Techno-economic analysis for fertilizer house using hybrid power stations

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Accepted: 31 December 2021 / Published online: 7 February 2022
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Abstract
Renewable energy sources are not necessarily declining carbon sources. A hybrid generation network may be used in the power market to maximize the usage of renewable energy sources. The aim is to model hybrid power station and to determine the most effective system design through cost estimation. The power consumption of an agricultural device illustrates fertilizer house electricity needs and agricultural land irrigated pumps providing an average of 165.44 kWh/h of electricity per hour, an overall energy use of 7.12 kW and a total load of operation of 19.57 kW. The standard radiation intensity is 5.35 kWh per m² per day, the luminosity amount is an around 0.534, and the maximum wind velocity is 4.60 m/s. Electricity generation is $323,659.25 and the gross electricity expense (CO2) is $1325 and reflects an annual monthly power consumption of 21,264 kWh (47.1%) and 12,756 kWh/yr (36.8%).

Keywords Techno-economic analysis · Renewable energy · Hybrid power stations

1 Introduction

Renewable sources of energies are not necessarily declining carbon sources. Renewable energy originates in vast amounts from natural resources on the planet such as the air, wind, lakes, rivers and plants (Lund 2007).

A hybrid grid (HG) is a distribution electrical network that facilitates the penetration of different local generation sources, with or without storage devices (Lund 2007). For reliability and economic purposes, a HG can include renewable energy source (RES), conventional generators, storage devices and consumption loads. A HG can operate in both grid-connected (GC) mode and isolated mode. In GC mode, the HG is linked to the main grid through a point of common coupling, and an energy trading can be benefit by receiving or sending energy with the grid as consumer or vendor.

In view of the challenges to renewable energy expansion, hybrid renewable energy (HRE) is considered of most significance in upcoming days for power generation systems (PGSs). Even as its research continues technologically and economically, HRE PGSs have shown internationally recognized environmental and social benefits. The non-consistent output power for a standalone power generation systems contribution between several options is highly likely to be PV-WP generation systems. Net-connected hybrids have a large potential. The optimal design of these systems requires care, requiring trade-offs between decision-making criteria to improve sustained energy development. The technical literature is rich in proposals on methods for optimizing the size of hybrid PGS. Specific techniques have in the past been used on various methods. The new program will provide a unique technological performance (Patel and Singal 2018; Yang et al. 2007; Solar Photovoltaic Energy 2014; Januar 2017; Das et al. 2016; Mousa et al. 2004; Kamran et al. 2018). PSO (Lund 2007), genetic algorithms (Shahzad et al. 2017) and (Sen and Bhattacharyya 2014), nonlinear, mixed integer program (Patel and Singal 2018), dual-simulation annealing tabu search algorithms (Yang et al. 2007) and specific prospects for dual GMP price optimization. A certain target feature is assumed in general to be reduced,
which mainly is the overall cost of the system; certain technological and environmental criteria may be incorporated in the sizing phase in two schemes: firstly, considering the necessities as restrictions and, secondly, the transfer of the additional method. Therefore, the ultimate judgment on both methods is similarly relevant to all system requirements / variables. With the aid of a multi-objective PSO or genetics algorithm, the Pareto system is considered to be a great solution collection in Vergura and Lameira (2011) and (Bouakkaz et al. 2019) at the same time to boost objective functions (environment, economic or technical). Thus these methods provide the best solution for different PV-WP configurations, thus leaving the decision maker’s final choice, which may not be a simple task. In addition, all the parameters in this case are equally relevant. Essence, the right hybrid PV-WP method, a big balance of various parameters in design, contributes to a suboptimal solution cannot be derived from the solutions that are already proposed. The particle swarm optimization (PSO) algorithm was used for optimal location and tuning of a new custom power device (CPD) for minimization of the total CPD-injected currents and the total harmonic distortion (THD) of current and voltage. Hence, the real-time control of reactive power with CPD was suggested. The hybrid approach incorporates a variety of generation technologies from both renewable and fossil-based sources (Shahzad et al. 2017; Sen and Bhattacharyya 2014). Usage of the dual generation network will be a way to improve and have a potential benefit for the usage of renewable energy in the power segment (Patel and Singal 2018).

