Hybrid energy system for Dier El Balah quarantine center in Gaza Strip, Palestine

Hala El-Khozondar (✉ hkhozondar@iugaza.edu)
Islamic University of Gaza
Fady El-batta
Ministry of Health
Rifa EL-Khozondar
Al-Aqsa University
Mansour Alramlawi
Fraunhofer Institute of Optronics, System Technologies and Image Exploitation

---

Research Article

Keywords: Hybrid Energy System, quarantine center, Solar PV, HOMER, diesel generator, wind energy, COVID-19

Posted Date: April 11th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1134651/v2

Abstract

A new off-grid Hybrid Energy System (HES) for Dier El Balah quarantine center (middle Gaza Strip, Palestine) that was built to host the infected Corona virus (COVID-19) people is studied. The proposed system is made up of three energy sources mainly photovoltaic (PV), wind, and a diesel generator. The HES is developed to adequately supply a load of 3952 KW/day. The technical and economic considerations are presented. HOMER program is used to develop an optimal system from the practical view point. The results revealed the potential of the HES to provide environment friendly, cost-effective and affordable electricity for the Dier El Balah quarantine center, as compared to using only diesel generators with lowest COE equals 0.348 US$/kWh.

Introduction

Hybrid energy system (HES) is an integration of using two or more energy sources including renewable energy sources such as sun and wind to produce electricity. Both solar radiation and wind speed depend on climate condition and time of the day, thus, solar-wind-based system cannot provide electricity all the time individually [1]. Therefore, diesel fueled generators or/and storage system is/are needed to support the system.

The Palestinian power sector depends mainly on imported power. In fact, Gaza Strip purchases most of its energy needs from Israel because there is only one local power station in the Gaza Strip [2]. This motivates the Palestinian to invest in using renewable energy resources in particular solar, wind, geothermal and biomass energy sources [3]. Solar energy is the most promising source of energy considering the fact that Palestine receives about 3,000 hours of sunshine per year and has an average solar radiation of 5.4 kWh/m [3]. The importance and spread of using solar energy are introduced in [4-5].

The renewable wind power type offers a feasible and cheap solution to distribute power over wide areas world-wide. Unfortunately, Gaza Strip is characterized by a very low wind speed throughout the year [6], with an annual average wind speed of about 2.5–3.5 m/s [7]. In Gaza Strip, there are some small individual experiences to exploit this type of renewable energy. A group of Al-Azhar University students and another group of Islamic University students separately succeeded to generate electrical energy using wind energy [8].

As COVID-19 is spreading in the world, several COVID-19 infected cases in a daily bases are announced in Gaza strip. Thus, ministry of health (MOH) built several Quarantine centers to host COVID-19 infected people. In august 2020, MOH in Gaza strip installed Dier El Balah quarantine center in Dier El Balah town in central region of Gaza Strip. It consists of 165 caravans (rooms). Each room can be occupied by three persons, with total of 495 persons. This quarantine center is powered by electrical grid supply along with electric generator with capacity around 400 KVA. However, this system is very costly. In addition, it increases the pardon on utility company which has deficiency in supplying electricity for Gaza Strip. This motived the authors to propose the new HES to power Dier El Balah quarantine center.

In 2019, a simulation study is performed to investigate the techno-economic possibilities of the integration of photovoltaic solar with the existing diesel generators at Nasser Hospital in Gaza City in Gaza Strip [9]. The results of the simulated system showed that the new system will decrease production cost and reduce environmental pollution [9].

Another simulation study is performed to study hybrid off-grid system which includes a PV array, DC to AC inverter, charge controller, battery bank and backup diesel generator to cover electricity of the Islamic University of Gaza (IUG) [10]. The study showed a clear reduction in unhealthy emissions caused by non-renewable energy sources [10]. In [11] a parametric study of solar and wind energy in Gaza Strip is proposed. The work results emphasized that renewable energy is an important energy source in Gaza that should not be ignored [11].

In this paper, we presented three different hybrid configurations of wind, photovoltaic (PV), and diesel systems for Dier El Balah quarantine center in middle part of Gaza Strip. The configurations are diesel only, wind-diesel, and wind-PV-diesel power generation systems. The three systems are designed and compared to select the optimal alternative system by considering the minimum cost of energy and least environmental impact. For sizing and optimizing the hybrid power systems, local hourly average wind speed, hourly total solar radiation, and hourly load data have been used as input.

