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Techno-economic analysis of a smart-grid hybrid renewable energy system for Brisbane of Australia

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Abstract

The immense percentages of people of the world are living mostly in the decentralized, rural and remote areas those are geographically secluded from the grid connection. Power distribution and continuous fuel transportation to produce the electrical energy for these areas pretences a great challenge. A smart-grid hybrid energy system has been designed and simulated to support a small community considering an average load demand of 34 kWh/d and peak load of 4.6 kW. The total simulation and optimization process of the hybrid energy system have been done by HOMER Software with the meteorological data. The simulation results ensure that the proposed system is economically and environmentally feasible. The results show that Net Present Cost (NPC) and CO_2 emission can be reduced about 29.65% per year compared to the conventional power plants. The NPC of the optimized system has been found about US$ 33,310.00 having the Cost of Energy (COE) about US$ 0.209/kWh. This analysed hybrid system will be applicable for similar meteorological and environmental conditions. This analysed hybrid system will be applicable for similar meteorological and environmental conditions. The urban area, including the central business district, are partially elevated by spurs of the Herbert Taylor Range, such as the summit of Mount Coot-tha, reaching up to 300 meters (980 ft) and the smaller Enoggera Hill, Brisbane, Australia. Using renewable energy resources in off grid hybrid energy system might be a solution of this issue. Moreover, high cost of renewable energy systems has led to its slow adoption in many countries. Hence, it is vital to select an appropriate size of the system in order to reduce the cost and excess energy produced as well as to maximize the available resources. Reduction of some greenhouse gasses as well as reduction of per unit cost according to the market price are main contribution of this research. The analysed hybrid solar-wind-diesel renewable energy system will be the most feasible and environment friendly in comparison with other traditional or conventional energy sources in terms of reliability and cost effectiveness.

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Keywords: HOMER; Off-shore Area; Optimization; Renewable Energy; Sensitivity; Simulation; Solar Energy; Wind Energy.

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1. Introduction

Usage of renewable energy for power generation is a priority research topic at the present situation. Remarkable efforts to expand the sources of various forms of energy to intensify a deployment of renewable and sustainable energy slots have been increasing all over the humanity. The first priority in intensifying renewable energy deployment in the 21st century is the combined effects of the depletion of fossil fuels and the awareness of environmental degradation [1]. Therefore, policy makers and researchers are paying more attention to research in this field. For an instance, before 2020 the European Union countries aim to use renewable sources and get at least 30% of its potential energy [2]. There are several renewable energy resources such as biomass, wind, geothermal energy, solar, hydro-electric and tidal power. Hybrid renewable energy resources can reduce the emission of harmful gases and reduce the use of imported power [3, 4]. The renewable energy resources such as solar and wind energy are being hugely enriched at the various places in Australia [5]. Over the last two decades, electrical energy consumption in Australia increased significantly for dramatically economic expansion and the lack of measurement of energy preservation. It is expected that peak loads will reach 65 GW in 2027 which causes over $100 billion might be the total investment. The Brisbane city is on a low-lying floodplain [6]. Many suburban creeks crisscross the city, increasing the risk of flooding. The city has suffered three major floods since colonization, in February 1893, January 1974, and January 2011. The 1974 Brisbane Flood occurred partly as a result of "Cyclone Wanda".

This paper is organized in five sections: Section 1 is the introduction, Section 2 described the Methodology, a hybrid renewable energy system model is discussed in Section 3, Section 4 presented the Simulation results and discussion and finally, the conclusion is in section 5 [7].

Nomenclature

NPC	Net Present Cost
COE	Cost of Energy
HOMER	Hybrid Optimization Model Energy for Renewable

2. Methodology

2.1 Data Resource and Location Analysis

The daily solar radiation data and average wind speed data have been collected for every month for a specific year from the Australian meteorological department. Brisbane is in the southeast corner of Queensland. The city is cantered along the Brisbane River, and its eastern suburbs line the shores of Moreton Bay. The estimation of solar insulation on horizontal surface has been done by using well known Angstrom Correlation and the sunshine hour data of Brisbane coastal area, Australia. Average output wind speed was tested for 16.3 km spatial resolution, and from the Australian Meteorological Department the considered data has been collected for the Brisbane coastal area [8].

