Comparative Study of Optimization of HRES using HOMER and iHOGA Software

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Comparative Study of Optimization of HRES using HOMER and iHOGA Software

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There has been several methodologies to size hybrid renewable energy system (HRES). This paper provides the comparative study of the simulation results between HOMER and iHOGA software packages. These two softwarepackages are used to optimally size renewable energy systems for a micro-grid. A small community in Aralvaimozhi, India is 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. In this study, the optimally sized HRES with least value of Net Present Cost (NPC) resulted from HOMER and iHOGA software packages have been discussed and their results have been compared for a definite scenario.

Keywords: HOMER, iHOGA, Hybrid Renewable Energy system, Micro-Grid, Optimization

Introduction

A renewed focus on renewable energy is establishing itself as a means to reduce the greenhouse gas (GHG) emissions mainly due to its sustainable nature. This when combined with a volatile conventional energy market makes it a formidable option[1]. Also contributing to this are the government's planning and promotion of renewable energy, which results in establishing a wider job market and related economic improvement[2]. This has resulted in exploring diverse renewable energy sources; in particular, improve the access to energy in rural areas. With the aforementioned benefits targeting renewable energy, a technological advancement over time would play a pivotal role in thrusting the renewable energy in the energy market [3-4]. While understanding the importance of renewable energy in the current scenario, the application of renewable energy as a distributed generation for a micro-grid has been discussed for a small community in India in this study. There are many methodologies used to size HRES in this aspect [5]. However, there is not much analysis made comparing the results of HOMER and iHOGA software. This paper aims at this analysis and highlights the pros or cons of both the software.

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Methodology and System Description

The high demand for energy supply to meet the energy demand with growing population is the need for the hour. This need is more appropriate especially in a country like India where the grid failure and blackouts are very common and observed predominantly in summer and rainy seasons. A reliable and resilient energy system using the grid is considered here. Designing and optimizing a micro-grid and analyzing their economic and environmental impacts are studied. Similar studies have been conducted using Photo-Voltaic (PV), Wind Turbines (WT), fuel cells (used either for energy conversion or as a storage unit) for isolated villages, islands, wind farms, resorts[6-9]. To design and optimize any micro-grid it is important to understand and study the load requirement of the desired location. This step is crucial during the design of a micro-grid without which it could lead to underestimating or overestimating the consumption, either of which could result in unmet load or oversized setup respectively. Various methods have been used to optimize a micro-grid including genetic algorithm and swarm optimization techniques[10,11]. Many software has also been used in such studies widely viz. MATLAB, Simulink, HOMER (Hybrid Optimization of Multiple Energy Resources), iHOGA (improved Hybrid Optimization using Genetic Algorithm) and RETScreen[12]. These methods used for optimally size the RES consider either the economic criteria or the power reliability criteria as performance indicators to size the renewable energy system. However, if multiple criteria are considered, there is no optimum RES system designed. HOMER and iHOGA are the software considered for nonlinear and single-objective analysis. This two software can simulate a large number of technologies and the variation in technological costs and availability of energy resources which would otherwise make the decision making difficult. When it comes to decision making, there are many options which depend on technology options and availability of the energy resources. HOMER software consists ofoptimization and sensitivity algorithms, which make the options for evaluation easier. The simulation operation results in a definite model configuration whilst the optimization process decides the best model configuration. The optimal solution for the desired model configuration suggested by HOMER satisfies all the constraints that user defines, and size the HRES for the least value of Net Present Cost (NPC). Meanwhile, iHOGA is a program that uses a genetic algorithm to determine the optimal sizing of desired energy system including diesel generator and hydrogen fuel cell. This software also can size the energy system model for both grid connected and isolated systems. iHOGA employs two genetic algorithms, one provides the optimum configuration of energy system considered, called the Main Algorithm; while the Secondary Algorithm considers the control strategies for the above combination of the systemresulting from the main algorithm.iHOGAPro+ version 2.4 and HOMER Pro 3.11.6561.20287 version software are used in the sizing of RES in this study. This paper discusses the sizing options of HRES for a small community in a small town, Aralvaimozhi in the state of Tamil Nadu, India. The location of the community is shown in Figure 1.