Next section introduces the methodology followed by system design & results in section III. Finally, conclusion is presented in section IV.

Table 1: Typical appliance rating and load demand for Dier El Balah quarantine center

Electrical device	Quantity(Qty)	Power (W)	Total power (KW)	Daytime hours 07:00 – 17:59	Evening Hours 18:00 – 21:59	Night Hours 22:00- 06:59	Total hours /day	Total Energy KWh/day
Air Conditioner 12000BTU	165	1060	174.9	3	3	3	9	1574.1
Heater 40 Liter	165	2500	412.5	1	1	1	3	1237.5
Heater 2 Liter	165	2200	363	0.5	0.5	0.5	1.5	544.5
Refrigerator 6 cu.ft	165	150	24.75	4	2	3	9	222.75
Washing Machine	16	1500	24	5	4	3	12	288
Inner light	165	40	6.6	1	5	3	9	59.4
Outer light	20	100	2	1	4	8	13	26
Total								3952

Methodology

Load profile

In this study, the power consumers are people infected with COVID-19. The quarantine period is at least 14 days and may reach to 21 days. The 24-hour load demand for Dier El Balah quarantine center is estimated based on the appliances available at the center as in Table I. The total power consumed at Dier El Balah quarantine center is 3952 KW/day as in Table I. In the calculation, it is assumed that the quarantine center is fully occupied. The electrical devices such as a heater (40L) and air conditioner operate depending on the air temperature (weather). The heater (2L) operates intermittently at use for a few minutes during the day. The refrigerator works throughout the day. The light operates concomitantly at night. The washing machine works according to demand. Quarantined patients do not need cooking devices to prepare their food as they receive ready meals in daily bases three times a day. HOMER is used to describe the daily, monthly and yearly loads. Fig. 1 shows daily load profile with daily peak power equals 240KW. The maximum (top line), average maximum, average (top of the box), average minimum (the bottom of the box), minimum values (bottom line) of all the days in the month are given for all months in the seasonal profile which is shown in Fig. 2. The middle line is the overall average for the whole month. The hourly load data (KW) of the Dier El Balah quarantine center for one year is represented in Fig. 3. The load demand is summarized in Table II. Note that, the load factor is a dimensionless number equal to the average load divided by the peak load. The baseline data represents the real values of the load while the scaled data represents the baseline data after scaling by a factor. The value of this factor is equal to the value that specify in "Scaled Annual Average" input variable divided by the baseline annual average. The scaled data retains the seasonal shape of the baseline data, but may differ in magnitude.

Project location

The proposed HES is to be applied to a quarantine center in Dier El Balah which is located at the middle region in Gaza strip, Palestine at 31° 24’ 35.03” N and 34° 21’ 6.25”E. Based on the afore stated benefits of adopting renewable energy sources, an analysis of utilizing small scale wind turbine, PV as well as diesel generator is carried out. Presently, Dier El Balah quarantine center is powered from utility company in additional to electrical generator. Considering the high cost of operation and maintenance of the gasoline generators, there is a need to explore the renewable energy technology to meet load requirements.

Renewable energy resources

solar resources

The global solar radiation data for the site was taken from NASA website using the area’s latitude and longitude. Also, solar radiation and temperature data can be downloaded from the HOMER website, entered manually month by month or imported as a time series data form a file. HOMER software will synthesize hourly data from monthly averages. The global horizontal irradiation (GHI) resource is used to calculate flat panel PV array output. GHI is the sum of beam radiation (also called direct normal irradiance (DNI)), diffuse irradiance and ground reflected radiation [12]. Fig. 4 shows the monthly average solar GHI data of Dier El Balah location. The solar radiation reaches its maximum in June and July months with a yearly average of 7.985KWh/m^2/day. The annual average solar GHI of Dier El Balah location is equal to 5.57 KWh/m^2/day. The brown colored curve with black dots in Fig. 4 represents the clearness index which is a fraction of the radiation on the horizontal surface of the earth to the extra-terrestrial radiation. The clearness index is a dimensionless value between 0 and 1. Higher values of clearness index occur in clear sky. HOMER software calculates the clearness index from the global horizontal irradiance. HOMER software uses the ambient temperature to calculate the PV cell temperature. The annual average temperature of Dier El Balah location is 20.29 °C. Fig. 5 shows the monthly average temperature data for Dier El Balah location.

