Design of a hybrid power system using Homer Pro and iHOGA

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***Abstract*—In this paper, a hybrid power system is designed for a house in St. John's. House located in Newfoundland is designed using the Energy 3D software and the annual energy (kWh) demand for the house is determined. The hybrid power system to meet this energy demand is designed and simulated using both Homer (Hybrid Optimization of Multiple Electric Renewables) Pro software and iHOGA (improved hybrid optimization genetic algorithm) software. Analysis reveals that for Homer Pro software, 95.8% (52,566kWh/yr) of the total annual energy is produced by the wind turbine and 4.2% (2,308kWh/yr) is produced by the solar cells. For the iHOGA software, 85.7% (8,188.6kWh/yr) of the total annual energy is produced by the wind turbine and 14.3% (1,361.6kWh/yr) is produced by the solar cells. Further analysis indicates that it more economical to design the hybrid power system in iHOGA software. However, irrespective of the software used in the system design, the energy generated for the isolated system is more than the energy demand of the house thus leaving excess electricity that can be sold to the grid system.**

Keywords—Isolated system, Energy 3D, Homer Pro, hybrid power system, iHOGA software.

I. Introduction

A hybrid power system for a house that produces as much energy the house can consume annually can be designed. Due to the fact that buildings account for large amount of energy demand, hybrid power system becomes inevitable in solving the energy crises being faced in the grid system. The problem of environmental pollution affecting the ecosystem being caused by non-renewable energy sources can be limited as renewable energy is more environmentally friendly. The sources of renewable energy include wind, solar, tidal, hydro and biomass. These sources can be replenished back to the ecosystem hence it is termed renewable. The combination of more than one energy sources is called hybrid. Hybrid energy system may include both renewable energy sources and the conventional energy sources. In the recent past, hybrid energy systems consisting of only renewable energy sources are gradually taking over the globe. In this paper, design of hybrid power system using Homer Pro and iHOGA software are considered.

II. Literature Review

A study [1] utilizes Energyplus software in simulating annual energy of Xiamen. The results obtained from their simulation indicates that the total annual consumption of the house was 12,544.9 kWh, which was 75.6% of the 16,590.5-kWh generated by the PV panels. The key objective of that paper was to produce new, innovative, clean and efficient energy technologies and also to give a better solution to build "Zero Energy Buildings". A system consisting of two renewable energy sources, comprising photovoltaic system and a wind turbine for ZEB is presented in [2]. An existing building was simulated which was compared with the modified building and hybrid system feeding the load was carried out with the application of Homer software. Based on simulation results, it was found that these renewable energy sources would be a feasible solution for zero energy buildings. A paper [3] demonstrates a hybrid renewable energy system developed for a net-zero energy low rise residential building located in Shanghai, China that hybrid renewable energy system consists of a water-based photovoltaic/thermal (PVT) collector and a ground water-source heat pump (GWSHP) which was designed to produce heating, cooling and electricity during both winter and summer by using solar energy and ground surface water energy respectively. The feasibility of that hybrid system for a detached house located in hot summer and cold winter city Shanghai was evaluated by both field test and modeling analysis. Results obtained indicates that the annual energy consumption of the studied case is 3658.7kWh, less than the annual on-site energy generation 4000.1kWh, and the system has been proved to be applicable on this on-grid zero-energy house, and hence has potential for low/zero-energy low-rise residential buildings in Shanghai. A work [4] analyzes the potentials of hybrid renewable energy system (HRES) to supply power and heat for a household with the optimal configuration. As a case study, a house was selected in the United Kingdom with its energy consumption collected and analyzed. Based on energy demands of the house, a distributed HRES including wind turbine, solar photovoltaic (PV) and biogas genset was designed and simulated to satisfy the power and heat demands. Hybrid Optimization Model for Electric Renewable (HOMER) Software was used to conduct this technoeconomic analysis. It is discovered that the HRES system with one 1-kW wind turbine, one 1-kW sized biogas genset, four battery units and one 1-kW sized power converter was the most feasible solution. In paper [5], a hybrid system involving multiple options to generate electricity was considered. These hybrid generation systems are designed to function in two ways, as a standalone system, which without being connected to the electricity grid supplies power to a set of loads, or as a grid-connected system, where a system undergoes transmission and distribution, to be integrated to the grid. The paper implements HOMER, iHOGA and RETSCREEN software tools for the design, analysis, optimization, and economic viability of the PV-Wind Hybrid Energy system. Result obtained indicates that optimal solutions were found using RETSCREEN, HOMER and iHOGA software tools. The best solution so obtained was 3kW panel, 1kW wind turbine, with unmet load of 0, having NPC of $4563 to power the sample load. The comparative study of the simulation results between HOMER and iHOGA software packages was presented in [6]. These two software packages are used to optimally size renewable energy systems for a micro-grid. A small community in Aralvaimozhi, India was considered. Aralvaimozhi has a good potential of Solar energy and Wind energy resources. If these resources are trapped efficiently using HRES, an efficient micro-grid could eventually replace the present old and less efficient electricity grid system. Their study reveals that the optimally sized HRES with least value of Net Present Cost (NPC) resulted from HOMER and iHOGA software packages was discussed and their results was compared.

