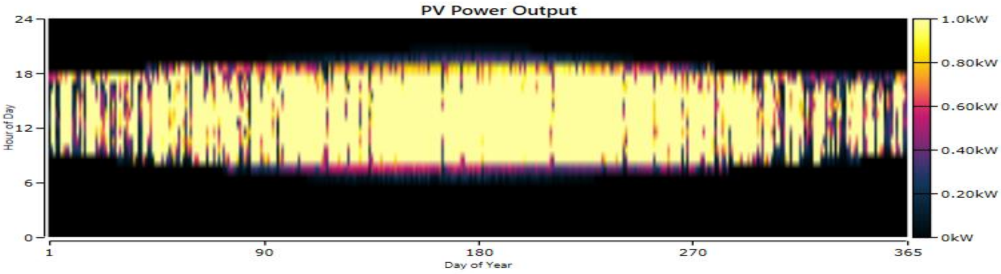

Figure 3. Variation of output power of PV panels over time

LITHIUM-ION BATTERY

Li-Ion batteries used for energy storage in the system have a nominal voltage of 6V, a nominal capacity of 1kWh and 167Ah; their efficiency is 90%. The maximum charge current is 167A, and the maximum discharge current is 500A. Changing the charge status of batteries over time is shown in Figure 4.

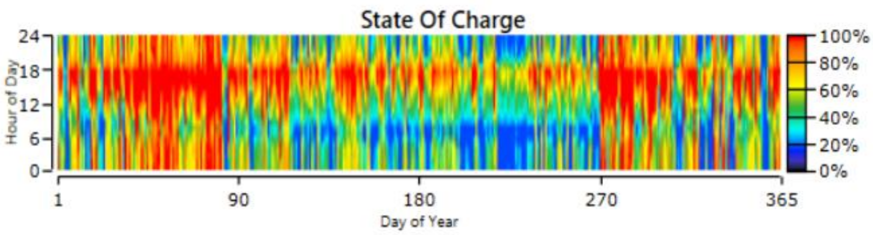

Figure 4. Change of charge state of batteries over time

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CONVERTER

In the system, 2.5 kW capacity DC-AC and AC-DC converters are used. The average output power of the inverter is 0.302 kW, the capacity factor is 12.1%, and the maximum output power is 2.36 kW. The average output power of the rectifier is 0.0280 kW, the capacity factor is 1.12%, and the maximum output power is 1.71 kW. A graph showing the change in output power of the inverter and rectifier over time is presented in Figure 5.

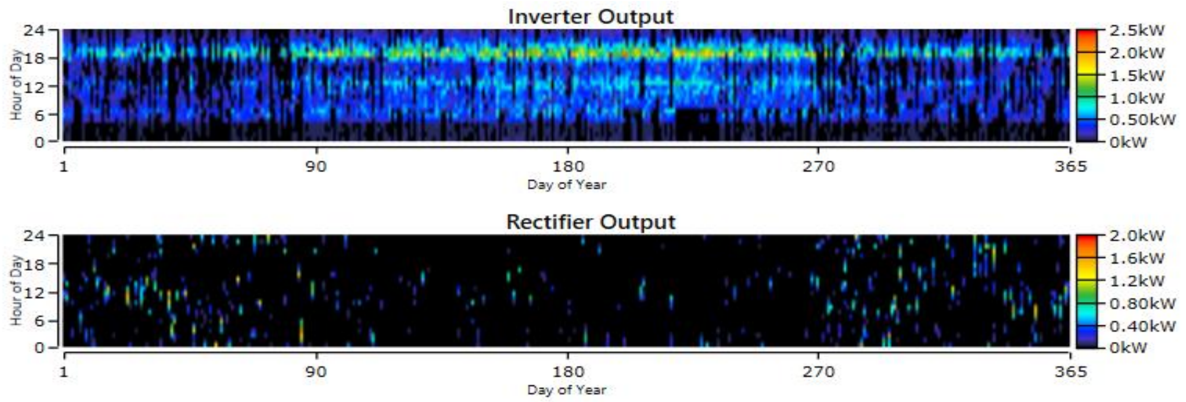

Figure 5. Variation of Inverter and Rectifier output power over time

WIND TURBINE

The capacity of the wind turbine used in the system is 1kW; the service life is 20 years. The hub height is 17 m, Capacity factor is 11.8%, and the average output power is 0.237 kW. The change in the output power of the wind turbine over time is presented in Figure 6.

