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Optimal Sizing of a Stand-Alone Wind/PV Hybrid Generating System Using Homer Software

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ABSTRACT: A methodology for optimal sizing of stand-alone PV/WG system is presented. The proposed methodology purpose is to recommend, among a list of commercially available system devices, the optimal number and type of units ensuring that the total system cost is minimized subjected to the constraint that the load energy requirements are completely covered, resulting in zero load rejection. The total system cost is equal to the sum of the respective components capital and maintenance costs. The cost function minimization is implemented using Homer software. In the optimization process, HOMER simulates every system configuration in the search space and displays the feasible ones in a table, sorted by total net present cost (NPC).

I. INTRODUCTION

Global environmental concerns and the ever increasing need for energy, coupled with a steady progress in renewable energy technologies are opening up new opportunities to utilize a combination of renewable energy resources. In particular, advances in wind and PV generation technologies have brought the integration of these two energy resources into reality.

Wind and solar energy resources are highly variable and site specific. The problems caused by the variable nature of these resources can be partially overcome by using the strengths of one source to overcome the weaknesses of the other. This is apparent by realizing the fact that in many areas more insolation and less wind are available during the summer months; and similarly, more wind and less insolation are available during the winter.

Design of a hybrid energy system is site specific and it depends upon the resources available and the load demand. This paper describes design, simulation and feasibility study of a wind/PV hybrid system for small loads. National Renewable Energy Laboratory's HOMER software was used to select an optimum cost of energy hybrid system. HOMER stands for the Hybrid Optimization Model for Electric Renewables. HOMER was developed as a hybrid system design tool 'accurate enough to reliably predict system performance, but simple and efficient enough to conveniently evaluate a large number of design options' and then rank the results to find the optimum configuration. HOMER identifies the least cost system for supplying electricity to remote loads by performing hourly simulations of thousands of potential power systems and rank ordering them by life-cycle costs. It also performs sensitivity analysis to evaluate the impact of a change in any of the input parameters and provides both annual and hourly outputs in tabular and graphic form. Hybrid system design is made difficult by the intermittency of renewable resources, the need to match electrical supply and demand, and the large number of potential component size combinations. A detailed design, description and expected performance of the system are presented in this paper.

2. Energy Resources: To model a system containing a PV array, the HOMER user must provide solar resource data for the location of interest. Solar resource data indicate the amount of global solar radiation that strikes Earth's surface in a typical year [1]. Fig. 2.1 shows the annual solar radiation in Trichy. The data can be in one of three forms: hourly

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average global solar radiation on the horizontal surface (kW/m2), monthly average global solar radiation on the horizontal surface (kWh/m2 day), or monthly average clearness index. The clearness index is the ratio of the solar radiation striking Earth's surface to the solar radiation striking the top of the atmosphere [3].

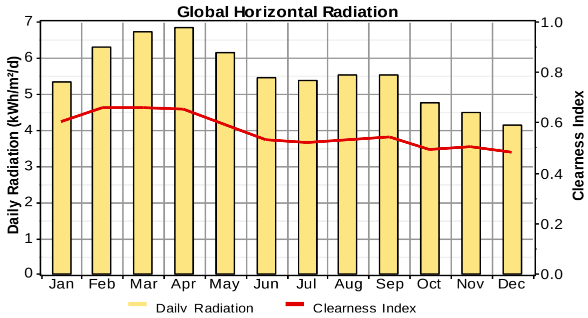

Fig. 2.1. Annual Solar radiation in Trichy

To model a system comprising one or more wind turbines, the HOMER user must provide wind resource data indicating the wind speeds the turbines would experience in a typical year [2][4]. The user can provide measured hourly wind speed data if available. Fig. 4.3. shows the annual wind speed for Trichy zone.