III. METHODOLOGY

A house located in Newfoundland was model and the annual energy (kWh) was determined with the aid of Energy 3D software. A hybrid power system of the house consisting of photovoltaic cell, wind turbine, battery, inverter and electrical load was designed and simulated with the aid of Homer Energy software to accommodate its annual energy (kWh). Also, the hybrid power system of the same house was designed and simulated under iHOGA software environment and the analyzed results was compared to that obtained from Homer Energy software.

A. *Modeling and sizing*

A 3-bedroom apartment located in Newfoundland was modeled in Energy 3D environment and the annual energy in kWh required by the house was optimized and simulated with the aid of Energy 3D software. The model obtained is shown in Figure 1. Based on the result obtained in Energy 3D software, annual energy consumption =18,533.2kWh as shown graphically in Figure 2.

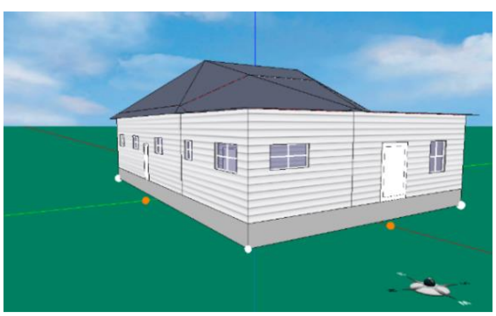


Figure 1 Model of 3-bedroom apartment in St. John's Canada

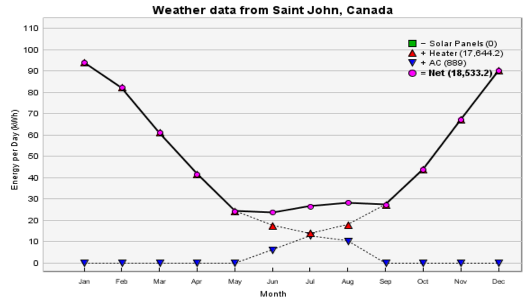


Figure 2 Line graph of annual energy consumption of a 3-bedroom building in St. John's Canada

The building was then located using Homer Google search on the internet as shown in Figure 3, the average wind speed of 9.23m/s and the average solar radiation of 3.15kWh/m2/day was determined as shown in Figure 4 and Figure 5 with aid of Homer software.