wind resources

The wind profile for Dier El Balah, Gaza strip was retrieved from references [13, 14]. A chart showing the monthly average values of wind speed related to the case study location is given in Fig.6. It is evident from Fig. 6, that the minimum speed of 3.99 m/s is experienced in August and maximum of 5.41 m/s in February. The average wind speed for the whole year is 4.68 m/s.

System Design & Results

Described in this section are the parameters used in the simulation and analysis of the proposed hybrid system[1]. Mathematical model details for all components used in this study can be obtained in [9, 15]. All techno-economic analyses are performed by HOMER based on these mathematical models. It is important to state that though Dier El Balah quarantine center in Gaza strip was selected as the study site, the methodology of this research can be reproduced globally.

Diesel Generator Only Option

In the first case, the study concentrated on the techno-economics of the existing diesel generating power station using required input. There are two generators, 500KW and 250 KW ratings respectively (Fig. 7). The optimal cost of generated electric energy is found to be 0.43 US$/KWh where two generators are used. Generators 500 KW and 250 KW were running for 1248 and 7512 hours during the year respectively. During the whole operation of one year, a total of 413,184 liters of fuel were used. The results of the HOMER simulation are shown in Table III. The total energy generation is 1,444,039KWh during the complete year of operation; 22.5 % was contributed by 500 KW generator while 77.5% was generated by 250 KW generator. From Table IV, the net present cost of proposed system is lower than the base system. The fuel consumption for proposed system in one year is lower than the base system.

Wind-diesel hybrid power system

The existing diesel system analyzed in previous section is supplemented by 8 wind turbines each of 25 KW with total power of 200 kW to reduce dependency on diesel generating sets as in Fig. 8. Wind turbine is also added to reduce air pollution and to encourage the use of clean and green energy sources in Gaza strip.

Table 2 Load demand for Dier El Balah quarantine centerusing HOMER

Metric	**Baseline**	**Scaled**
Average (kWh/day)	**3,952.2**	**3,952.2**
Average (kW)	**164.68**	**164.68**
Peak (kW)	**403.9**	**403.9**
Load factor	**.41**	**.41**

The wind turbine used in this system is a three bladed turbine with 30 m rotor diameter and a hub height of 30 m. The cut-in speed of the Eocycle is 3.5 m/s and rated wind speed of 12 m/s with service life of 20 years. The capital cost of each wind turbine was taken as 40,000 US$ and the operation and maintenance cost is 2000 US$/year. The simulation results of the wind-diesel hybrid system obtained from HOMER are summarized in Table V.

Table 3 Electrical summery for Diesel Generator Only

Excess and Unmet		
Quantity	Value	Units
Excess Electricity	1,486	kWh/yr
Unmet Electric Load	0	kWh/yr
Capacity Shortage	0	kWh/yr
Production Summary		
Component	Production kWh/yr	Percent %
Diesel generator 500kW	325,534	22.5
Diesel generator 250kW	1,118,505	77.5
Total	1,444,039	100
Consumption Summary		
Component	Production kWh/yr	Percent %
AC Primary Load	1,442,553	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	1,442,553	100

The hybrid system consisting of two diesel generators and 8 wind turbines each of 25 kW was found to be optimal with minimum cost of energy (COE) of 0.377US$/kWh. The COE of wind-diesel hybrid system is 0.053 US$/kWh lower than the diesel only power system (COE=0.43US$/kWh). The total fuel consumed by the diesel generators decreased to 332164 liters as compared to the diesel only system which consumed 413,184 liters. The hybrid power system generated a total of 1,538,335KWh of electricity during the year with 433471KWh (28.2 %) of energy produced by wind turbines and 1104864KWh of energy contribution from the diesel generators (as in Table VI).

