Meeting the Hospital Oxygen Demand with a Decentralized Autonomous PV System: Effect of PV Tracking Systems

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Abstract

When it comes to supplying oxygen, current standard hospitals in Iran have proven inadequate in the face of the COVID-19 pandemic, particularly during infection peaks. Power disruptions drastically reduce the oxygen pressure in hospitals, putting patients’ health at risk. The present study is the first to attempt to power an oxygen concentrator with a solar-energy-based system. The HOMER 2.81 package was used for technical–economic–environmental–energy analysis. The most notable aspects of this work include evaluating different available solar trackers, using up-to-date equipment price data and up-to-date inflation rate, considering the temperature effects on solar cell performance, sensitivity analysis for the best scenario, considering pollution penalties, and using a three-time tariff system with price incentives for renewable power. The study has been carried out at Hajar Hospital, Shahrekord, Chaharmahal and Bakhtiari Province, Iran. The study showed that, by supplying 60% of the power demand, the dual-axis solar tracking system offered the highest annual power output (47,478 kWh). Furthermore, generating power at $0.008/kWh due to selling power to the grid, the vertical-axis tracker was found to be the most economical design. Comparing the configuration with a vertical-axis tracker with the conventional scenario (relying on the power distribution grid), the investment is estimated to be recovered in three years with $234,300 in savings by the end of the 25th year. In the best economic scenario, 6137 kg CO2 is produced, and the analysis revealed the negative impact of a temperature rise on the performance and solar power output.

Graphical Abstract

Keywords National power grid · Ambient temperature · Net present cost · Battery · Power converter

1 Introduction

Access to electric power is essential for societies to thrive and improve living standards (Jahangiri et al. 2019a). The well-being and health quality of the people are telling
indicators of the level of standards in a country and require well-equipped, reliable healthcare facilities to uphold. To be able to provide their services, healthcare facilities of any size, namely large, e.g., hospitals, medium, e.g., health centers, and small, e.g., clinics, must have access to modern equipment and technologies, all of which operate on electricity (Franco et al. 2017).

Given the high-reliability requirements of the equipment used in healthcare facilities, as the slightest disruption could inflict irrecoverable damage, the power input must be supplied to ensure the highest availability (Ghaderian et al. 2020). Patients are most at risk during power cuts when vital equipment ceases to operate, making secondary power supplies essential. For this purpose, hospitals often rely on diesel generators, which are challenged by environmental pollution, high power production costs, loud noise, high maintenance costs, and long supply delays (Olatomiwa 2016).

The solution can be found in renewable sources of energy, such as solar, that are environmentally friendly, highly reliable and durable, and abundant (Jahangiri et al. 2018a; Zaniani et al. 2015; Pahlavan et al. 2018). Figure 1 shows global solar power production over the past decade (Renewables 2021 Global Status Report 2021). As evident, with an additional 139 GWh compared to the preceding year, solar power production reached 760 GWh in 2020.

The high cost of Photovoltaic (PV) systems necessitates maximizing their efficiency (Jahangiri et al. 2020a). To increase efficiency, the orientation of the solar panels to the variable position of the sun in the sky and normal to its rays must be maintained. Accordingly, solar trackers are used to follow the sun’s movements and maximize energy collection (Bouzakri et al. 2021). Two types of trackers are used in solar systems, namely single- and dual-axis trackers. Figure 2 illustrates the different types of solar trackers.

Oxygen supply is an essential part of treatment for infectious disease, asthma, bronchitis, chronic lung disease, and COVID-19 patients (a COVID-19 patient needs 30 times as much oxygen as a typical patient), and its interruption can be fatal. Figure 3 shows the significance of oxygen concentrators as essential equipment in healthcare facilities, particularly larger ones, including hospitals. The hospital oxygen concentrator’s failure or its power cut will claim lives (Stoller et al. 2000). A schematic of the oxygen concentrator is depicted in Fig. 4, outlining its internal components and function.

In the following, the literature on the power supply of equipment in a hospital, a hospital unit, or a clinic using renewable energy, particularly solar energy, is reviewed (Table 1).