Figure 3 Location of building using Homer Google search

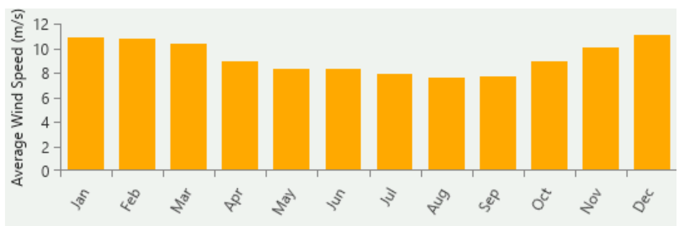


Figure 4 Annual average wind speed of wind turbine

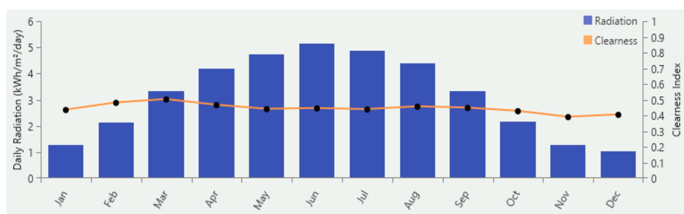


Figure 5 Annual average radiation of solar panel

The schematic diagram of an off-grid hybrid power system consisting of photovoltaic cell, wind turbine, battery, inverter and load shown in Figure 6 was designed by Homer Energy software. The energy consumed by the House is produced by both the PV module and the wind turbine. This system does not require energy generated from the grid system; it is completely off-grid. Again, with the same load profile obtained from Energy 3D, the hybrid power system of the same building was designed and simulated in iHOGA software environment as shown in Figure 7. In this case, the average annual wind speed and average annual solar irradiance obtained are 9.22m/s and 3.12kWh/m2/day respectively as shown in Figure 8 and Figure 9.

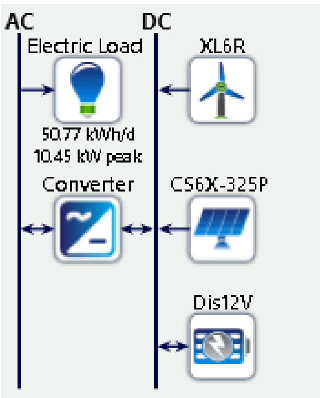


Figure 6 Schematic diagram of hybrid power system from Homer software

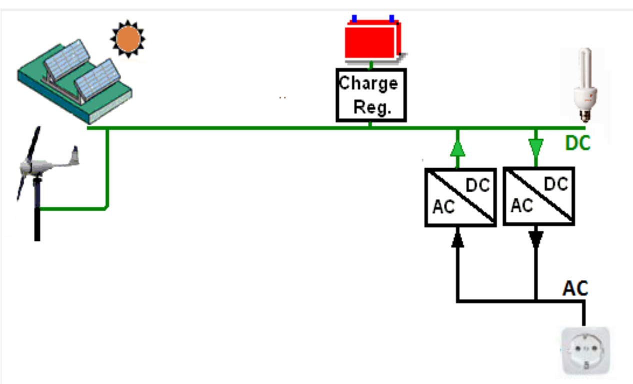


Figure 7 Hybrid power system from iHOGA software

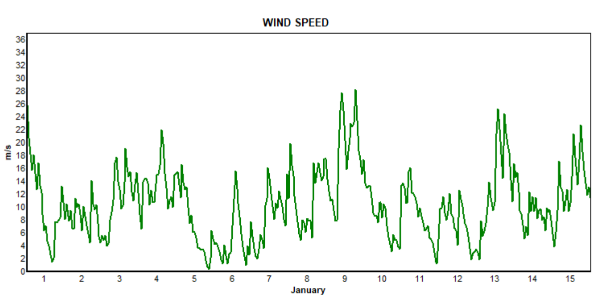


Figure 8 iHOGA annual average wind speed

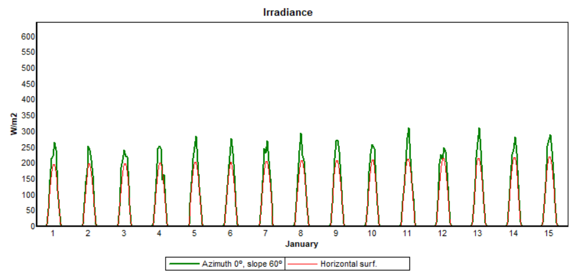


Figure 9 iHOGA annual average solar irradiance

IV. RESULT AND DISCUSSION

TABLE I LIST OF COMPONENTS IN HOMER PRO DESIGN

Components	**Homer Pro**		
	Nominal voltage (V)	***Rating***	***Life span***
Wind turbine	48	6kW	20
Solar Cells	12	0.325kW	25
Battery	12	260Ah	20
Converter	48	12kW	15

TABLE II LIST OF COMPONENTS IN IHOGA DESIGN

Components	**iHOGA**		
	Nominal voltage (V)	***Rating***	***Life span (years)***
Wind turbine	48	1.5kW	15
Solar Cells	24	325W	25
Battery	12	97Ah	10
Converter	48	5kW	10

Table I and Table II indicates the component parts, nominal voltage, power rating and life span specification of both Homer Pro and iHOGA designs.