Table 4 Compare Economics for Diesel Generator Only

	Base System	**Proposed System**
Net Present Cost ($)	9.30M	8.06 M
CAPEX ($)	60,000	82,500
OPEX ($)	714,556	617,232
LCOE (per kWh) ($)	0.499	0.432
CO 2 Emitted (kg/yr)	1,237,331	1,091.681
Fuel Consumption (L/yr)	467,781	413,184

Table 5 Cost summery for wind-diesel hybrid power system

Net Present Costs						
Name	Capital ($)	Operating ($)	Replacement ($)	Salvage ($)	Resource ($)	Total ($)
Diesel generator 250kW	22,500	51,633	52,952	- 40.43	5.31 M	5.44 M
Diesel generator 500kW	60,000	9,592	0	- 781.56	1.00 M	1.07 M
Wind power	320,000	206,840	0	0	0	526,840
System	402,500	268,065	52,952	- 821.98	6.31 M	7.03 M

Table 6 Electrical summery for wind-diesel hybrid power system

Excess and Unmet		
Quantity	Value	Units
Excess Electricity	95,782	kWh/yr
Unmet Electric Load	0	kWh/yr
Capacity Shortage	0	kWh/yr
Production Summary		
Component	Production kWh/yr	Percent %
Diesel generator 500kW	181,905	11.8
Diesel generator 250kW	922,960	60.0
Wind power	433,471	28.2
Total	1,538,335	100
Consumption Summary		
Component	Production kWh/yr	Percent %
AC Primary Load	1,442,553	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	1,442,553	100

Table 7 electrical summery for wind-pv-diesel hybrid power system

Excess and Unmet		
Quantity	**Value**	**Units**
Excess Electricity	212,553	kWh/yr
Unmet Electric Load	0	kWh/yr
Capacity Shortage	0	kWh/yr
Production Summary		
Component	Production kWh/yr	Percent %
Solar power	274,500	16.5
Diesel generator 500kW	156,875	9.46
Diesel generator 250kW	800,388	48.2
Wind power	427,276	25.8
Total	1,659,038	100
Consumption Summary		
Component	Production kWh/yr	Percent %
AC Primary Load	1,442,553	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	1,442,553	100

Wind-PV-diesel hybrid power system

Finally, as in Fig. 9 a wind-PV-diesel hybrid power system with wind capacity of 25, 50, 75, 100, 125, 150, 175, and 200 KW; PV capacities of 50, 100 and 150 KW; inverter capacities of 50, 100 and 150 kW; and two generators were simulated using HOMER software to find out optimal hybrid option and sizes with minimal COE. The

simulation results showed that the minimum COE of 0.348US$/kWh is obtained for a hybrid system comprised of wind turbine (200 kW), 150 kw PV panels, 150 kW inverter, and two diesels generators of 750 kW rated power. The total energy requirement of 1442553KWh which means an excess of 212553 kWh of energy during the yearlong operation (Table VII). Of this total amount of energy, the contributions of wind, solar and diesel components were 427276 (25.8%), 274500 (16.5%), and 857263KWh (57.7%) respectively. The cost of the fuel consumed during the year was 437,828.769 US$.

---

[1] All systems costs and ratings are taken from local market in Gaza (PV an diesel generators) and/or from neighboring countries in case of wind turbine.

Conclusions

Analysis, simulation and evaluation of affordable alternative energy systems for Dier El Balah quarantine center in Gaza Strip have been evaluated. This work took quarantine center in Deir al-Balah as a case study because, there is a power shortage problem facing Gaza Strip at the same time the spread of COVID-19 creates new demands of electricity to supply newly built quarantine centers. In the present case, the power systems viz. diesel only, wind-diesel, and wind-PV-diesel are analyzed based on fuel cost of 1.47 US$/L. The optimal solutions and sizes of hybrid components were determined. The lowest COE is found when we used PV-wind-Diesel hybrid power system that equals 0.348 US$/kWh.