Based on these studies and the authors’ investigation, oxygen supply for a hospital unit by using a PV-based on-grid system has never been addressed before. The problem is even more tangible in the wake of the COVID-19 crisis and the dire need for oxygen in Iranian hospitals. The sensitivity analysis performed in this work, which has not been done in any of the previous works with a similar goal, makes the results of the present work comprehensive. The results make the effect of climate change on the system performance predictable. Also, the solar trackers effect has been investigated for the first time in the field of supplying electricity to hospital equipment. The results show whether the higher cost of using different types of solar trackers, which will lead to more electricity production and energy security, is economically viable or not.

The main research questions are as follows:

- What are the results of taking into account the penalties for pollutants on the system’s performance?
- What is the effect of different trackers (single-axis, dual-axis, no tracker) on the system’s performance?
- What are the results of the system analysis from the energy–economic–technical–environmental point of view?
- What is the price of electricity produced per kWh for the PV-grid system with the 3-time tariff electricity exchange with the national electricity grid?
- What are the economic results of the investigated system considering the temperature?

Replying to the above questions which have been rarely addressed before, makes the results of the present study highly realistic.

It must also be noted that, despite being a case study, the results of the present work can be used as a reference for any area with a similar climate. Moreover, the analysis...
method can be replicated for any part of the globe regardless of the climate.

2 Location Under Study

In this study, Hajar Medical and Educational Center, Shahrekord, Chaharmahal and Bakhtiari, Iran, operating with 373 beds and over 30 units, was considered. This hospital has 15,000 m² of infrastructure and its view and location are shown on the map of Iran in Fig. 5. The hospital is located at 32° 17' N/50° 59' E coordinates. Shahrekord stands 2060 m above sea level (Iran’s highest elevated provincial capital) and according to the 2020 census, 204,679 live in it. The city has mild summers and extremely cold winters.
3 Methodology

The commercial software package HOMER was employed for a technical and economic evaluation of the renewable system. The package relies on two optimization algorithms (Baruah et al. 2021), namely HOMER Search Space and HOMER Optimizer. HOMER Search Space uses the grid search algorithm, and Optimizer relies on a proprietary derivative-free algorithm for simulation.

These algorithms aim to go through all possible configurations to find the system with the minimum cost (Jahangiri et al. 2017). Figure 6 depicts HOMER’s function using a flowchart. The inputs, parameters, and optimization at different stages are all shown on the flowchart.

The inputs of HOMER analyses are introduced in the following:

3.1 Load Data

An AirSep NewLife oxygen concentrator with continuous flow and a maximum output capacity of 10 LPM oxygen with 92% ± 3% purity was used. The device has a 590 W power rating (Stationary Oxygen Concentrator Comparison Chart 2021), and in this study, it was attempted to supply 10 oxygen concentrators with grid-connected solar cells.

In the calculations, 15% and 20% of random day-to-day and hour-to-hour variability were taken into account, respectively (Mostafaeipour et al. 2020a). Figure 7 depicts the power demand profile with an 11.5 kW peak in March. Moreover, the load factor is 0.514.

3.2 Resource Assessment

Renewable power production relied on solar energy, for which the selected area has the great potential (Ghaderian et al. 2020). Figure 8 presents the average monthly radiation, average monthly clearness index, and average monthly temperature. The annual averages of these parameters are 5.06 kWh/m²-day, 0.591 and 14 °C, respectively.

3.3 System Component

Figure 9 shows a schematic of the simulated system. Solar cells have been used to produce power, batteries to store the surplus output, and a converter to transform DC to AC