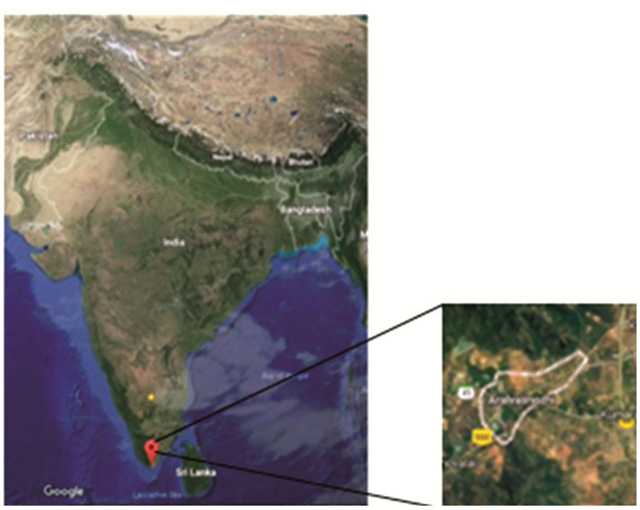

Fig. 1 — Location of the selected site, Aralvaimozhi, India

Identifying the Available Resources

Given the arbitrary behavior of renewable energy sources, their energy prediction has always been chllenging and hence unit sizing and optimization method study would help to downsize the system cost and improve system reliability. Although oversizing the system components may make the system economically costly, under-sizing them would lead to unmet load. Hence an optimum resource management is a pivotal strategy for a reasonable trade-off between them[13]. Aralvaimozhi has a good source of solar and wind energy. Wind speed was measured at a site near Aralvaimozhi, the annual average was 7.16m/s. Using the NASA surface and solar energy database[14], the average solar radiation at Aralvaimozhi was 5.05kWh/m^2/day. The clearness index which measures the clearness of the atmosphere at a desired placed was also considered from the same surface and solar energy database. It has been observed that the cleanness index at Aralvaimozhi has a minimum of 0.431 in November and maximum of 0.596 in March. Aralvaimozhi has been identified as potential wind farm location according to the Government of Tamil Nadu. Figure 2 represents the Solar energy and Wind energy availability in Aralvaimozhi, India.

Load Analysis

The task to integrate Solar and Wind energy systems to the small community are challenging, hence it is mst important to understand the stochastic behavior of available energy to serve the load. To understand the load for integrating renewable energies at Aralvaimozhi, the energy consumption for 70 houses for 2 years was considered. Average energy consumption is 183.403kWh/day for 70 houses,

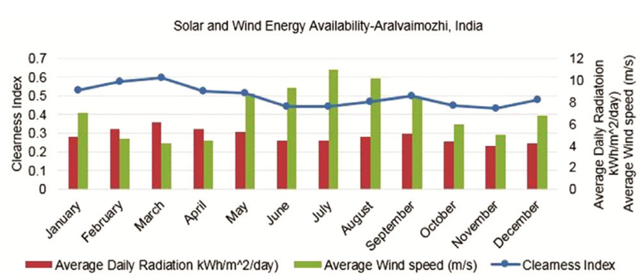

Fig. 2 — Solar and Wind energy availability at Aralvaimozhi, India

which is about 2.62kWh/day/house. The daily activity of a house is between 6hrs to 21 hrs. In the morning when there is enough sunlight, PV can meet the electrical load. However, there is a necessity to address the load which mostly peaks in the evening. Hence, wind turbines and battery were introduced into the model. iHOGA and HOMER consider the available resources and constraints set by the user and size the HRES for the given location according to the least Net Present Cost (NPC) for a mono-objective analysis. NPC decides the profitability of an HRES, which is a prime economic factor to be considered for a developing country like India. Additionally, this study provides the techno-economic analysis discussing the NPC and size of HRES, environmental and Social factors involved in designing an HRES. Factors like CO_2 emissions, job creation criteria have been considered for environmental and social factors.

System Description

The HRES is designed by considering PV. WT and battery with 2.4 hours of autonomy and connecting them to the grid. The sensitive variables considered to perform the financial analysis are shown in Table 1. The inflation rate dropped to a record low of 2.99% in April 2017 in India[15]. Demonetization was one of the other reasons for this fall in the inflation rate. Hence the inflation rate of 7.13%, as the average from 2012 until 2017, has been considered in the calculation. The interest rate provided by a nationalized bank in India was considered with the range 15.5% and minimum renewable energy penetration of 70% [16]. The HRES was modeled for the annual capacity shortage of 0%, which means that the total load is either met by the renewable energy, battery or by the AC grid and no load is unmet, as shown in Table 1. The micro-grid system considered by HOMER and iHOGA for Aralvaimozhi community is shown in Figure 3a and Figure 3b respectively. A generic 1kW PV is considered with a capital cost of INR[*79600Unitron energy] 1.5kW wind turbine with the capital cost INR2.5Lac[*] and Trojan 105 batteries of capital cost INR 19,500 were considered. These costs are the actual market costs provided by the supplier. These systems were modeled according to the specifications shown in Table 2 using HOMER and iHOGA software and the results were analyzed.