References

1. O. M. Babatunde, J. L. Munda and Y. Hamam, “Hybrid energy system for low-income households,”IEEE Africon 2017 Proceedings, 07 November 2017.
2. Palestinian Central Bureau of Statistics, General Administration of Geographical Statistics, Department of Natural Resources Statistics, “Renewable energy in Palestine,” 2015, report number 2169. http://www.pcbs.gov.ps/pcbs_2012/Publications_AR.aspx
3. E. Ajlouni, H. Alsamamra, “A Review of Solar Energy Prospects in Palestine,” American Journal of Modern Energy,vol. 5, No. 3, 2019, pp. 49-62.
4. H. J. El-Khozenadar, F. El-batta,”Solar Energy as an alternative to conventional energy in Gaza Strip: Questionnaire based study,” *An-Najah University Journal for Research - A (Natural Sciences),* vol. 32(1) , 2018, pp. 47-74.
5. H. J. El-Khozenadar and F. F. El-batta, “Survey study for the usage of solar energy at household by the employees of Al-shifa medical complex in Gaza Strip”, IOP Conf. Series: Journal of Physics: Conf. Series **1108** 012093, 2018.
6. H. S. Salem, “The potential of wind energy in Palestine with health care and residential examples in the west bank and the Gaza Strip, ”Journal of Nature Science and Sustainable Technology, vol. 13, , 2019, pp. 74-97, Nova Science Publishers,ISSN: 1933-0324.
7. A. Juaidi, F. G. Montoya, I. H. Ibrik, F. Manzano-Agugliaro, “An over view of renewable energy potential in Palestine,”Renewable and Sustainable Energy Reviews, vol. 65, November 2016, pp. 943-960.
8. https://www.alwatanvoice.com/arabic/content/print/193174.html.
9. J. abu taha and H. Shaheen, “PV diesel hybrid energy supply for nasser hospital in gaza strip,” 2019 IEEE 7th Palestinian International Conference on Electrical and Computer Engineering (PICECE),26-27 March 2019, DOI:10.1109/PICECE.2019.8747171.
10. T. I. Abu Dabousa , M. M. Abdelati, “Modelling, simulation, and optimization of a Hybrid PV Solar System,” Journal of Al Azhar University-Gaza (Natural Sciences), vol. 20 (2), 2018, pp. 63-80.
11. J. Y. Alaydi, “ A parametric study of solar and wind energy in Gaza Strip,”International Journal of Scientific & Engineering Research, vol. 4, December-2013, pp. 140-147.

12. T. I. Abu Dabousa, ”Comparative study of photovoltaic solar systems installed in Gaza Strip,”M.Sc. Thesis in Electrical Engineering, The Islamic University of Gaza, February-2018.
13. H. Albisher, H. Alsamamra, “An overview of wind energy potentials in Palestine,”Journal of Energy and Natural Resources, vol. 8, 2019, pp. 98-108.
14. Y. F. Nassar, S. Y. Alsadi, “Wind energy potential in Gaza Strip-Palestine state,” Solar Energy and Sustainable Development, vol. 7, Dec. 2018, pp: 42 – 57.
15. R. Al Badwawi, M. Abusara and T. Mallick, “A review of hybrid solar pv and wind energy system,”Article inSmart Science, Smart Science, vol. 3, January 2015, pp. 127-138.

Figures

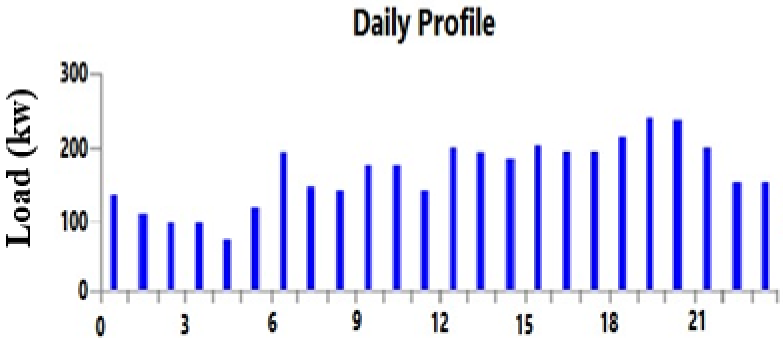

Figure 1

Daily Load profile for Dier El Balah quarantine center using HOMER.

Figure 2

Seasonal load profile for Dier El Balah quarantine center loadusing HOMER.