| Reference, Year | Location | Grid connection | Solar tracker | Temperature effect | Sensitivity analysis | Purpose | Result |
|-----------------|----------|-----------------|--------------|-------------------|---------------------|---------|--------|
| Talukdar (2017) | India    | No              | No           | No                | No                  | Analysis of PV panels for a remote area | In four months of the year, hydrogen production is more than hydrogen consumption |
| Snodgrass et al. (2018) | Uganda | No              | No           | No                | No                  | Using portable apparatus for measuring nucleic acid | The result of the portable apparatus was 94% similar to the comparable non-portable device |
| Kumar and Dansereau (2014) | Iran    | Yes             | No           | No                | Yes                 | Using RE-based microgrid to improve the power production flexibility in a local clinic | The RE-based system with LCOE of $0.000003 emits 2115 kg/year of emission less than a diesel-based system with LCOE of $0.0396 |
| Ghaderian et al. (2020) | Iran    | No              | No           | No                | No                  | Provide PV-wind-diesel generator electricity for NICU | Solar is superior to wind and with LCOE of 0.0636, 18% of energy is supplied by PV |
| Alizadeh et al. (2021) | Iran    | No              | No           | No                | Yes                 | Generation of PV-wind-diesel generator electricity to meet the clinic energy demand | LCOE is 0.721 $ and CO2 emission is 1861 kg/year |
| Present work (2022) | Iran    | Yes             | Yes          | Yes               | Yes                | Meeting the hospital oxygen demand with a PV system | Finding the best system from energy, environmental and solar tracker usage aspects |
and vice versa. The studied system is connected to the grid. The implementation of the system is readily discussed.

### 3.3.1 Solar PV

Solar panels convert solar radiation to electric power. The output power of PV cells is a function of radiation, cell temperature, and the derating factor (Moein et al. 2018). The power output of the solar cells is calculated based on the following relationship using HOMER (Moein et al. 2018):

\[
E_{PV} = E_{RPV} \times g_{PV} \times \frac{T_T}{T_{T,STC}} \times (1 + \beta_p \times (T_C - T_{C,STC}))
\]

where \(E_{RPV}\) denotes the nominal capacity of PV arrays (kW), \(g_{PV}\) is the derating factor (%), \(T_T\) represents solar irradiance reaching on the surface of PV arrays in present conditions (kW/m²), \(T_{T,STC}\) is solar irradiance reaching on the surface of PV arrays under standard test conditions (kW/m²), \(\beta_p\) is the temperature coefficient of power (kW/C), \(T_C\) shows the temperature of solar cell surface in present conditions (°C), \(T_{C,STC}\) is the temperature of solar cell surface under

\[
T_C = \frac{T_a + 7T_T \left( \frac{T_{C,STC} - T_{a,NOCT}}{T_{T,NOCT}} \right) \left( 1 - \frac{T_{a,NOCT}}{T_{a,STC}} \right) \eta_m,STC (1 - \beta_p (T_{C,STC} - T_{C,STC}))}{1 + (T_{C,NOCT} - T_{a,NOCT}) \frac{T_T}{T_{T,NOCT}} \frac{T_{a,NOCT}}{T_{a,STC}}}
\]
standard test conditions \(^{({}^\circ C)}\), \(T_a\) denotes ambient temperature \(^{({}^\circ C)}\), \(\eta_{mp}\) is the efficiency of electric power conversion of the PV arrays (%), \(\eta_{mp,STC}\) shows the nominal working temperature of the solar cell \(^{({}^\circ C)}\), \(T_{a,NOCT}\) denotes ambient temperature when the nominal working temperature was measured \(^{({}^\circ C)}\), \(I_{T,NOCT}\) shows the solar irradiance.
Fig. 7 Power demand profile of oxygen concentrators over a year

Fig. 8 Monthly average of climatic inputs; a solar radiation and clearness index; b ambient temperature

Fig. 9 Schematic of the simulated system to be studied
when the nominal working temperature was measured \( (\text{kW/m}^2) \), \( \alpha \) is the absorption coefficient of solar cell, and \( \tau \) represents solar transmittance of the PV array coating.