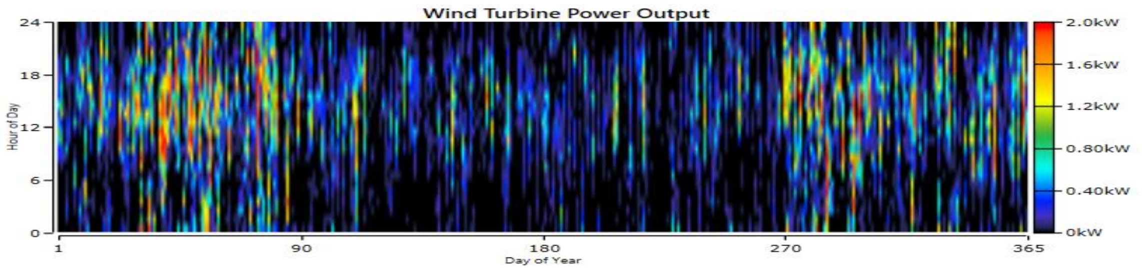

Figure 6. Variation of the output power of the wind turbine over time

FINANCIAL ANALYSIS

When the unit costs of the equipment used in the system are examined, 1 kW of PV panels is 2200 ₺, one piece of Li-Ion Batteries is 1500 ₺, 1 kW of Converter is 1000 ₺, and wind turbine is 10000 ₺. Installation of the system Labor and material costs are excluded from calculations.

FINDINGS and DISCUSSION

Twenty-seven thousand four hundred eighty-six different combinations of selected System elements (Fig. 2) with HOMER Pro Software have been evaluated according to net present cost (NPC), and cost of energy (COE), and the optimal conditions have been reached. In addition, analyses were carried out for different values of wind speed. Accordingly, the hybrid system model obtained by the capacities or numbers of optimal system elements is given in Table 2.

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Table 2. Analysis results of the hybrid system under different conditions

Condition number	Hub height (m)	Wind scaled average (m/s)	PV panel (kW)	PV-MPPT (kW)	Wind turbine (piece)	Li-Ion battery (piece)	Converter (kW)	COE (₺)	NPC (₺)	Operating cost (₺/yr.)	İnitial cost (₺)	Energy product. (kWh/yr..)
1	17	5.56	6.25	1	2	8	2.5	0.521	94705	974.30	48750	5433
2	20	5.80	5.75	1	2	7	2.5	0.495	89992	929.51	46150	5813
3	30	6.20	6.75	1	1	7	2.5	0.420	76542	809.71	38350	5154
4	35	6.30	6	1	1	7	2.5	0.409	74436	800.06	36700	5228

In Table 2, wind turbine hub heights were examined in four different cases. Wind turbine hub height wind speed at altitudes varying increased according to the analysis, turbine hub height increases as the amount of energy produced by the system to be founded has increased while the cost of energy (COE) and net present costs have decreased. In addition, the classification of electrical energy produced by the hybrid system according to renewable energy sources was also made. Accordingly 1st case, it was determined that 61.8% of the 5443 kWh/yr. Electrical energy generated by the system would be supplied from the solar energy system and 38.2% from the wind turbine. In October, 1274 kW (23.5%) of the energy generated by the system was found to be extra generated energy.

In the same way, in the fourth case, the wind turbine hub height is 35m, and the wind speed is 6.30 m/s, it was determined that 66.3% of the electricity generated would be covered by solar energy and 33.7% by the wind turbine. In response to the increasing values of wind speed, wind energy cannot be used more because only one wind turbine is considered sufficient for the system. In this case, it was determined that the unused electricity capacity generated by the system would be 1.003 kWh/yr.

CONCLUSIONS

Techno-economic analysis of a grid-independent hybrid system to be created according to solar and wind energy potential from renewable energy sources of Tekirdağ province, Süleymanpaşa district was carried out with HOMER Pro software. According to the data obtained, it was determined that 5433 kWh of electrical energy would be generated annually from the system to be installed with a 6.25 kW solar panel, 1 kW PV-MPPT, 2 wind turbines with 1 kW capacity, 8 lithium-ion batteries with 6V-167 Ah capacity and a 2.5 kW converter. In addition, it was determined that 61.8% of this energy produced would be derived from solar energy and 38.2% from wind energy, and the simple repayment period of the investment will be 14 years.

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