2.2 Hybrid Energy System Component

2.2.1. Solar (Photovoltaic) Energy System Module

The annual average solar radiation data can be collected from the meteorological department. The synthesized 2304 hourly values for a year can be created by HOMER renewable energy software. US$ 50/kW has been considered as the rate of PV component counting the mechanism for coastal areas of Brisbane, Australia. The life span of the system has been preferred as 2 decades. There are 3 types of module have been considered for PV modules, such as 5 kW, 18 kW and 30 kW. Table 1 shows the factors of PV module related with the simulation [9]. The monthly average solar irradiation data has been collected from the Australian Meteorological Department [10]. Same scale of load (kW) have been used for both summer and winter demand for comparison and analysis.

Table 1. PV array expenses.

Factor	Value
Net Cost	50 $/kW
Substitution Cost	40 $/kW
Maintenance and Operation Cost	1 $/kW
Life span	20 Years
Derating factor	80 %
Tracking System	N/A

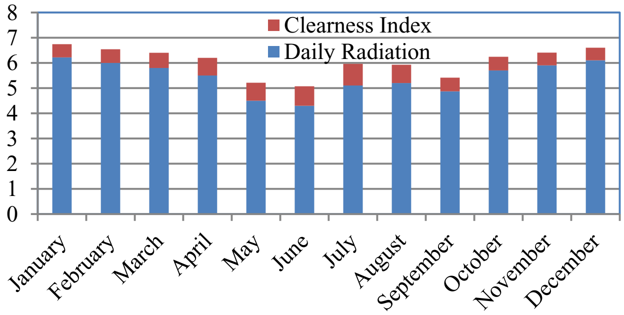

Fig. 1. Monthly average solar irradiation of Brisbane, Australia [10].

Fig. 1 shows yearly solar irradiation for a specific areas of Brisbane, Australia. Fig. 2 shows the cost curve of solar module. The cost curve has been drawn according to the current market price, power generation process and other costs.

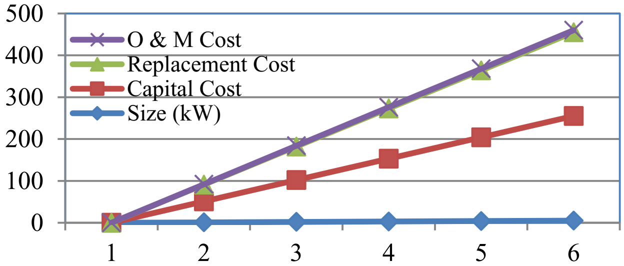

Fig. 2. Cost curve of PV array.

2.2.2. Wind Energy (Wind Turbines) System

How firmly the wind speed confides on the time of the day can be identified by the diurnal pattern strength [11]. The value of diurnal pattern strength has been taken as 0.25 for this analysis. The time of day leans to be the windiest on a standard all through the year can be addressed by the term hour of peak wind speed. The value of the hour of peak wind speed has been taken as 15 for this analysis. AXLS BWC EXCEL-S 10 kW wind turbine has been considered for this smart-grid hybrid renewable energy system. Table 2 represents the financial and methodological factors for preferred wind turbine. Fig. 3 shows the cost curve of wind turbine. The monthly average wind speed data has been collected from the Australian Meteorological Department [12].

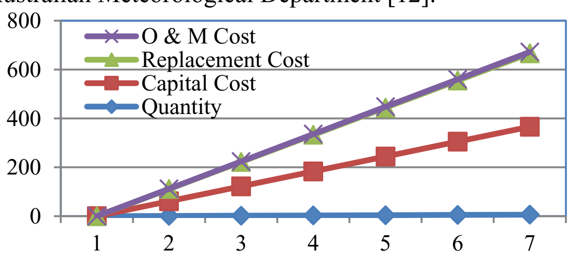

Fig. 3. Cost curve of wind energy.