The usage of electricity on an area involves composting houses and pumping activities with a minimum of around 21.4 kW for irrigation and other specifications.

1.1 Wind and solar hybrid power generation system

Hybrid power production combines PV, wind power, pump, inverter and control (Patel and Singal 2018). A hybrid network has been developed with device load, loading of the battery and loading the safety system (system load) (Solar Photovoltaic Energy 2014).

1.2 Deployment of PV energy

Photovoltaic (PV) technology turns the produced lunar energy into one of the world’s greatest origin of electricity. Such photovoltaic system is one of the technologies most mature such that it is a future-oriented product (Solar Photovoltaic Energy 2014; Januar 2017).

When operating, solar cell apparatus like PV modules, converters, inverters, cables, transformers and additional apparatus must be arranged according to their supporting component (Mousa et al. 2004). The usage of solar power technologies is split down into grid networks and off-grid technologies. The electricity expended on battery storage in off-grid systems (Januar 2017; Mousa et al. 2004).

Silicium has grown well as a key substance for PV panels. The use of silicon as a raw material in the manufacture of solar panels is shown by the advancement of the technologies that follows and by the availability of silicon. Silicone types have been identified as mono-c-Si, poly-c-Si and EFG ripple silicone (Januar 2017; Mousa et al. 2004), respectively, c-Si. Silicone is a type of mono-c-Si.

PV modules must be designed for the usage of the photovoltaic system in a power station design. Such photovoltaic modules are attached to help apparatus like batteries, inverters, wires, converters and other associated devices (Kamran et al. 2018). Therefore, with an off-grid system (Januar 2017; Mousa et al. 2004; Vergura and Lameira 2011) in the system for solar electricity which needs the use of batteries is suitable.

1.3 Efficiencies of photovoltaic modules

The efficiency of PV cell component is illustrated by the photovoltaic material’s physical properties, as the PV cell soak up heat from the daylight, then converted into electrical power. The PV module function factor is presented in the next equation (Solar Photovoltaic Energy 2014):

\[ P_m = -(pD_h + q)(T_u + 0.03375D_h) + rD_h + s \]  

where \( D_h \) is the power consumed by PV cells as a least amount solar radiation, \( W / m^2 \); \( T_u \) is the available temperature across PV cells, \( K \); and \( p, q, r \) and \( s \) are a constant in the PV regression.

1.4 Arrangement of PV cells

In real-life uses, the PV module is required to manufacture a mixture of PV-solar modules. The system for PV module may be series and parallel based on the requirements when the pressure of the DC decreases or output. The following equation indicates the solar cell unit voltage (Patel and Singal 2018):

\[ V_{PV} = N_{PV}.V_{PV} \]  

Also the output power \( P_{PV} \) of the PV cell is:

\[ P_{PV} = N_{PV}.N_{PV}.V_{PV}.J_{con}J_{oth} \]

where \( N_{PV} \) is a sequential PV link number; \( N_{PV} \) is the parallel PV module strings link number; and \( J_{con} \) and \( J_{oth} \) are the variables that cause contact losses and other damages, such as loss triggered by accumulation of other module particles.
1.5 Inclusion of radiation by PV cells

The sum of sunbeams that can be provided by the PV panels is the cause that produce electric power. In reality, the data of the calculated or observed sunlight intensity on a weather can only give the energy taken by the PV cell for the flat circumstance but the orientation of the installation of the PV panel given a twisted angle to maximize its values (Januar 2017). The model from Perez:

\[
\zeta = \frac{(X_{yu} + X_{E})/X_{yu} + 1.041\phi_z^2}{1 + 1.041\phi_z^2}
\]

(4)

\[
\Lambda = \frac{X_{yu}m}{X_{on}}\frac{X_{yu}m}{X_0/\cos \phi_z} = \frac{X_{yu}}{X_0}
\]

(5)

where \(m\) is the mass of air.