The cost of designing a hybrid power system suitable for the house in iHOGA software is $34,149.8 as shown in Figure 10 and Table 3. For Homer Pro design, the cost is $35,929.53 as depicted in Figure 11. In terms of economics, it is more economical designing a hybrid power system with the aid of iHOGA software. Results from Homer Pro show that 95.8% (52,566kWh/yr) of the total energy was generated by the wind turbine and 4.2% (2,308kWh/yr) was generated by the solar module as shown in Figure 12. The total energy generated by this design (54,874kWh/yr) is more than the load (18,521kWh/yr) of the system similarly with the iHOGA design, 85.7% (8,188.6kWh/yr) of the energy generated to the load is from wind energy and the solar energy generates 14.3% (1,361.6kWh/yr), this is shown in Figure 13. In both designs, the total energy generated exceeds the load demand of the house.

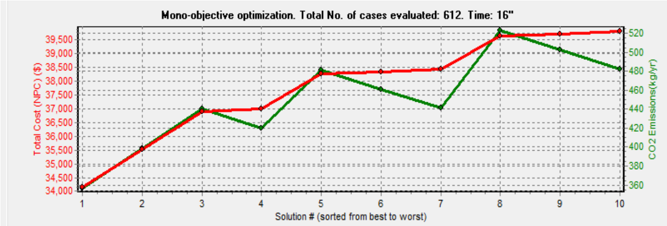
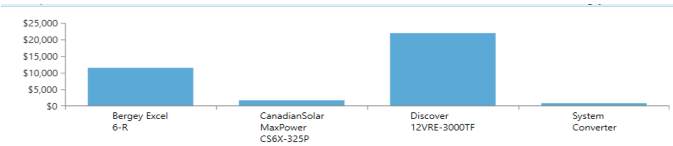


Figure 10 iHOGA representation of graphical installation cost

TABLE III IHOGA INSTALLATION COST

#	Total Cost (NPC)($)	Emission (kgCO2/yr)	Unmet(kWh/yr)	Unmet(%)	D.aut	Cn(Wh)/(Ppv+Pw)(W)	Ren(%)	LCOE($/kWh)	Simulate	Report
1	34149.8	356.6	0	0	3	18.2	100	0.48	SIMULATE..	REPORT.
2	35515.3	398.2	0	0	3	15.5	100	0.5	SIMULATE..	REPORT.
3	36880.9	439.8	0	0	3	13.5	100	0.52	SIMULATE..	REPORT.
4	36970.3	419.54	0	0	3.3	17	100	0.52	SIMULATE..	REPORT.
5	38246.5	481.4	0	0	3	11.9	100	0.53	SIMULATE..	REPORT.
6	38335.9	461.14	0	0	3.3	14.8	100	0.54	SIMULATE..	REPORT.
7	38425.2	440.88	0	0	3.6	18.6	100	0.54	SIMULATE..	REPORT.
8	39612	523	0	0	3	10.7	100	0.55	SIMULATE..	REPORT.