### 3.3.2 Grid

Since the studied system was grid-connected, HOMER calculated power exchange with the grid from Eq. 3 (Ebrahimi et al. 2019).

\[
C_{\text{Grid, energy}} = \sum_{i} \sum_{j} \left\{ \begin{array}{ll} E_{\text{net grid purchases}, i, j} C_{\text{power}, i} & \text{if } E_{\text{net grid purchases}, i, j} \geq 0 \\
E_{\text{net grid purchases}, i, j} C_{\text{sellback}, i} & \text{if } E_{\text{net grid purchases}, i, j} < 0 \end{array} \right\}
\]

(3)

In this relation, \( E_{\text{net grid purchases}} \) represents power purchase from the grid minus power sale in the \( j \)th month at the rate \( i \) in kWh, \( C_{\text{power}, i} \) is the grid’s power price at the
rate $i$ in $\frac{\text{\$}}{\text{kWh}}$, and $C_{\text{sellback, } i}$ is the price at which power is sold to the grid at the rate $i$ in $\frac{\text{\$}}{\text{kWh}}$.

### 3.3.3 Battery

Batteries were used to store the surplus power output to compensate for the unreliability of renewable energy sources. The maximum storage capacity of the battery can be calculated from the following relation using HOMER (Jahangiri et al. 2018b):

$$P_{\text{batt max}} = \frac{\min(P_{\text{batt max kbm}}, P_{\text{batt max mcr}}, P_{\text{batt max mcc}})}{\eta_{\text{batt, C}}}$$

(4)

where $P_{\text{batt max kbm}}$ is the maximum power output of the battery for a given period in kW, $P_{\text{batt max mcr}}$ is the charging power corresponding to the maximum charging rate in kW, $P_{\text{batt max mcc}}$ denotes the charging power corresponding to the maximum charging current in kW, and $\eta_{\text{batt, C}}$ shows the charging efficiency of the battery in a percent.

### 3.3.4 Converter

A power converter is needed to maintain the stability of renewable energy systems and convert between AC and DC power. Converters comprise inverters and rectifiers, the output powers of which ($P_{\text{inv out}}$ and $P_{\text{rec out}}$) can be cal-

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**Table 4** Simulation results for the four scenarios

| Scenario | Tracker type | Grid | PV | Batt | Conv | Dispatch strategy | Initial capital ($) | Operating cost ($) | Total NPC ($) | LCOE ($/kWh) | Ren. Frac |
|----------|--------------|------|----|------|------|------------------|-------------------|------------------|--------------|-------------|----------|
| 1.1      | No tracker   | yes  | 20 | –    | 18   | CC               | 27,484            | – 3523           | 8224         | 0.023       | 51%       |
| 1.2      | No tracker   | yes  | 20 | 1    | 18   | CC               | 27,658            | – 3529           | 8363         | 0.023       | 51%       |
| 1.3      | No tracker   | yes  | –  | –    | –    | CC               | 0                 | 4187            | 22,892       | 0.081       | 0         |
| 1.4      | No tracker   | yes  | –  | 1    | 1    | LF               | 312               | 4211            | 23,334       | 0.082       | 0         |
| 2.1      | Horizontal   | yes  | –  | –    | –    | CC               | 0                 | 4187            | 22,892       | 0.081       | 0         |
| 2.2      | Horizontal   | yes  | 20 | –    | 18   | CC               | 44,904            | – 3969           | 23,208       | 0.063       | 54%       |
| 2.3      | Horizontal   | yes  | –  | 1    | 1    | LF               | 312               | 4211            | 23,334       | 0.082       | 0         |
| 2.4      | Horizontal   | yes  | 20 | 1    | 18   | CC               | 45,078            | – 3975           | 23,349       | 0.063       | 53%       |
| 3.1      | Vertical     | yes  | 20 | 0    | 18   | CC               | 32,584            | – 6518           | – 3049       | – 0.003     | 58%       |
| 3.2      | Vertical     | yes  | 20 | 1    | 18   | CC               | 32,758            | – 6522           | – 2897       | – 0.007     | 58%       |
| 3.3      | Vertical     | yes  | 0  | 0    | 0    | CC               | 0                 | 4187            | 22,892       | 0.081       | 0         |
| 3.4      | Vertical     | yes  | 0  | 1    | 1    | LF               | 312               | 4211            | 23,324       | 0.082       | 0         |
| 4.1      | Two axis     | yes  | 20 | 0    | 20   | CC               | 48,260            | – 7799           | 5623         | 0.014       | 60%       |
| 4.2      | Two axis     | yes  | 20 | 1    | 20   | CC               | 48,434            | – 7801           | 5789         | 0.014       | 60%       |
| 4.3      | Two axis     | yes  | 0  | 0    | 0    | CC               | 0                 | 4187            | 22,892       | 0.081       | 0         |
| 4.4      | Two axis     | yes  | 0  | 1    | 1    | LF               | 312               | 4211            | 23,334       | 0.082       | 0         |
culated from the following equations using HOMER (Baruah et al. 2021).