The beam suppression coefficient \(y\) and \(u\) is the visibility coefficient, \(X_1\) and \(X_2\), are the features galaxy illumination correspondingly. The relation is subjected to as the Perez factor and its usage is shown in Table 1.

\[
P_1 = P_{11}(\zeta) + P_{12}(\zeta)\Delta + P_{13}(\zeta)\phi_z
\]

(6)

\[
P_2 = P_{21}(\zeta) + P_{22}(\zeta)\Delta + P_{23}(\zeta)\phi_z
\]

(7)

The angular position of the whole solar circumference is found by the ratio:

\[
\frac{d}{e} = \frac{\text{peak}[0, \cos \theta]}{\text{peak}[\cos 45, \cos \theta_z]}
\]

(8)

After that the diffused radiation on the inclined plane can be determined by:

\[
X_{th} = X_{yu} \cos^2 \left(\frac{\beta}{2}\right) (1 - P_1) + X_{yu}P_1 \left(\frac{d}{e}\right)
\]

+ \(X_{yu}P_2 \cdot \sin \beta
\]

(9)

1.6 Wind turbine conversion system

The power produced by the wind turbines is influenced by many factors. Factors affecting the output capacity include aerodynamic performance efficiency, mechanical transfer \(\mu\) and electric energy conversion efficiency \(\mu\) (Bouakkaz et al. 2019). In addition, the wind turbine’s efficiency depends often on the state of the wind turbine field and the elevation of the center showing the generator location toward the ground floor (Yang et al. 2007).

The measurement effects of the wind turbine installed are described by:

\[
P_w(W_v) = \begin{cases} 
P_w \left(\frac{v}{v_d - V_d}\right) & V_d \leq V_v \leq V_n \\
0 & V_v \leq V_d \text{ and } V_v \geq V_n 
\end{cases}
\]

(10)

where \(P_w\) is wind output power, \(V_d\) is reduced wind speed, \(V_n\) is standard wind speed and \(V_v\) is velocity of wind.

The wind speed system had a significant effect on the strength of the generated wind turbine. The vertical profiled speed of wind in a horizontal homogenous environment, like desert, grassland, plane field and other areas, is strongly defined by this wind speed profile. The equation shown below provides the fundamental outline of the wind speed perpendicularly (Yang et al. 2007):

\[
\frac{v}{v_d} = \left(\frac{e}{e_{ref}}\right)^k
\]

(11)

where \(v\) is the wind velocity of center \(e \text{ m } / \text{s}\); \(v_d\) is speed of the wind comparison \(e_{ref}\); \(m / s\); and alpha is a model of the power rule.

1.7 Optimized model for renewable energy using MATLAB

The hybrid optimization model for renewable energy developed in MATLAB software is created for the design and comparison of power generation technologies by the US National Renewable Energy Laboratory (NREL) (Shahzad et al. 2017; Sen and Bhattacharyya 2014) and (“HOMER xxxx), developed in the USA. MATLAB models reflect the physical comportment and total cost power of the device, which includes overall deployment and cost of operation (Okonkwo et al. 2017).

Past research presented findings and assumptions about the MATLAB model in hybrid device development (Lund...
The goal of this analysis is to model hybrid systems and to decide, according to cost estimates, the best device configuration (Figs. 1 and 2).

2 Research techniques

2.1 Power load

In addition, the demand for electric power is not so strong in farm land contrasted with the need for electric power both in industrial and rural areas in the residential sector. Power requirement in the fertilizer house and the power

Fig. 1 Methodology of Hybrid Power Generation Systems

Fig. 2 Optimization of MATLAB program ("HOMER xxxx)
needed for irrigation pumps in the agricultural area are the requirements for electric power which have to fulfill in an agricultural sector. Figures 3 and 4 display regular and monthly demands for electricity.

The total power usage in the hour is 165.44 kWh/day, the total energy required in the university farm is 6.89 kW and the highest electricity use during use is 20.46 kW, shown in Fig. 5. Based on a one-year usage model, the utilization of electrical resources in the farm unit at 7 a.m. indicated that all equipment, such as watering pumps and sprinkles and water deliveries to agriculture, was operationally efficient at that period.