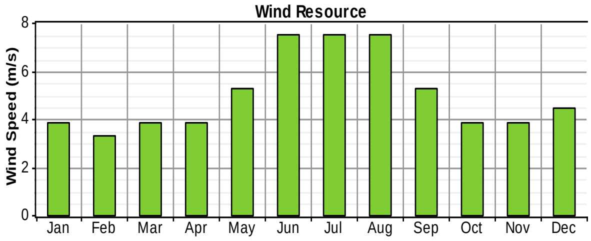

Fig. 2.2. Annual Wind speed for Trichy

HOMER models a wind turbine as a device that converts the kinetic energy of the wind into ac or dc electricity according to a particular power curve, which is a graph of power output versus wind speed at hub height [5].

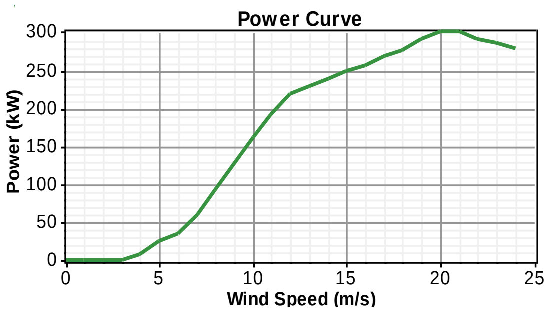

Fig. 2.3. Power curve for Wind turbine

3. Load Pattern: In HOMER, the term load refers to a demand for electric or thermal energy. HOMER models three types of loads. Primary load is electric demand that must be served according to a particular schedule. Deferrable load is electric demand that can be served at any time within a certain time span. Thermal load is demand for heat [7].

Fig. 3.1. shows the load profile of this project which is the hourly demand of Anna University of Technology, Tiruchirappalli.

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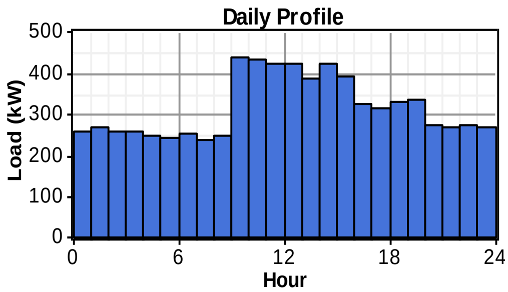

Fig. 3.1. Load profile of AUT-T

4. Economic Modelling: Economics play an integral role both in HOMER's simulation process, wherein it operates the system so as to minimize total net present cost, and in its optimization process, wherein it searches for the system configuration with the lowest total net present cost [6]. The NPC includes the costs of initial construction, component replacements, maintenance, fuel, plus the cost of buying power from the grid and miscellaneous costs such as penalties resulting from pollutant emissions.

Fig. 4.1. shows the schematic diagram of this project, which consists of wind turbines, solar panels, generator, converter and the load.

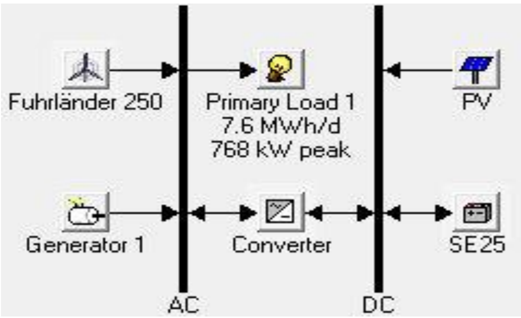

Fig. 4.1. Schematic diagram

HOMER will simulate list of various feasible solutions. To produce these solutions, we have assigned multiple values of sizes for each component of the system.

The selection of components of hybrid energy system is done using National Renewable Energy Laboratory, Hybrid Optimization Model for Electric Renewables (HOMER) [8]. HOMER is general purpose hybrid system design software. HOMER performs comparative economic analysis on a generation power systems. Inputs to HOMER will perform an hourly simulation of every combination of components entered and rank the system according to user-specified criteria, such as capital cost or cost of energy (COE).

HOMER uses the following equation to calculate the levelized cost of energy:

$$COE = \frac{C_{ann,tot}}{E_{prim} + E_{def} + E_{grid,sales}}$$

Where Cann,tot is the total annualized cost, Eprim and Edef are the total amounts of primary and deferrable load, Egrid,sales is the amount of energy sold to the grid per year.

