

REVIEW OF HYBRID RENEWABLE ENERGY SYSTEM USING HOMER

Vinoth John Prakash¹, P.K.Dhal²

Veltech Rangarajan Dr.Sagunthala R&D Institute of Science & Technology

svjprakash@veltech.edu.in¹, kdhalp@veltech.edu.in²

Abstract: This paper describes the review of hybrid solar and wind renewable energy system for an off grid residential application in Chennai, Tamil Nadu 600003, India(13°5.0'N, 80°16.2'E) from(July 1983-June 2005)according to NASA data. The aim of the study is to know the performance and number of operating hours for Photovoltaic system and wind system per year have been analyzed. The optimal combination of renewable sources and energy storage was obtained based on average solar radiation and wind speed in Chennai according to NASA data for 22 yearsfor residential demand. In this paper we used HOMER software to find the, levelized cost for solar and wind system, Number of operation hours per year, total production in a year and capacity factor for solar and wind system and converter was calculated. The result shows that the Instantaneous Renewable output divided by load, Instantaneous Renewable output divided by generation, Monthly Average of Electricity Production by Solar PV System and which is feasible thing to operate the solar and wind system calculated for lifetime for 22 years lifetime.

Keywords: Renewable Energy System, Photovoltaic System, Wind System, Solar irradiance, wind speed

1. Introduction

The Hybrid renewable energy systems plays an important role in reliable power supply for residential or commercial applications [11]. The solar radiation and wind speed will change every period of time. The system should design in order to satisfy the load demand for every time. The demand should not be constant but it will change over every period of time for residential or commercial applications. The load can be categorized as peak load and non peak loads. The cost of energy could be Rs.1.50 Rs/KWh for half peak hours and the cost of energy will be 5 Rs/KWh for peak hours. According to the year 2016 data, the power outage factor in India is 286hrs/year. Now a days many countries has dynamic tariff. It is required to design a hybrid system with less cost i.e operating cost,

maintenance cost, and generation cost [12]. There are many studies have been conducted in order to have high reliability and lowest cost for hybrid renewable energy system [1-3]

The best way to use solar energy is to convert the sun light directly into electricity and this is accomplished effectively by means of Photo-voltaic cells [4,6]. The DC electricity is generated by the above mentioned cells, without involvement of any mechanical system, as sunlight falls on them. The generation of an electromotive force as the result of absorption of ionizing radiation is defined as the Photo voltaic effect. Energy conversion devices that use photovoltaic effect in order to convert sunlight to electricity are called Solar cells [4].

The Solar PV System operate depending on the sun rays period and wind system operate when the environment has wind speed. Both the system can't operate all time. But the demand should be satisfied by renewable source be the ultimate objective of current research. The battery banks are provided for storage of energy. The Sizing of battery should be taken in consideration when there is excess electricity. The optimal size of the system designed to have optimal solution [13]. The converters are designed in such a way that, the losses should be minimized and the operation should be efficient.

The Location is important to identify to choose a renewable energy system. Where there is solar radiations like Kashmir, India or where there is no speed when the system is located, the use of renewable energy will not be reliable. The System want to identify when the solar or wind system should operate in particular location. The Optimal combination of different components have been chosen for every period of time to operate the hybrid renewable energy system. The HOMER (Hybrid Optimization Model for Electric Renewables) have been chosen in order to optimize multiple energy sources. The other renewable energy based software only optimize sing source at a time. For knowing average solar radiation, wind speed (25 years period) for particular location, HOMER is a best software designed by NASA. By Cycle charging

and load following the HOMER software will optimize the system. At present an outpouring of researches have been said to work on modelling, sizing and simulation of such hybrid energy systems from design to operation [5].

2. Proposed Block Diagram Using Homer

The proposed block diagram for Hybrid Renewable Energy System is shown in Figure 1

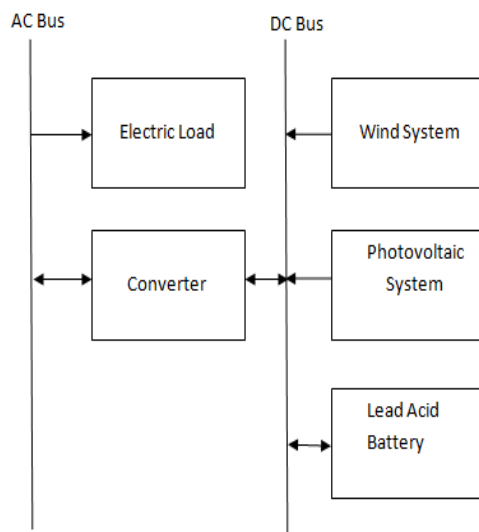


Figure 1. Hybrid Renewable Energy System

The Renewable sources such as solar and PV system connected to the DC bus for generating power. In case of less renewable energies, lead acid batteries supply power to the load in order to have continuity of generation. The converter used to convert either AC to DC or DC to AC for providing power to residential applications [17,18]. The Load is connected to AC bus which will vary according to every period of time. The Solar PV and wind system will operate depending on the load demand.