### 2.1.1 Solar irradiance available across the earth

The solar irradiance schemes provides normal radiation details at the research site for one year. The study also displays the sunlight index norm with information regarding the surplus of solar energy on the surface of the planet and shifts in the atmosphere (Adaramola et al. 2014). Figure 6 indicates an overall 5980 W/m²/radiation day and a radiation source of 3,870 W/m²/day, and a lower radiation amount of 2380 W/m²/day is recorded in February and 5380 W/m²/day in November. The maximum ranking for sunlight is 0472, for February it is 0513 and for October it is 0433, the lowest. The value is high of 0.434. The data indicate a linear connection between the overall sum of sunlight and the lightness of the same month.

### 2.1.2 Wind sources

The monthly forecasts of the wind speed over a year show. The statistics in Fig. 7 indicate that the wind speed limit is
3.30 m/s. The highest wind speed is 3930 m per second in August and the lowest wind speed is 3380 m per second in March. Air speed scale is 0 m above sea level and a reference point is 50 m above sea level. For the wind speed trend, a linear meaning of wind strength varies between 0.01 m (Askari and Ameri 2012) and surface ruggedness (Akinyele et al. 2018).

2.1.3 Fuel sources

The properties of the diesel fuel are shown in Fig. 8. The estimate reveals that 43.20 MJ / kg is the lowest fuel heating weight, 820 kg/m³ is diesel fuel mass, 88% of fuel oil is gasoline, and 0.4% of fuel sulfide is jet petrol. Different factors equal to $0.7/L were liable at the time of these investigations for purchasing diesel fuel and rising inflation due to increased demand.

2.2 Parameters of hybrid system

Figure 9 displays hybrid device elements composed of plane horizontal PV, wind generators, engines, batteries and converters. The hybrid device architecture demonstrates that the network has been designed to accommodate non-run generation systems for wind generators, photovoltaic systems and generators. This hybrid network is intended to fulfill the enhancing power supply from renewables. If green power is not enough for the generation of electricity, turbines are used as backups for resources. In
every segment of the hybrid system, the following is explained.

### 2.2.1 Wind generator

The common model 1 kW wind turbine chosen in this analysis is G1 abbreviation with an output of 1 kW. With a rate of €7,000.00, the expense of repairing the wind turbine after it has finished is $7,000.00, so the running so repair benefit of the turbine is $140,00 a year. The expense of removing the turbine after its expiry. The wind turbine runs for 20 yrs. and the length of the turbine pitch is 18 m long.

The wind power generator mounted transfers electricity to the wind speed of the wind turbine. Based on the air speed obtained and shown in Fig. 10, the wind turbines produced electricity. It can be seen from the picture that the Typical 5 kW-type wind generator has a rising strength at wind speeds of up to 9 m/s and that the generator output decline at the speed of up to 15 m/s.
2.2.2 PV module

Research includes a solar platform with wind mill and generators to fulfill electrical resource requirements in agriculture. Standard PV flat plate is named after the solar panel and the average production of 1 kW of solar panel, the construction cost is $3,000.00 (Fig. 11 indicates the costing curve for the building of solar panels in kW) and with a maintenance expense of $10,00 a year if the 25-year utilization cap of 12.00 is exceeded.

2.2.3 Generator

The analysis should have a power of 21.4 kW for the energy required in the university farm. Renewable energy production does not guarantee adequacy as solar panel systems do not produce power during the night and wind turbines’ output is heavily contingent on the availability in the natural environment of wind energy. The electronic power generators used are mechanical fuel types, diesel fuel type and $0.7% of the quality which have characteristics such as minimum heating intensity 45.4 MJ / kg, 820 kg / m3 mass, 88% carbon content which 0.4% sulfur. The price for $per kW of generators is $500.00, the expense for repair during the running cycle is $15,000.00, and the prices for production and repairs are $0.030 and $500.00.

2.2.4 Storage batteries

When the power flow cannot begin directly from the produced energy source, batteries must meet electricity requirements. The electricity generated by the wind turbines, solar panels and generators is provided by batteries. The form of battery in Table 2 for this analysis is standardized 1 kWh NI-OH with a nominal 12 V voltage and a standard output of 2kWh and an overall stated capacity of 94.3 Ah battery. The total expense is $300.00, the expense of maintenance for 10 years and the cost of service and rehabilitation of $20.00 a year.