\[ P_{\text{inv-out}} = \eta_{\text{inv}} P_{\text{DC}} \] (5)

\[ P_{\text{rec-out}} = \eta_{\text{rec}} P_{\text{AC}} \] (6)

where \( \eta_{\text{inv}} \) denotes the inverter efficiency in percents, \( \eta_{\text{rec}} \) is the rectifier efficiency in percents, \( P_{\text{AC}} \) shows the AC input power in kW, and \( P_{\text{DC}} \) is the DC input power in kW.

### 3.4 Financial Parameters

The most notable financial outputs of HOMER are total NPC and LCOE which represent the total Net Present Cost and the average cost of effective power production by the system per kWh. These parameters are calculated as follows (Abdali et al. 2019; Jahangiri et al. 2020b).

\[ \text{total NPC} = \frac{C_{\text{ann-tot}}}{\text{CRF}(i \cdot R_{\text{proj}})} \] (7)

\[ \text{LCOE} = \frac{C_{\text{ann-tot}}}{E_{\text{served}}} \] (8)

where \( C_{\text{ann-tot}} \) is the total annual cost in $, CRF denotes the capital recovery factor, \( i \) shows the real interest rate in percent, \( R_{\text{proj}} \) is the useful life of the project in years, and \( E_{\text{served}} \) is the total electric load supplied in kWh/yr.

### 3.5 Technical and Functional Details

In this study, prices and other technical parameters of the equipment were selected based on availability in the Iranian market. In Table 2, the technical specifications of the equipment used in this work are listed. In Table 3, the cost details of the equipment are listed.

Considering the three-time tariff of electricity in Iran and the different tariffs imposed on renewable electric power than power from the grid, Fig. 10 presents the details of power prices to purchase from and sell to the grid (Jahangiri et al. 2019b).

The annual real interest rate was assumed to be 18% (Trading Economics, Interest Rate, Asia 2021) and the project service life to be 25 years (Jahangiri et al. 2018c). Penalties were considered for production of CO\(_2\), CO, SO\(_2\),
and NOₓ, namely 3.1 $/ton, 57 $/ton, 560 $/ton, and 184 $/ton.

3.6 Constraints

Some constraints were also considered in this work that will be readily discussed. A maximum capacity of 20 kW was observed for installing PV arrays, which conforms to the guaranteed purchase directive of SATBA, stating the highest renewable energy price for 20-kW-and-less solar power plants (Kalbasi et al. 2019). Space limitation was another constraint that kept the production capacity at 20 kW. The number and type of equipment were selected based on availability in the Iranian market.

3.7 Limitations of Methodology

Demand fluctuations over one hour are unreliable in HOMER. Moreover, voltage variability and current fluctuations cannot be applied from the source side, and the software can only take them into account in the overall output. Further, other potential complications, such as power cuts, transmission loss, and equipment failure, cannot be applied to the software. Regardless, HOMER still
offers close-to-real results (HOMER Energy 2021) and is widely used for analysis (Mostafaeipour et al. 2020b, c; Jahangiri et al. 2020c, 2019c; Teshnizi et al. 2021).

### 4 Results

In Table 4, the results of the four evaluated scenarios are shown. It was found that the highest solar power production, supplying 60% of the demand, corresponded to the case of using a dual-axis tracker. Configurations with vertical- and horizontal-axis trackers follow with 58 and 54% fulfillment. Without trackers, solar cells would provide 51% of the power demand. According to these results, coupling solar cells with power from the grid is the most cost-effective option in the first, third, and fourth scenarios. However, relying solely on the grid, the cheapest choice is the second scenario (with a horizontal-axis tracker). Cycle Charging was also found to be the superior dispatch strategy compared to Load Following in all scenarios.

