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Economic Analysis and Simulation of Solar PV, Wind Turbine Hybrid Energy System Using HOMER pro

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A B S T R A C T

The aim of this study is the simulation and optimization of renewable hybrid energy system. The hybrid energy system includes solar PV, wind turbine, converters and battery storage system. Homer is a computation software used for this work that it is simulation model that analyzed the sizing, costing optimization and control strategy of the hybrid energy system. This paper determines the optimal renewable power generation system architecture for one of the largest metropolitan cities in Canada, Victoria metropolitan city. Hybrid energy systems feeding AC primary load of 2047.1 kWh/day energy consumption with a 290.62 kWh peak load demand. The simulation results indicate that optimized components and optimized cost of energy (COE) about 2.04 $, with 19.7 M$ of net present cost (NPC) and 100% of renewable fractions. The excess electricity in the suggested framework is observed to be 64.3%.

1. Introduction

In recent decades, energy consumption has been increased globally because of the population growth and technology development and because of limitation for fossil fuel resources, it caused a global energy crisis [1-4].

If all countries especially countries with higher energy consumption want to decrease the dependence on the fossil fuels, some other sources for energy should be introduced as a substitution [2,3,6]. Renewables could be the best option not only for remote communities but also for large and even metropolitan cities but due to the large energy consumption of these cities and limited supply of energy that is obtained from renewable energy sources because of their dependency on environmental condition like solar radiation or wind speed,

renewables cannot support and provide the demanded electricity continuously for metropolitan cities [3,5-8]. The integration of hybrid renewable systems will be a completely trustworthy and also environmentally friendly system. Hybrid renewable system is a combination of several different renewable technologies [6-12].

The purpose of this study is the simulation and optimization of solar PV and wind hybrid energy system for electrical energy supply. Hybrid optimization model for electric renewable (HOMER) simulator has been used in present study. The object is to reach a design that optimizes the operation of a solar photovoltaic, wind turbine hybrid energy system.

2. HOMER program software

HOMER is an abbreviation of hybrid optimization model for electrical renewable and it developed by U.S. National renewable energy laboratory (NREL) [5,13]. Homer is a micro power simulation and optimization software that simplifies system evaluation and pricing in two grid-connected and stand-alone modes for a variety of applications. To use

HOMER, a model with inputs that describes the technology options, the cost of each component and the availability of resources are prepared. HOMER uses these inputs or a combination of components to simulate various system configurations. The results of HOMER simulation could be observed as a list of possible configurations arranged on the Net Present Cost (NPC) [3,5.8,14-16].

3. Population and location of area of study

Victoria is the capital city of the Canadian province of British Columbia, and is located on the southern tip of Vancouver Island off Canada's Pacific coast. Population of the city is about 85,792, while the metropolitan area of Greater Victoria, and has a population of 367,770, making it the 15th most populous Canadian urban region. The city is 48°25.7′ of latitude and 123°21.9′ of longitude (Figure 1).

Figure1. location of Victoria metropolitan city

4. proposed hybrid energy system

A solar photovoltaic energy source should be hybrid with other energy sources, whether used in either a stand-alone or grid-connected mode. For each hour, homer pro calculates the flows of energy to and from each component of the system. The simulation model has been designed by homer pro software, and consist of a solar PV, wind turbine, converter and battery storage. Figure 2 shows the block diagram of proposed hybrid energy system in this study.

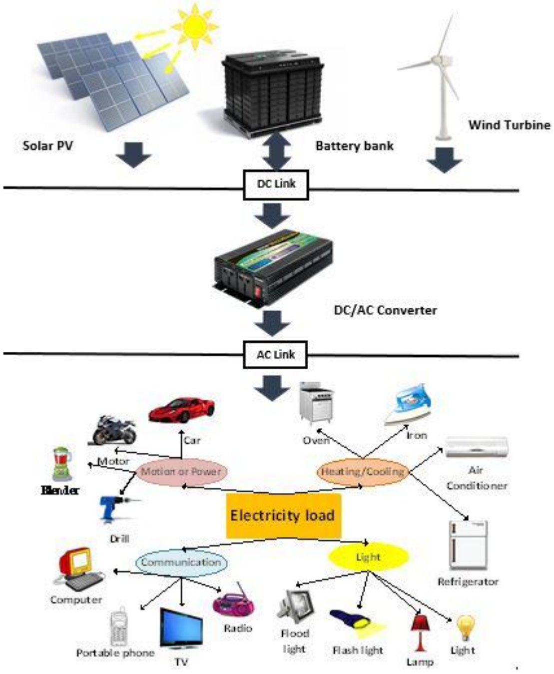

Figure 2. Hybrid Renewable Energy System block diagram

4. System component

4.1. Solar photovoltaic

We chose the Generic flat plate PV model for our simulation. A 1 kW solar PV energy system's capital and replacement costs are taken as 3000 $ while the annual O&M cost is considered 10$ per 1 kW capacity. The lifetime of the solar PV is taken as 25 years while a derating factor of 80% was applied on the electric generation from each PV panel. This study also considers the air temperature effects, thus there is a decrease in power efficiency of 0.5%/C. We assumed 20% of ground reflection percentage. Also no tracking system is included in the solar PV.