2.2.5 Converter

As DC transducers that are generated in the form of AC power that renewables, a converter will be required. In order to do this analysis, the converter type utilized is a 2-kW unit converter, with $300.00 installation costs, which includes a $300.00 service fee over 15 years.

3 Results and analysis

3.1 Study of complex cases

A variation of variable response factor is used in susceptibility situations. As the importance of several wind speeds and other fuel price values is calculated, cases of vulnerability subtract each importance in conjunction with the amount of variations of each value. Homer would then refine all the responsiveness values reached. In the sensitivity study, when assessing the design of the device, the importance of the fuel price and maximum wind speed is taken into account. At 0.7$/l and average wind velocity at 3.30 m per square meter during network growth, the price of diesel fuel was. This research rate has a retail value of $0.35 to $0.70 to $1.40. The wind speed differs from $3.00, 3.30 and 8.00 m / s, respectively. Figure 12 displays the sensitivity analysis figures, showing the instability of the growing factor of responsiveness in optimization experiments, the amount of power created by each kind of device, for example, solar panels, wind turbines and generators. For this study, lowest power, operational and initial capital costs and the maximum jet fuel reactivity levels are seen with the fuel price of $140 /L with average wind speeds of 80.0 km/s for comparison with $350 /l diesel fuel and an average wind speed of 33.0 m/s.

The findings of this study are shown in a surface graph in Fig. 12, showing that the Y-axis reflects the average diesel fuel price ($/L), the wind vector value (m / s) for the X-axis. A surface graph of the cost of electricity (CoE) and the Net present cost (NPC) calculation is taken into account for the product evaluation.

3.2 Outcomes of optimization

For the device setup with a sensitivity in diesel fuel rates of $70.0 / L and an usual wind speed of 33.0 m / s, optimization outcome shall be given. The outcomes of the development phase was focused on the lowest cumulative current (NPC) net expense of $211,894.30 and energy costs of $0,424. A 15.0 kW generator, 15.5 kW solar cell, a
A 15-string battery, a 7.83 kW converter and a system of charging of processes are created by designing multiple components.

The gross operating loss and fixed costs are shown in Fig. 13 which represent the system optimization results, respectively, at $21,894 and $16,576. The study of budget overviews covers capital spending, operating expenses, depreciation, improvements and investment in real estate. The net present cost valuation of capital and operating expense for the fixed expenses needed a valuation of 34.75%. This expense demonstrates that the cost of capital is a core asset and a foundation for device growth.

The estimated generation of electrical power per month is 20.436 kWh/year and 22.745 kWh/year per solar cell component and turbine. The color coding reveals the color orange, as the electricity generated in a pv module is 47.1% and the energy in a generator is 52.9%, as shown in Fig. 14. The result indicates that energy supplied by the high-value turbine is compared to energy created by the solar cells throughout power generation. Annual AC power consumption at the university plant contributes to 39,055 kWh/year. The unit has produced 45,130 kWh/year of electricity, and the energy surplus can be retained in the battery at 1.882 kWh/year or 4.17%.
4 Conclusions

The aim of this analysis is to study the hybrid farm’s energy fulfillment system and economic efficiency by simulating a hybrid power plant network and deciding on the optimal configuration and costs. The average power output per hour is 146.33 kWh/d per annum. The usual radiation is 4.71 kWh per m² per day. GHI Study records. In the sensitivity study, there are differences in the results of the sensitivity element, measuring the strength from different power plant types, such as solar panels, wind turbines or generators. The findings for improving the design of the system with a price sensitivity vector in diesel fuel of 3.30 m per s are $0.700 per liter. The gross expense is $0.424 and the cost of power is $0.424, as a result of various components being combined, with the aggregate costs of a generator of 12.0 kW, a pv module of 12.5 kW, a 15 V-line battery, a transformer of 7.83 kW and a loading process. The total electricity per month (47.1%) and 23 866 kWh/year (52.9%) was provided by PV cells and power generators. The total production of the AC power farm is 39,055 kWh/year and its machine generates 45,130 kWh/year, which ensures it is capable of producing an additional 1892 kWh/year or 41.7% surplus electricity.