In all four scenarios, substantial investment capital is needed in configurations using solar cells, but power sales to the grid at a higher price than what is paid to the grid for power results in negative operation costs. Accordingly, in solar-cell-based scenarios, the total NPC is much lower than those without solar cells.

According to Table 4, with a negative COE, the third scenario, where a vertical-axis tracker is used, is the most economical. This advantage can be attributed to the lower price of the vertical-axis tracker than the horizontal-axis and dual-axis trackers. Moreover, this system produces approximately 6000 kWh/yr more than the horizontal-axis tracker but only 3000 kWh/yr less than the dual-axis tracker, making it the most cost-effective scenario of the four scenarios.

Based on its advantage over the others, scenario 3.1 was adopted for detailed evaluation in the following.

In Fig. 11, scenarios 3.1 and 3.3 (conventional power supply) are compared. It is shown that scenario 3.1 has a positive slope as a result of the annual power sales to the grid, whereas scenario 3.3 has a negative slope due to buying power from the grid and maintenance costs. According to Fig. 11, Scenario 3.1 breaks even with scenario 3.3 in three years, indicating a payback period of 3 years. The figure also shows that, in scenario 3.1, by the end of the 25-year lifetime of the project, due to selling power to the grid, $234,300 will have been saved. The comparison in Fig. 11 was made considering a 32.9% internal rate of return.

In Fig. 12, the cash flow over the project’s 25-year lifetime for scenario 3.1 is plotted. The costs at the beginning (0th year) included the purchase of solar cells and converters. The cost of replacing the power converters in the 15th year was also considered, in addition to the annual maintenance expenses of the converters and solar cells. The revenue includes power sales to the grid during the 25-year service life. The power converter is salvaged in the 25th year, also contributing to the revenues.

In Fig. 13, the average monthly power output is plotted, showing that 58% of the required electricity is supplied by solar cells and the rest by the national grid. Power production was the highest in June, whereas December corresponded with the lowest power output.

In Fig. 14, the output power contour of the solar cells is depicted. Between 11 AM and 3 PM, power output peaked

### Table 5 Power exchange with the grid in the 3.1 scenario

| Month | Energy purchased (kWh) | Energy sold (kWh) | Net purchases (kWh) |
|-------|------------------------|-------------------|---------------------|
| Jan   | 3114                   | 1117              | 1997                |
| Feb   | 2473                   | 1190              | 1284                |
| Mar   | 2819                   | 1425              | 1393                |
| Apr   | 2428                   | 1641              | 787                 |
| May   | 2129                   | 2223              | -94                 |
| Jun   | 2015                   | 2446              | -431                |
| Jul   | 2093                   | 2279              | -186                |
| Aug   | 2330                   | 2124              | 206                 |
| Sep   | 2327                   | 2120              | 206                 |
| Oct   | 2595                   | 1720              | 875                 |
| Nov   | 2779                   | 1313              | 1466                |
| Dec   | 3148                   | 943               | 2205                |
| Annual| 30,252                 | 20542             | 9710                |

### Table 6 Pollution production in scenario 3.1

| Pollutant | Emissions (kg/y) |
|-----------|------------------|
| CO₂       | 6137             |
| SO₂       | 26.6             |
| NOₓ       | 13               |
at 22.2 kW. The average daily output was 122 kWh, and the solar cells had a capacity factor of 25.4%. Every year, solar cells produce 44,453 kWh in 4385 working hours.

In Fig. 15, the output power contour of the inverter is depicted. The average inverter output reached 4.8 kW, with a maximum output of 18 kW and a 26.7% capacity factor. The inverters showed an annual loss of 2217 kWh, which is the discrepancy between their 44,337 kWh input and 42,120 kWh output.

Table 5 shows power exchange with the grid. According to the results in Table 5, more power is sold to the grid than bought from it in May, June, and July. December corresponds to the biggest purchase from the grid, namely 3148 kWh. Also, Table 5 shows that 20,542 kWh is sold to the grid every year, whereas 30,252 kWh is received from it. Based on the three-time tariff and Fig. 14, most of the power was sold to the grid during average demand hours for 0.445 $/kWh$.