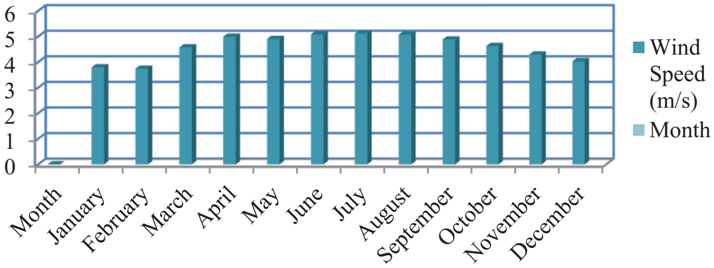

Fig. 4. Average wind speed of every month of Brisbane, Australia [12].

Fig. 4 shows the average wind speed of every month of a specific year for Brisbane of Australia.

Table 2: Financial and procedural factors of wind turbine.

Factors	Value
Rated Wind Speed	8 m/s
Starting Wind Speed	3 m/s
Cut-off Wind Speed	10 KW
Rated Power	15 m/s
Net Cost	40 $/kW
Substitution Cost	40 $/kW
Lifetime	15 Years
Maintenance and Operation expense	1 $/kW

2.2.3. Specification of Diesel Generator module

The fuel used in HOMER is modelled by a linear curve characterized by a slope and intercept at no load. Table 3 shows the assumptions of cost for a diesel generator and the other factor related with power generation and range of capacity. Fig. 5 shows the cost curve of a diesel generator. The cost has been generated by the power generation costs according to the fuel price [13].

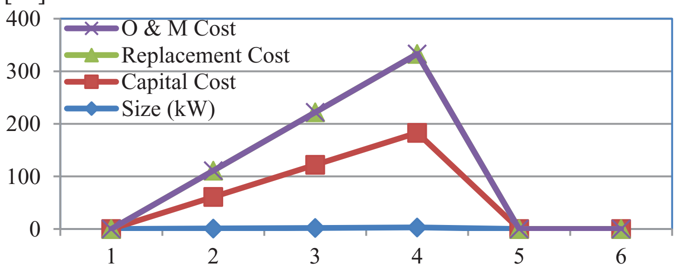

Fig. 5. Cost curve of diesel generator.

Table 3: Procedural parameters with cost conjecture for diesel generators.

Factors	Value
Net Cost	50 $/kW
Substitution Cost	45 $/kW
Maintenance and Operation Expense	0.022 $/kW
Lifetime	900000 Minutes (20,000 Hours)
Least Load quotient	30 %
Fuel Curve Slope	0.441/h/kW $_{output}$
Fuel Curve Intercept	0.062/h/kW $_{rated}$
Fuel Cost	0.5 $/litre

2.2.4. Battery module:

In that smart-grid hybrid renewable energy system, the Hoppecke 6OPzS 300 storage batteries have been utilized. There are five stipulations such as life time, initial state of charge, battery per string; substitution and principal cost have been shown in Table 4.

Fig. 6 shows the cost curve of battery module according to the relation between the cost and the capacity of a battery module [12]. The cost curve shows the relationship between the value and the parameters of battery module.

Table 4: Procedural parameters with cost assumptions for battery module.

Parameter	Value
Lifetime	1 decade
Initial State of charge	100 %
Battery per string	1 (2 V bus)
Principal Cost	40 $/kW
Substitution Cost	35 $/kW

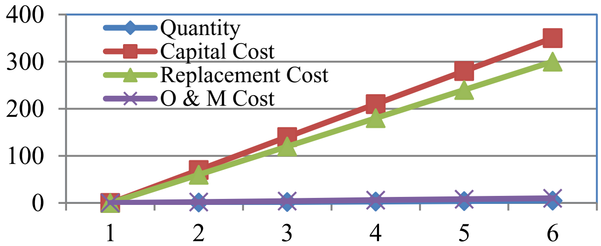

Fig. 6. Cost curve of battery.