The proposed method has been applied for the optimal sizing of a system which is yet to be erected. Table 4.1. shows the optimization results for the proposed system.

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PV (kW)	FL250	Label (kW)	SE25	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Label (hrs)
1000	5		600	800	$ 2,497,750	40,139	$ 3,010,866	0.086	1.00	0.00		
1000	5	50	1000	900	$ 4,587,750	12,796	$ 4,751,323	0.135	1.00	0.00		0
1500		400	1000	900	$ 25,842,876	81,226,160	$ 1,064,185...	30.165	0.72	0.00	256,966	1,986
	5	400	1000	1100	$ 16,544,000	91,095,920	$ 1,181,055...	33.488	0.69	0.00	285,798	2,228
1500	5	300		900	$ 21,994,876	124,112,504	$ 1,608,569...	45.912	0.74	0.02	271,857	4,034
	5	400			$ 16,248,000	244,429,424	$ 3,140,876...	89.782	0.55	0.02	499,665	5,956
1500		400		900	$ 25,746,876	262,318,368	$ 3,379,056...	96.149	0.44	0.01	590,867	6,387
		350	900	800	$ 14,136,000	299,206,240	$ 3,838,996...	109...	0.00	0.01	960,577	8,317

Table 4.1. Optimization results from HOMER

Sensitivity analysis of the HOMER is shown the overall winner which shows that the most least cost and optimize hybrid system is combination of the 1000kW PV array and five 250kW wind turbine [9]. This can be shown in Table 4.2 which shows a complete list of HOMER solutions from the best worst.

Solar (kWh/m²/d)	Wind (m/s)	Diesel ($/L)	PV (kW)	FL250	Label (kW)	SE25	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage
5.550	6.020	0.800	1000	5		600	800	$ 2,497,750	40,139	$ 3,010,866	0.086	1.00	0.00
5.550	6.020	0.900	1000	5		600	800	$ 2,497,750	40,139	$ 3,010,866	0.086	1.00	0.00
5.550	5.000	0.800	1300	5		700	800	$ 7,867,125	99,258	$ 9,135,981	0.263	1.00	0.02
5.550	5.000	0.900	1300	5		700	800	$ 7,867,125	99,258	$ 9,135,981	0.263	1.00	0.02
5.550	7.000	0.800	1000	3		600	800	$ 2,404,750	37,777	$ 2,887,663	0.083	1.00	0.01
5.550	7.000	0.900	1000	3		600	800	$ 2,404,750	37,777	$ 2,887,663	0.083	1.00	0.01
5.000	6.020	0.800	1000	5		600	800	$ 2,497,750	40,139	$ 3,010,866	0.087	1.00	0.02
5.000	6.020	0.900	1000	5		600	800	$ 2,497,750	40,139	$ 3,010,866	0.087	1.00	0.02
5.000	5.000	0.800	1500	5		600	800	$ 10,000,875	120,583	$ 11,542,337	0.332	1.00	0.02
5.000	5.000	0.900	1500	5		600	800	$ 10,000,875	120,583	$ 11,542,337	0.332	1.00	0.02
5.000	7.000	0.800	1000	4		600	800	$ 2,451,250	38,958	$ 2,949,264	0.084	1.00	0.00
5.000	7.000	0.900	1000	4		600	800	$ 2,451,250	38,958	$ 2,949,264	0.084	1.00	0.00

Table 4.2. Sensitivity results

However the main contribution of the wind/PV hybrid system is totally environment friendly therefore the system is very promising for a long term policy.

V. CONCLUSION

The application of hybrid wind/PV generation for utilizaiton as a stand-alone generating system was investigated. This optimization study indicates that energy requirements to provide electricity for a particular area (i.e) Anna University of Technology, Tiruchirappalli can be accomplished by a combination of the 1000 kW PV array and five 250 kW wind turbine.

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