Table 6 shows the amount of generated pollutants due to 9710 kWh/y purchase of net electricity from the grid. With 6137 kg/y, CO$_2$ accounts for the biggest part of the pollutants, whereas NO$_x$ had the smallest share with 13 kg/y.

In Fig. 16a, b, the sensitivity analysis results for solar radiation and ambient temperature are shown. It is found that the PV grid is the most economical option for average solar radiation of 5–15 kWh/m$^2$-day and an average ambient temperature of 14–28 °C. According to Fig. 16a and as anticipated, higher solar radiation would increase the solar power output, whereas higher ambient temperature would decrease it. Figure 16a also shows that solar power output peaked at 60,843 kWh/yr, for solar radiation of 15 kWh/m$^2$-day and an ambient temperature of 14 °C. In Fig. 16b, the LCOE is plotted, showing the parameter to be negative for all sensitivity analysis scenarios, except for 5 kWh/m$^2$-day.
radiation and 28 °C ambient temperature. In other words, for an annual output of 41,984 kWh, the power sold to the grid will be cheaper than that bought from it, resulting in LCOE of $0.0059/\text{kWh}$.

5 Limitations and Recommendations for Future Works

One of the limitations of HOMER software is that the input data must be accurate and high quality, otherwise the software will give wrong outputs. Also, the limitations and size of the used equipment in the system should be determined based on the previous experiences of the user. Also, if some of the data are not available, HOMER software cannot estimate and calculate them and gives an error. HOMER software cannot estimate sudden blackouts and possible outages and include them in the calculations. The smallest time interval in the software is one hour and it is not possible to observe load change for one hour.

Because the focus of the present work is on the use of the solar tracker in the mode of on-grid with battery backup, it is suggested that the off-grid mode with diesel generator backup, which is also very common in Iran, is investigated and the results are compared. Also, evaluating the potential of other renewable sources such as wind energy and biomass energy in supplying the required electricity is another point that can be done in the continuation of the present work.

6 Conclusion

Oxygen concentrators are vital equipment in hospitals for patients with breathing difficulties due to various diseases. Producing oxygen faster and cheaper than using oxygen tanks that are also difficult to refill are other advantages of using oxygen concentrators. The reliance of the equipment on electric power is a challenge that was attempted to overcome by a solar–battery–grid supply system. The present study is the first to simulate supplying the 142 kWh\text{day}$ power demand of the oxygen concentrators of a hospital in Chaharmahal and Bakhtiari province, Iran, using HOMER 2.81. Four scenarios (configurations), namely without a tracker, with a single-axis horizontal tracker, with a single-axis vertical tracker, and with a dual-axis tracker, were considered for the grid-connected system. Unlike most previous works, this study takes into account the effects of ambient temperature on the performance of solar cells, considers environmental-pollution penalties for using power from the grid, and applies price incentives for solar power. The results show that:

- The configurations with a dual-axis tracker and without any tracker corresponded to the highest and lowest solar power outputs, namely 47,478 and 35,424 kWh\text{yr}$.
- As a result of power exchange with the grid, using solar cells lead to negative operating costs in all four scenarios.
- The most cost-effective scenario, with LCOE of $-0.008/\text{kWh}$, corresponds to the case of using a vertical-axis tracker.
- Compared to the case of conventional power supply (from the power grid), the economically optimal system has a payback period of 3 years and a 32.9% internal rate of return.
- In the best economic scenario, 58% of the power demand is supplied with solar energy, considering 2217 kWh\text{yr}$ loss in the inverters.
- In the best economic scenario, the net power purchase from the grid is negative from May to July.
- Annually, over 6 tons of various pollutants are produced in the best economic scenario, as the power demand is partially supplied by the grid.
- A sensitivity analysis for the best economic scenario shows that renewable power output and, consequently, cost-effectiveness will be improved as ambient temperature decreases and solar radiation increases.

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Declarations

Conflict of interest There is no conflict of interest.

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