3. Hybrid Renewable Energy System Model

An electrical primary load demand, renewable energy resources such as wind resource and solar resource and other mechanisms as like as PV array, battery storage, wind turbines and converters constitute an smart-grid hybrid renewable energy system. Fig. 7 shows the model of a complete hybrid renewable energy system. A community of 4 shops and 30 households has been considered in accordance with average load demand of that area in this analysis. The load demand can be classified by two groups such as pick hour and another one is off-pick hour. Yearly peak load up to 8.1 kW and primary load demand up to 80 kWh/d has been balanced by the arbitrariness and noise.

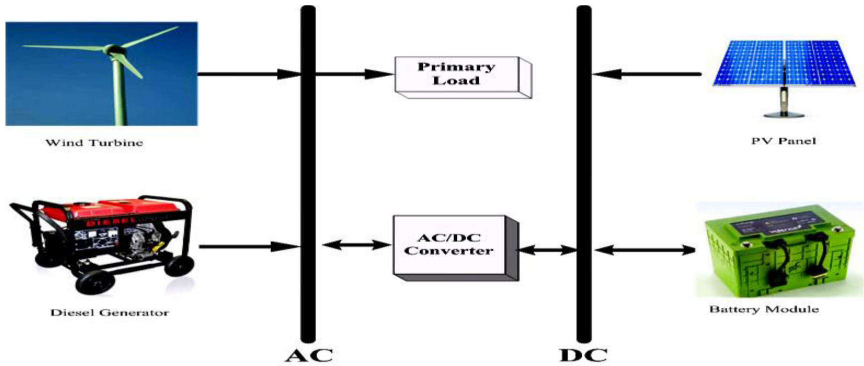

Fig. 7. Schematic diagram of a hybrid energy system.

4. Simulation Results and Discussion

For the assessment of the performances of different hybrid renewable energy systems in this research, HOMER simulation mechanisms have been used to perpetrate optimal systems performance analysis. The optimized outcomes for a specific group of sensitivity parameters akin to average wind speed, global horizontal solar radiation, highest yearly capacity shortage, diesel cost, and renewable fraction are represented emphatically in that optimization software. An optimal hybrid renewable energy system can be designed by HOMER renewable energy software. Fig. 8 shows the electrical energy generated with practicability from the smart-grid hybrid PV-wind-diesel-battery hybrid energy system. At the same time, with a base NPC of USD 160,226 and base COE of USD 0.431/kWh, a smart-grid hybrid PV, wind turbine, diesel generator and battery hybrid system is efficiently more feasible and this is observed by the sensitivity analysis. For the analysis HOMER renewable energy software and Matlab have been used precisely but the results represented here only from HOMER. Because the analytic result have also been validated by the mathematical modelling.

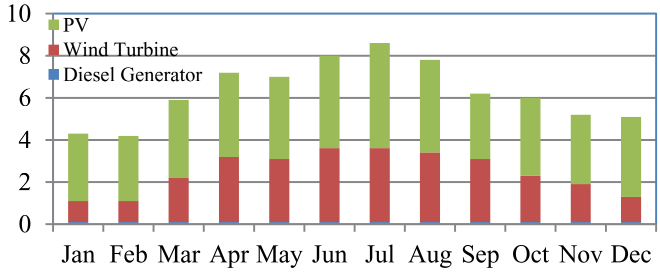

Fig. 8. Energy generated with practicability from the smart-grid hybrid PV-wind-diesel-battery energy system.

5. Conclusion

This study proposed a PV-wind-diesel-battery hybrid energy system for providing the power supply to a smart-grid community in Brisbane of Australia. A detailed simulation has been performed by HOMER considering manufacturing cost and efficiency for the proposed optimized hybrid renewable energy system model. The results confirmed that the COE of the optimized system is about USD 0.209/kWh, the NPC of the optimized system is about USD 33,310.00 and the operating cost is USD 2,037/year. The total sensitivity analysis, optimization and simulation process has been conducted through HOMER renewable energy software. The proposed hybrid system also ensured the reduction of CO_2 emission about 1600 tons per annum which indicates a significant environmentally friendly effort to the earth. From the simulation results, it is clearly indicated that the proposed hybrid renewable energy system model is economically and environmentally feasible in comparison with other conventional power generation systems. From the analysis and simulation results it can be said that the analysed hybrid energy system will be applicable for all over the world where the environment and other situation would be same.

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