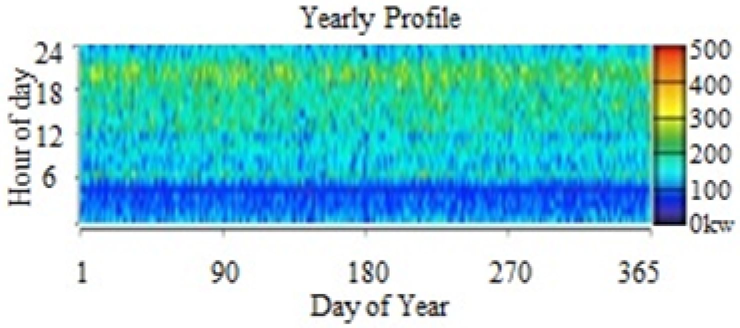

Figure 3

Yearly load profile for Dier El Balah quarantine center load

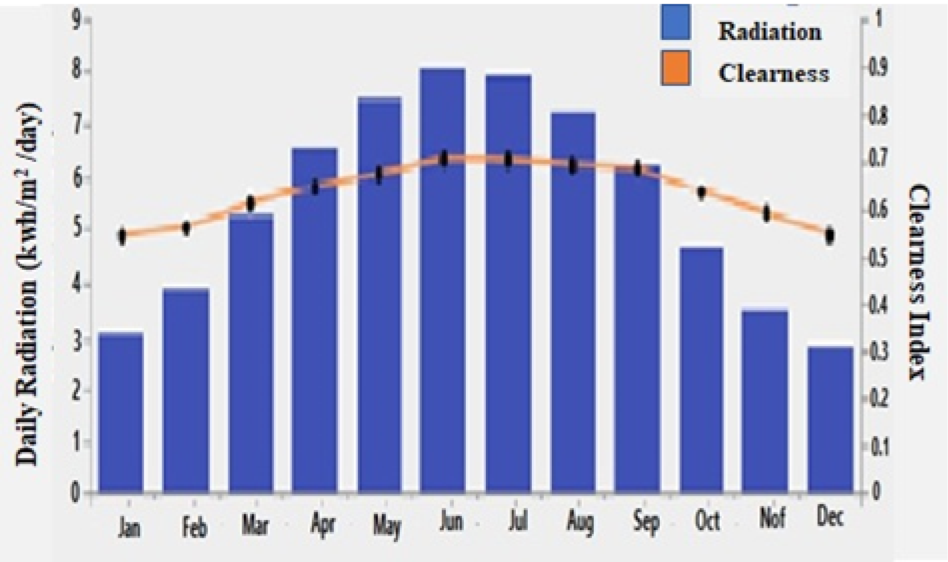

Figure 4

Solar GHI data for Dier El Balah location.

Figure 5

Temperature data for Dier El Balah location.

Figure 6

Monthly average wind speed for Dier El Balah location.

Figure 7

diesel-only system.

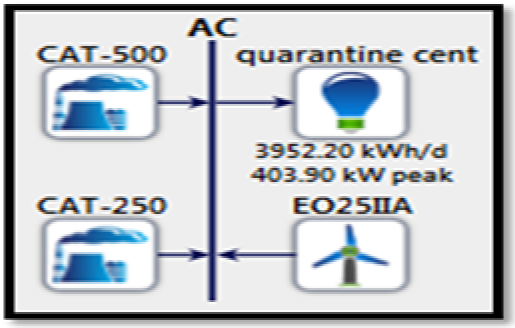

Figure 8

Wind-diesel hybrid power system.

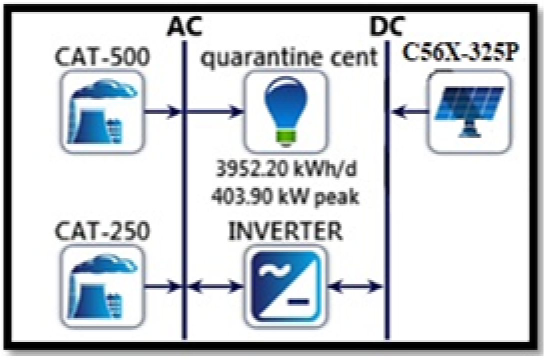

Figure 9

Wind-PV-diesel hybrid power system.