Economic Criteria for Sizing HRES

The architecture of HRES system consists of PV arrays, wind turbine, controller, and batteries. To minimise the cost of the system and meet the load demand, software like HOMER and iHOGA defines a few terminologies which are deciding factors for the

Table 1 — The inputs used for economic analysis using HOMER and iHOGA

Inflation rate	7.13%
Discount Rate	15.5%
Lifetime of the Project	15 years
Annual Capacity shortage	0%
Minimum Renewable energy fraction	70%
Grid Power Price	2.16INR/kWh
Grid sell back	5.10INR/kWh
Unmet load	0%

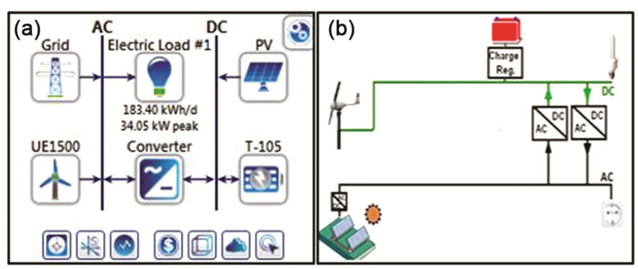

Fig. 3a —The HRES considered for Aralvaimozhi community by HOMER software (left); The HRES considered for Aralvaimozhi community and iHOGA (right)

Table 2 — The HRES components, component specifications and market price

Components	Specification		Cost in INR	
Solar Panels (PV)	Nominal Voltage	12V	Capital Cost	79600/year
	Shortcut Current	8.23A	O&M Cost	100/year
	Nominal power	1000Wp		
	Lifespan	25 years		
UE 1500 Wind Turbine	Height	12m	Capital cost	250,000
	Rated Power	1500W	Replacement cost	250000
	Life Span	20 years	O&M cost	10/year
Trojan-105 Battery	Nominal Capacity	254Ah	Capital cost	19500
	Voltage	6V	O & M cost	20
	SOC	20%	-	-

suggested model[13].They are expressed as follows:

Net Present Cost (NPC): Net Present Cost determines the profitability of the project, which is the total net present value of the component subtracted by the (income) profit it incurs for the complete lifetime of the project

$$NPC = \sum[(\text{Total Cash flow} / (1+ \text{Rate of Interest})^{\text{Project Lifetime}}) - \text{Initial Investment}] \quad \text{... (1)}$$

Annualized cost: Annualized cost is that cost of the set up when factored equally over the entire lifetime of the project considered

$$\text{Annualized Cost} = \text{Total Project cost} \times \text{Discount Rate} /[1- (1+ \text{Discount Rate})]^{-\text{Project lifetime}} \quad \text{... (2)}$$

Levelised cost of Energy (LCOE) or Cost of energy (COE): It is the average cost of useful electrical energy produced by the system. To calculate the levelised cost of energy, HOMER divides the annualized cost of producing electricity (the total annualized cost minus the cost of serving the thermal load) by the total electric load served, using the following equation:

$$LCOE = \text{Total Annual electricity production} / \text{Load served by the system} \quad \text{... (3)}$$

Renewable energy penetration: It is the amount of renewable energy that serves the load annually.

Both software packages, HOMER, and iHOGA simulates the results considering all the constraints defined by the user and tabulates the results according to the least value of NPC.