4.2. Wind turbine

The wind turbine that is considered in this simulation is a generic 10 kW. The capital, replacement and annual O&M costs of wind turbine are 5000$, 5000$ and 50$, respectively. The lifetime of a turbine is considered 20 years and the height of a hub were set as 24 meter.

4.3. Battery

The battery chosen for this study is generic 1kWh Li-Ion from the battery types provided by HOMER. The specification of the battery is 6 V, 167 Ah and 1 kWh with a lifetime of 15 years. The capital cost and replacement cost of battery is considered to be 600$ while the annual O&M cost are considered to be 10$.

4.4. Converter

Capital and replacement costs of converter for 1 kW is considered to be 300$ and 300$ respectively while the annual O&M cost are considered to be 0$. The

solar data information is shown in Figure4. Lifetime of the converter was set as 15 years, while the inverter efficiency was assumed to be 95%.

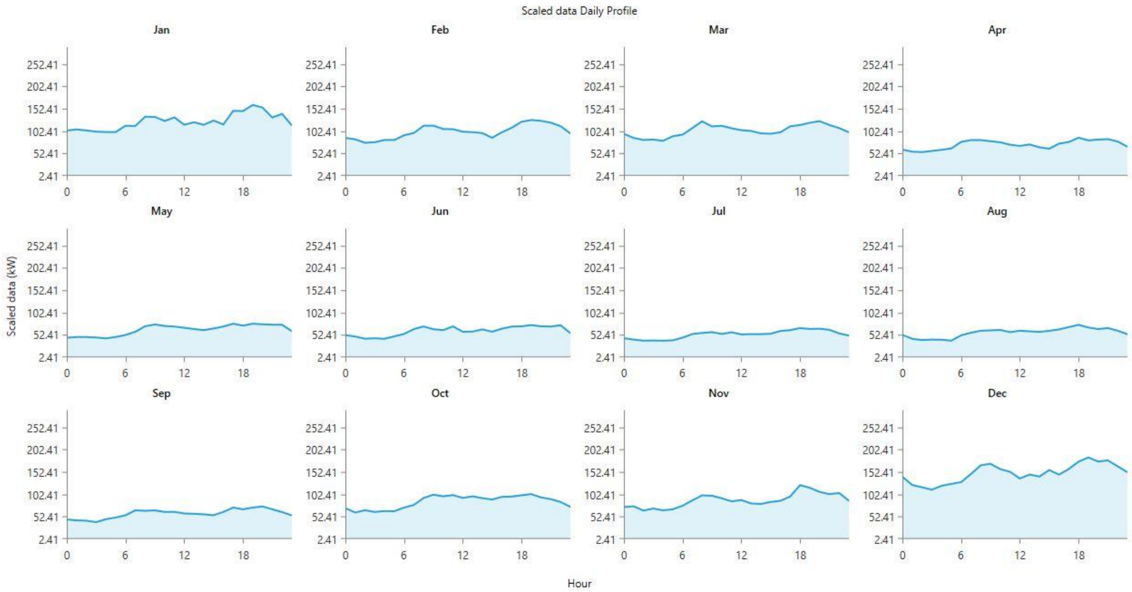

Figure3. The 1/500 scale monthly load profile for Victoria metropolitan city.

5. Model input information

5.1. Primary load information

The electrical demand is termed as load. The energy demand was estimated by considering the residential load consist of light, motion or power, heating, cooling and communication. The first step in architecture of system is to enter the hourly load in HOMER software. A 1/500 scale was applied in this study since data on Victoria metropolitan city electricity consumption comprised largescale load information. Monthly load profile shows in figure 3. Scaled annual average of the system is 2047.1 kWh/day and the peak load is 290.62 kWh. The load factor is 0.29.