Declarations

Conflict of interest The authors confirm that no conflict of interest.

References

Adaramola MS, Agelin-Chaab M, Paul SS (2014) Analysis of hybrid energy systems for application in southern Ghana. Energy Convers Manag 88(2014):284–295. https://doi.org/10.1016/j.enconman.2014.08.029
Akinyele D, Belikov J, Levron Y (2018) Challenges of microgrids in remote communities: A Steep model application. Energies 11(2):1–35. https://doi.org/10.3390/en11020432
Askari IB, Ameri M (2012) “Techno-economic feasibility analysis of stand-alone renewable energy systems (PV/bat, wind/bat and hybrid PV/wind/bat) in Kerman, Iran. Energy Sour Part B Econ Plan Policy 7(1):45–60. https://doi.org/10.1080/1556724090330384
Bai S, Rao KVS (2014) Design and integration of solar-biomass hybrid energy system for drip irrigation pumping. J Chem Pharm Sci 2014:247–248
Bouakkaz A, Haddad S, Martin-García JA, Gil-Mena AJ, Jiménez-Castañeda R (2019) Optimal scheduling of household appliances in off-grid hybrid energy system using PSO algorithm for energy saving. Int J Renew Energy Res 9(1):427–436
Cotfas DT, Cotfas PA, Kaplanı̈ E, Somolı̈a C (2014) Monthly average daily global and diffuse solar radiation based on sunshine duration and clearness index for Brasov Romania. J Renew Sustain Energy. https://doi.org/10.1063/1.4896596
Das HS, Dey A, Wei TC, Yatim AHM (2016) Feasibility analysis of standalone PV/wind/battery hybrid energy system for rural Bangladesh. Int J Renew Energy Res 6(2):402–412
“HOMER 404.”
Januar R (2017) Comparative analysis of 20-MW solar thermal and PV power plant in rongkop, Indonesia using LCOE simulation method. J Clean Energy Technol 5(5):383–388. https://doi.org/10.18178/jocet.2017.5.5.402
Kamran M, Asghar R, Madsar M, Ahmed SR, Fazal MR, Abid MI, Zameer MZ (2018) Designing and optimization of stand-alone hybrid renewable energy system for rural a. Int J Renew Energy Res 8(4):2385
Lund H (2007) Renewable energy strategies for sustainable development. Energy 32(6):912–919. https://doi.org/10.1016/j.energy. 2006.10.017
Mousa M, Sagar VR, Gajbhiye VT, Kumar R (2004) Pesticides persistence in/on fresh and dehydrated brinjal. J Food Sci Technol 41(4):429–431
Okonkwo EC, Okwose CF, Abbasoglu S (2017) Techno-economic analysis of the potential utilization of a hybrid PV-wind turbine system for commercial buildings in Jordan. Int J Renew Energy Res 7(2):908–914
Patel AM, Singal SK (2018) Economic analysis of integrated renewable energy system for electrification of remote rural area having scattered population. Int J Renew Energy Res 8(1):523–539
Sen R, Bhattacharyya SC (2014) Off-grid electricity generation with renewable energy technologies in India: an application of HOMER. Renew Energy, https://doi.org/10.1016/j.renene.2013.07.028
Shahzad MK, Zahid A, Rashid T, Rehan MA, Ali M, Ahmad M (2017) Techno-economic feasibility analysis of a solar-biomass off grid system for the electrification of remote rural areas in...
Pakistan using HOMER software. Renew Energy 106:264–273. https://doi.org/10.1016/j.renene.2017.01.033

Solar Photovoltaic Energy (2014) “Technology Roadmap Solar photovoltaic energy.” Current.

Vergura S, Lameira V (2011) Technical-financial comparison between a PV plant and a CSP plant. Sist Gestação 6(2):210–220. https://doi.org/10.7177/sg.2011.v6.n2.a9

Yang H, Lu L, Zhou W (2007) A novel optimization sizing model for hybrid solar-wind power generation system. Sol Energy 81(1):76–84. https://doi.org/10.1016/j.solener.2006.06.010

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