HOMER and iHOGA Software Result Analysis and Discussion

This section compares the optimized results for Aralvaimozhi using HOMER and iHOGA. Both the software calculates the NPC using the methodology mentioned earlier on considering the inputs defined by the user for the HRES models and sort the results according to the least value of NPC. The Primary Algorithm used by iHOGA is Genetic Algorithm while the Secondary Algorithm considered all the combinations of the population resulted from the Primary Algorithm. 70.9% of cases and evaluated 29993 cases in 1hr 39 seconds. However, HOMER considered all the possible combinations and simulated 1171 cases out of which 1057 were feasible in less than 5 minutes. In this aspect, HOMER produced 100% possible optimized results while iHOGA considering Primary and Secondary Algorithms simulating results close to the optimized result taking longer time. This long duration in the simulation is also due to the control strategy defined for iHOGA, while this is an option lacking in HOMER. For example: the priority to charge the batteries were given to the renewable energy source. If the renewable energy is excess at an instant, it can be sold to the grid. In current study case, the control strategy considers prioritizing renewable energy and battery to meet the load, if in any case renewable energy and battery are not available to meet the load, the grid is flexible to meet the load. Thus the presence of the grid in the designed micro-grid system is to supply any excess energy to the load in case of a deficit in renewable energy supply, it also acts as the dumping unit when there is excess renewable energy thus creating revenue through feed-in-tariff. The HRES for HOMER and iHOGA was validated against the available model in the literature[17,18].The size of HRES for Aralvaimozhi by HOMER and iHOGA simulations are almost similar, however, there is a very small discrepancy in their values. This is shown in Table 3. This smaller discrepancy is due to the methodology used by both the software to calculate the NPC, the control strategies dealt by iHOGA is more precise compared to HOMER software. There are two models discussed here with the HOMER simulated results, both the models showcase results which are similar to iHOGA optimized results. Model-1 from HOMER was considered due to the renewable energy penetration being close to 70%, while Model-2 was the optimized model by HOMER when the autonomy of battery was close to 2.4hr, the results of all optimized model by HOMER and iHOGA are similar and are highlighted in Table 3. The two optimized model from HOMER: Model-1 and Model-2 are the models chosen as the closest comparable optimized model simulated in comparison with the iHOGA simulated model. Model-1 of HOMER has the renewable energy penetration of 71 %, this is comparable to the iHOGA simulated model having renewable energy penetration of 70.1%. However, Model-2 is the HOMER optimized model for with the autonomy of 2.07hr which is comparable to the iHOGA simulated optimized model having an autonomy of 2.4hr. It is observed from the analysis that the optimum results from both iHOGA and HOMER are very similar for the given constraints. This is observed even when the COE is considered

Table 3 — Result comparison from HOMER and iHOGA software

		HOMER		iHOGA	Comments
		Model-1	Model-2		
SIZE	PV	10.3kW	15.3kW	18kW of PV	PV sized by iHOGA is large by a few kilo-Watt
	WT	10	10	11 Wind turbine of 18kW	Similar size WT by HOMER and iHOGA.
	T105 (Trojan Battery)	20 batteries (30.5kWh Nominal Capacity)	13 batteries (19.8kWh Nominal Capacity)	Batteries connected as 8strings*3parallel with 36.5kWh	Battery size with Nominal Capacity is compared, Model-1 has a nominal capacity close to the iHOGA sized model.
	Converter	7.07kW	4.33kW	10kW	Bigger converter sized by iHOGA than HOMER.
Economics	NPC:	INR 4.25M	INR 5.53M	INR 5.771M	Large NPC from iHOGA is due to the bigger sized converter. However, iHOGA does not consider the revenue from the HRES system from like HOMER software does to calculate NPC.
	COE:	5.6 INR/kWh	5.27 INR/kWh	5.75INR/kWh	If COE is calculated by the method iHOGA and HOMER software differ due to the value of NPC. (This discrepancy in software calculated values have been noted in the literature[18,19]. However, the reason for this discrepancy has not be provided in the literature).
Renewable Energy penetration		71%	72.3%	70.1%	Renewable energy penetration from the HRES resulted by HOMER is higher than iHOGA.
Emissions		CO_x: 16,072kg/yr SO_x: 69.7kg/yr NO_x: 34.1kg/yr	CO_x: 15,549kg/yr SO_x:67.4kg/yr NO_x:33kg/yr	CO_x: 17,3412kg/yr	Emissions for poisonous gases like CO_x, NO_x, SO_x and other particulate matters are considered in HOMER. iHOGA considers only Cox emissions.
Job creation		-	-	0.0633	This feature is not available in HOMER software
Human Development Index (HDI)		-	-	0.9225	This feature is absent in HOMER software
Autonomy		3.189hr	2.07hr	2.4hr	Autonomy of the system in Model-1 and Model-2 is close to 2.4hr