5.2. Solar radiation information

The solar radiation data for region of selected area of study is obtained from the NASA Surface meteorology and Solar Energy database. The data showed that the Scaled annual average is 3.40 kWh/m2/d. the Victoria metropolitan city's monthly

5.3. Wind speed information

Wind energy data for region of selected area of study introduced by NASA surface meteorology. Scaled annual average of wind speed is 4.95 m/s. Figure5 shows the monthly wind speed for Victoria metropolitan city.

6. Results & Discussion

In this part HOMER simulation model has been utilized to consider a Hybrid energy system of solar PV, Wind turbine, battery and converter. The result of system architecture, cost summary and electrical are presented as below.

6.1. System architecture

The HOMER Simulation model presents a hybrid energy system architecture including 1102 PV panels, 116 Wind turbines, 9100 batteries and 839 converters as the optimal renewable power generation system at a 1/500 scale for Victoria metropolitan city. Table 1 are shown the simulation results of hybrid energy system architecture.

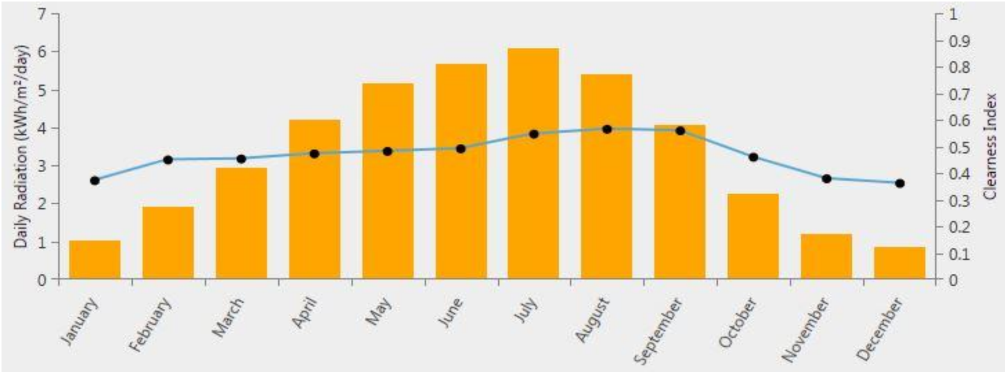

Figure4. Monthly solar data information for Victoria metropolitan city.

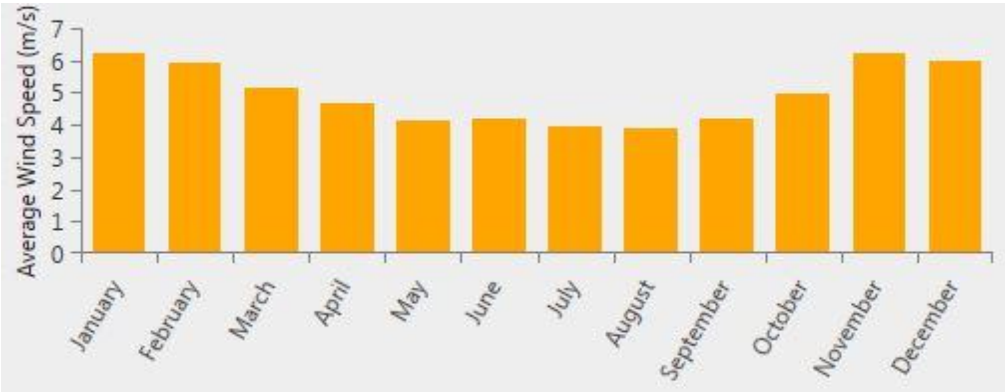

Figure5. Monthly wind speed for Victoria metropolitan city.

Table 1. hybrid energy System architecture

components	model	index
PV (kW)	Generic flat plate PV	1102
Wind Turbine	Generic 10 kW	116
Battery (strings)	Generic 1kWh Li-Ion	9100
Converter (kW)	System Converter	839

6.2. Cost analysis

The primary objective of the HOMER is to provide a cost-effective solution by minimizing the net present cost (NPC) in the optimized hybrid energy system architecture. In order to depict a clear picture of involved cost, Homer software generates a cash flow summary. Figure 6, shows the cash flow summary that involves the capital, fuel, operating, replacement and salvage costs with respect to the NPC for the solar PV and wind turbine hybrid power system. The cost of energy (COE), total net presented cost (NPC), operating cost and initial capital of the hybrid system are 2.04 $, 19.7 M$, 374,623 $ and 14.8 M$, respectively.

The NPC and annualized costs of the system are shown in Tables 2 and 3.