A. Data Collection

The Air temperature and monthly average value over 22 years period (July 1983-June 2005) calculated and wind speed at 50m above the surface of earth for terrain similar to airports monthly average value over 10Years period (July 1983- June 1993) calculated according to National Renewable Energy Laboratory as shown in table-I

Table 1. Average monthly solar radiation & speed

Months	Solar PV System	Wind System	
	Clearness Index	Daily Radiation (KWh/m ² /day)	Average wind speed (m/s)
January	0.508	4.309	4.87
February	0.6	5.558	4.46
March	0.573	5.773	4.45
April	0.587	6.192	4.49
May	0.535	5.673	4.86
June	0.464	4.878	5.52
July	0.464	4.882	5.3
August	0.456	4.794	5.24
Sep	0.49	4.988	3.83
October	0.483	4.564	3.56
Nov	0.471	4.061	4.56
Dec	0.475	3.892	5.28

B. Photovoltaic System

Here flat plate generic PV used of rated capacity of 100KW. The Photovoltaic module is designed and analyzed in order to have less losses and better efficiency [6]. The capital, replacement, O&M cost for Solar PV System as shown in table-II

Table 2. PV Size and cost

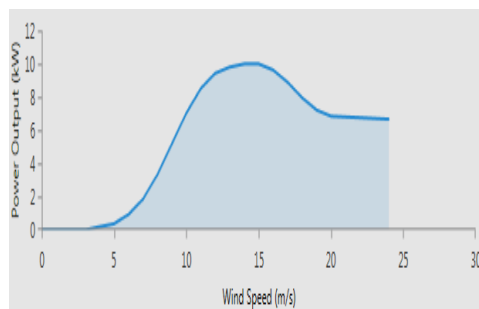
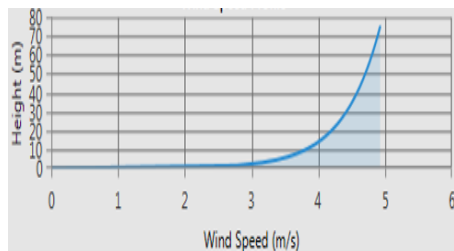
Size (KW)	Capital Cost (Rs)	Replacement Cost (Rs)	O&M cost (Rs/Yr)
1	36,000	30,000	3600
5	1,80,000	1,50,000	18,000
10	3,60,000	3,00,000	36,000

C. Wind System

Here 10KW wind turbine used in our study. The capital, replacement, O&M cost for wind System as shown in table-II

Table 3. Wind Turbine Quantities & cost

Quantity	Capital Cost (Rs)	Replacement Cost (Rs)	O&M cost (Rs/Yr)
1	2,40,000	1,80,000	12,000
2	4,80,000	3,60,000	24,000
5	12,00,000	9,00,000	60,000

**Figure 2.** Wind Turbine Power curve**Figure 3.** Height (m) vs wind speed (m/s)**Table 4.** Wind speed vs Output Power

Wind speed (m/s)	Power Output (KW)
0	0
3	0
4	0.19
5	0.37
6	0.93

D. Battery Storage

A battery stores electrical energy in a reversible chemical reaction [19, 21, and 22]. The renewable energy (RE) source (PV, wind) produces the energy, and the battery stores it for times of low wind speed or there is no solar radiation or no renewable energy produced due to environmental condition. Energy storage using batteries is accepted as one of the most

important and efficient ways of stabilizing electricity networks and there are a variety of different battery chemistries used. Lead is the most efficiently recycled commodity metal and lead batteries are the only battery energy storage system that is almost completely recycled with over 99% of lead batteries being collected and recycled in Europe and USA [15]. Lead-acid has been used for large-scale stationary energy storage for some considerable time [16].

This is a generic 12V Lead acid battery with 1KWh of Energy Storage with Nominal capacity of 1KWh and maximum capacity of 83.4Ah used. The capital cost, replacement cost and operational & Maintenance (O&M) cost as shown in table-V

Table 5. Battery Quantities & Costs

Quantity	Capital Cost (Rs)	Replacement Cost (Rs)	O&M cost (Rs/Yr)
1	15,000	12,000	1,500
2	75,000	60000	7,500

E. Electric Load

The load demand profile for every months in a year have been updated. The Electric load have been included in a system so that renewable energy will satisfy the demand. The seasonal and daily load profile as shown in in Figure4 and 5. The average load, peak load and load factor obtained are shown in table-VI.