amongst the HRES of the models simulated by HOMER and iHOGA.All the three models have the COE in the range of 5INR/kWh. However, the optimized HRES by HOMER has a greater renewable energy penetration of 71.3% and 72.3% compared to iHOGA software which has 70.1%. When the size of the optimized HRES is considered for the given constraint, HOMER and iHOGA sizes the system for the least value of NPC. The HOMER optimizes the HRES to 100% accuracy, while iHOGA optimizes system close to the optimized value. The optimized model produced by iHOGA has a larger PV penetration of 18kW compared to the two models simulated by HOMER with 10.3kW and 15.3kW respectively. The WT size simulated by HOMER matches with the iHOGA ,which is 10 and 11 respectively. However, the batteries sized by HOMER in Model-2 and iHOGA are similar, this is evident from the battery autonomy being similar. The converter sized by iHOGA is large compared to the two models resulted by HOMER. This could be due to the large PV penetration in the iHOGA optimized model. The poisonous gas emissions are clearly explained for different gases like- CO_x, NO_x, SO_x , particulate matter in HOMER software. The iHOGA software considers only COx gas emissions. The CO_x emissions of the iHOGA simulated model and HOMER simulated models are alike. This is directly related to the size of optimized HRES resulted by the software. iHOGA discussed the job creation and HDI [19]. These two results could be one of the important factors to discuss for a developing country like India. The Job creation of 0.0663 generated per GWh if this project is sanctioned for installation. Similarly, HDI calculated by iHOGA for the optimized model is 0.9225.

Conclusion

In this work, HOMER and iHOGA packages have been used to size HRES for Aralvaimozhi community. The analysis of the results provides an opportunity to compare and comment on the facilities provided by these two software packages. The iHOGA software has not been much explored like HOMER software. This was the motivation for the current study. HOMER software is a flexible, user-friendly and more generic in terms of control strategies compared to iHOGA. HOMER lacks the explicit procedure to apply control strategies like iHOGA. HOMER sizes according to the available renewable energy and chooses the best HRES model by minimizing the cost. In case of iHOGA, especially for a battery connected to the grid models, the user can choose if the battery can inject the electricity to the grid or when it can be discharged and provide the battery availability during the day. The absence of such control strategies makes iHOGA more accurate in simulating the HRES in a definite method. iHOGA differs from HOMER by showcasing the HRES connection option either by series connection or parallel connection on considering the DC and AC voltage given by the user. HOMER does not provide this option. The energy resources like solar energy and wind energy are directly downloaded from the NASA database website in HOMER, however, iHOGA has inbuilt models that have the facility to calculate the solar and wind energy available on providing latitude and longitude of the system. In spite of iHOGA having the above advantages, the main disadvantage of iHOGA software other than it not being as user-friendly as HOMER is that it takes a longer time to simulate when Genetic Algorithm is considered either as Primary Algorithm or Secondary Algorithm or both (however, it shall also be noted that the time taken by iHOGA software analysis also depends on the size of the load, different components of HRES and the control strategies). The simulated result considers small population, unlike HOMER which simulates all the combinations producing 100% population. It is also observed that iHOGA has the flexibility to choose "evaluate all combination" for both Primary and Secondary algorithm to produce 100% population, while this option takes a long time to simulate when compared to HOMER. Since iHOGA requires detailed control strategies to consider two types of the algorithm (Main Algorithm and Secondary Algorithm) for simulating a set of results. This is the reason for the time required by iHOGA analysis is longer than the HOMER software. HOMER software considers all the combinations of HRES, hence obtaining 100% results for all the feasible combination is possible, while iHOGA software utilizes more time for simulation and makes HOMER a better software in such case. Other than mono-objective optimization (minimizing NPC), iHOGA has an option for multi-objective optimization which HOMER does not provide. When the results are analysed between HOMER and iHOGA software, both the software sized the HRES ofsimilar size with a little discrepancy in the PV and inverter size. The methodology used to find NPC by both the software is different. It has to be noted that the inflation rate and discount rate are considered for an individualcomponent, including the grid, but this is not considered by the HOMER software. Hence there is a small discrepancy in the NPC of the optimized HRES system given by the two software although the COE values are similar. The discrepancy in the result between HOMER and iHOGA has been observed in the literature[20,21]. However, The NPC measured by HOMER: The net present cost (or life-cycle cost) of a Component is the present value of all the costs of installing and operating the Component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime. HOMER calculates the net present cost of each Component in the system, and of the system as a whole. Nevertheless, in most cases where optimization is applied through iHOGA, cash flows are usually expensed only (purchasing, replacement, maintenance, and fuel costs, etc), with no income. The different costs throughout the whole of the study period are referred to the initial time of the investment using the discount rate (approximate interest rate minus inflation rate), thereby producing the NPC. Thus iHOGA does not consider the revenue from the HRES while HOMER does, and this is the reason behind the discrepancy along with the aforementioned differences in the working of the software. Though both the software are paid software, iHOGA is more expensive compared to HOMER, this could be an additional factor for this software to have been likely explored. Unlike HOMER, iHOGA has many possible features that have to be explored and this shall be donein future research.

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