COMPONENTS: PV modules Canadian: CS6U-325P (325 Wp): 4s.x 2p. (100% PV#1: slope 60º, azimuth 0º) // Batteries Trojan12V:27TMX (97 Ah): 4s. x 10p. // 1 Wind Turb. DC Bornay: 1500(1660 W at 14 m/s) // Inverter Voltronic: MKS 5K 48 of 5000 VA // Rectif. included in bi-di inverter // PV batt. charge controller included in bi-di inverter // Unmet load = 0 % // Total Cost (NPC) = 34149.8 $ (0.48 $/kWh)



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Bergey Excel 6-R	$9,856.00	$1,963.85	$796.34	$0.00	($1,106.76)	$11,509.43
CanadianSolar MaxPower CS6X-325P	$1,728.25	$0.00	$0.00	$0.00	$0.00	$1,728.25
Discover 12VRE-3000TF	$10,869.76	$2,824.13	$8,782.44	$0.00	($605.53)	$21,870.80
System Converter	$610.71	$259.11	$0.00	$0.00	($48.77)	$821.05
System	$23,064.72	$5,047.10	$9,578.77	$0.00	($1,761.06)	$35,929.53

Figure 11 Homer Pro installation cost

Production	kWh/yr	%
CanadianSolar MaxPower CS6X-325P	2,308	4.21
Bergey Excel 6-R	52,566	95.8
Total	54,874	100

Consumption	kWh/yr	%
AC Primary Load	18,521	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	18,521	100

Quantity	kWh/yr	%
Excess Electricity	34,544	63.0
Unmet Electric Load	9.99	0.0539
Capacity Shortage	18.5	0.100

Quantity	Value	Units
Renewable Fraction	100	%
Max. Renew. Penetration	6,145	%

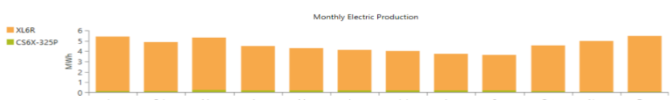


Figure 12 Homer Pro energy generation

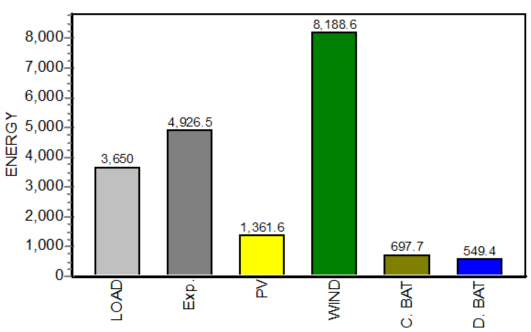


Figure 13 iHOGA energy generation

V. CONCLUSION

In this paper, hybrid power system was designed using Homer Pro and iHOGA software. Simulated results shows that optimal design was found using iHOGA software. In this design, 1.5kW wind turbine, 24V, 325W photovoltaic modules, 12V, 97Ah battery and 5kW, 48V converter was used at a cost of $34,149.8 to meet the load demand of the house. However, Homer Pro was used to design the same hybrid power system though more expensive.

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REFERENCES

[1] S. Feng, W. Shaosen, H. Jinjin and H. Xiaoqiang, “Design strategies and energy performance of a net-zero energy house based on natural philosophy”, Journal of Asian Architecture And Building Engineering, Vol. 19, No. 1, pp. 1–15, 2020.

[2] P. Satya, K. R. Vijaya and C. Saibabu, “Integration of Renewable Energy Sources in Zero Energy Buildings with Economical and Environmental Aspects by using HOMER”, International Journal of Advanced Engineering Sciences and Technologies, Vol. No. 9, Issue No. 2, pp. 212 – 217, 2015.

[3] Z. Shihao , Z. Zhi, H. Yidong, Y. Baoshun and T. Hongwei, “Applicability Study on a Hybrid Renewable Energy System for Net-Zero Energy House in Shanghai”, Applied Energy Symposium and Summit, Energy Procedia 88, pp. 768 – 774, 2016.

[4] M. Chunqiong, T. Kailiang, W. Yaodong and J. Long, “Technoeconomic Analysis on a Hybrid Power System for the UK Household Using Renewable Energy: A Case Study”, Energies, pp. 1-19, 2020.

[5] S. I. George, “Performance Analysis of a Hybrid Energy System”, International Journal of Advanced Science and Technology, Vol. 29, No. 5s, pp. 3211-3220, 2020.

[6] N. Saiprasad, A. Kalam and A. Zayegh, “Comparative Study of Optimization of HRES using HOMER and iHOGA Software”, Journal of Scientific & Industrial Research, Vol. 77, pp. 677-683, 2018.