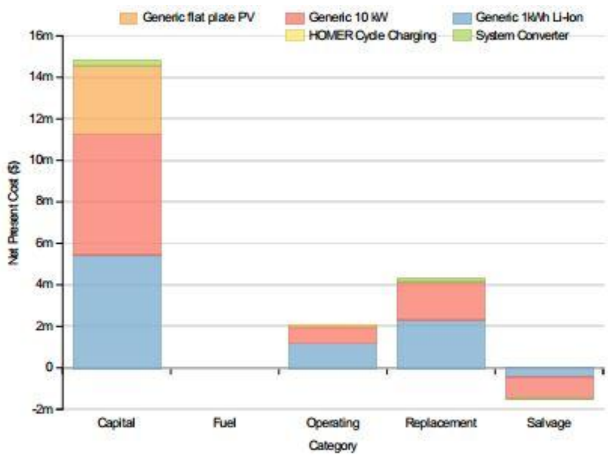

Figure 6. Cash flow summary of system

Table 2. NPC of the System

Components	Capital ($)	Replacement ($)	O&M ($)	Salvage ($)	Total ($)
PV	3,307,407	0	142,522	0	3,449,929
Wind Turbine	5,800,000	1,849,083	749,796	-1,042,077	7,356,802
Battery	5,460,000	2,316,535	1,176,404	-435,995	8,516,944
Converter	251,666	106,775	0	-20,096	338,345
System	14,819,073	4,272,393	2,068,772	-1,498,168	19,662,019

6.3. Electrical analysis

The electrical power generated by the sources is used to feed the AC primary load. The production amount of the monthly average electricity is shown in figure 7. From Figures 7 it is obvious that PV plays a bigger role in summer in the production of electricity from hybrid system and wind has a greater share in the production of electricity in winter. Table 4 shows the amount of electricity production, consumption and excess electricity of hybrid system.

The suggested system can produce a significant amount of electricity so that excess electricity is 64.3%.

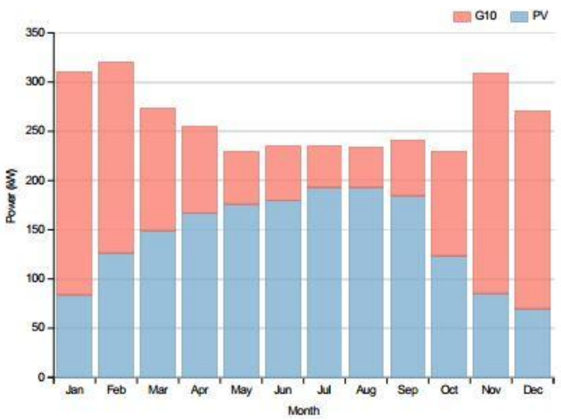

Figure 7. Average electricity production of the system

Table 4. Annual electrical component production, load and quantity

Quantity	Value (kWh/yr)	Percent (%)
Excess electricity	1,468,076	64.3
Unmet load	536	0.1
Capacity shortage	716	0.1
Renewable percent	100	100
Component	Production (kWh/yr)	Percent (%)
PV	1,265,718	55,43
Wind Turbine	1,017,820	44,57
Total	2.283,538	100
Load	Consumption (kWh/yr)	Percent (%)
AC Primary Load	746,664	100
DC Primary Load	0	0
Total	746,664	100

7. Conclusions

In this paper simulation and optimization of a renewable hybrid energy system consist of solar PV and wind turbine for a 1/500 scaled Victoria metropolitan city have been carried out using HOMER software. The simulation recommends that the most optimal solution comprises 1102 kW PV flat plate panels, 116 generic 10 kW wind turbines, 9100 generic 1 kWh Li-Ion batteries and 839 kW converter. A total net present cost (NPC) of 19.7 M$, a cost of energy (COE) of 2.04 $, an operating cost of 374,623 $ and an initial capital of 14.8 M$, with a renewable fraction of

Table 3. Annualized cost of the System

Components	Capital ($)	Replacement ($)	O&M ($)	Salvage ($)	Total ($)
PV	255,842	0	11,025	0	266,867
Wind Turbine	448,655	143,035	58,000	-80,609	569,081
Battery	422,355	179,194	91,000	-33,726	658,823
Converter	19,467	8,260	0	-1,555	26,172
System	1,146,320	330,488	160,025	-115,890	1,520,943

100% is found in the results of simulation. The excess electricity in the suggested system is found to be 64.3% thus system can produce a significant amount of electricity. This research shows that a hybrid energy system using solar and wind power is economically feasible and the hybrid model suggested in this study will be able to meet the load demand with a reasonable COE and feed varying load requirement in all the season.

A 100% renewable energy-based power generation system could considered to some of the small residential districts and an outlying district of Victoria metropolitan city that either have optimal solar and wind generation conditions or have low energy independence.

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