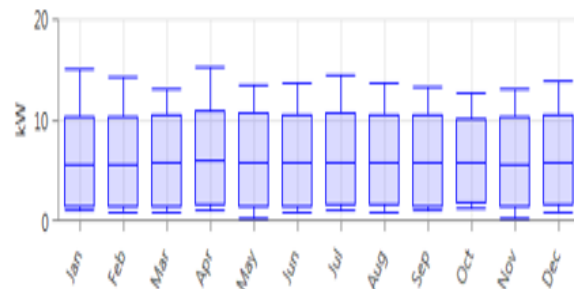
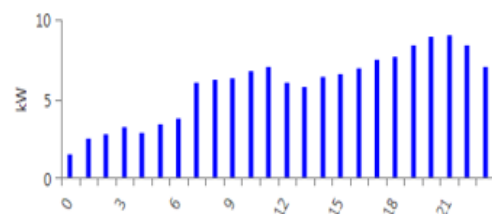
**Figure 4.** Seasonal load profile**Figure 5.** Daily load profile

Table 6. Load specification

Metric	Baseline	Scaled
Average (KWh/d)	141	141
Average (KW)	5.88	5.88
Peak (KW)	15.21	15.21
Load factor	0.39	0.39

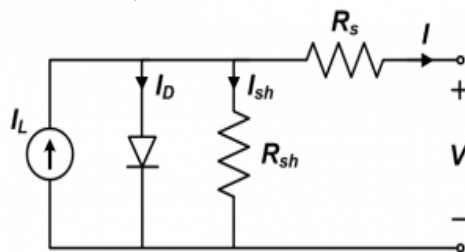
F. Converter

The converter is used to convert AC Voltage into DC Voltage or DC to AC depending on the application [23]. The size used is 5KW capacity generic system converter used with capital cost of Rs.1,20,000

3. System Modelling

The modeling of the system shown in fig (1) includes Solar PV system, Wind System, Battery Storage, Converters used in our study. The system is modeled to determine the governing equation for the single diode model in solar PV system [8], Relationship between output power from wind turbine and wind speed in wind system, discharging and charging energy for batteries.

A. Photovoltaic System

**Figure 6.** Equivalent circuit of PV system

The governing equation for the equivalent circuit of Photovoltaic system shown in Figure6 is formulated using Kirchhoff's current law for current:

$$I = I_L - I_D - I_{sh} \dots \dots \dots (1)$$

I_L -Light-generated current in the cell,

I_D -Voltage-dependent current lost to recombination

I_{sh} - Current lost due to shunt resistances.

In this single diode model, I_D is modeled using Shockley equation for an ideal diode:

$$I_D = I_0 \left[\exp \left(\frac{V + IR_s}{nV_T} \right) - 1 \right] \dots \dots (2)$$

where 'n' is the diode ideality factor (unit less, usually between 1 and 2 for a single junction cell), I_0 is the saturation current, and V_T is the thermal voltage given by

$$V_T = \frac{kT_e}{q}$$

where k - Boltzmann's constant (1.381×10^{-23} J/K) and 'q' is the elementary charge (1.602×10^{-19} C)

Writing the shunt current as $I_{sh} = (V + IR_s) / R_{sh} \dots \dots \dots (3)$

Thus combining above equations (1), (2), (3) results in the complete governing equation for the single diode model:

$$I = I_L - I_0 \left[\exp \left(\frac{V + IR_s}{nV_T} \right) - 1 \right] - \frac{V + IR_s}{R_{sh}} \dots \dots \dots (4)$$

B. Wind System

The relationship between output power from wind turbine and wind speed is given by

$$P_{WT} = \begin{cases} c_p(\lambda, \beta) \frac{\rho A}{2} v_{wind}^3, & v_{cut-in} \leq v_{wind} \leq v_{cut-out} \\ 0 & , otherwise \end{cases} \dots \dots (5)$$

Where

P_{WT} -Mechanical output power of the wind turbine (W), c_p is the performance coefficient of the wind turbine,

c_p - coefficient of wind turbine

ρ -air density (kg/m³),

A - turbine swept area(m²),

v_{cut-in} -cut-in wind speed (m/s),

v_{wind} -windspeed (m/s),

$v_{cut-out}$ -cut-out wind speed (m/s), λ - tip speed ratio of the rotor blade tip speed to wind speed

β -blade pitch angle (deg).

The turbine will not operate below the cut-in speed as it will not produce sufficient power. The wind turbine stops operation above the cut-out speed in order to prevent overload on turbine components or any damage to equipment's [9-10].

C. Battery Storage

For system shown in fig (1), generic 12V Lead acid battery with 1KWh of Energy Storage with Nominal capacity of 1KWh and maximum capacity of 83.4Ah used. The discharging and charging energy are expressed by equation (6)

$$E_{discha} = E_0 - K \cdot \frac{Q}{Q - it} \cdot i^* - K \cdot \frac{Q}{Q - it} \cdot it + Laplace^{-1} \left(\frac{Exp(s)}{Sel(s)} \cdot 0 \right)$$

$$E_{cha} = E_0 - K \cdot \frac{Q}{it - 0.1 \cdot Q} \cdot i^* - K \cdot \frac{Q}{Q - it} \cdot it + Laplace^{-1} \left(\frac{Exp(s)}{Sel(s)} \cdot \frac{1}{s} \right)$$

..... (6)

4. Simulation Results and Performance Analysis

In order to analyze the system performance the number of operating hours for Solar PV System and wind system in a year for Chennai, Tamil Nadu 600003, India (13°5.0'N, 80°16.2'E) have been calculated. By obtaining solar radiation and wind speed data, through HOMER optimization techniques, following output have been simulated as shown in Figure7-9

- (i) Instantaneous Renewable output divided by load
- (ii) Instantaneous Renewable output divided by generation
- (iii) Monthly Average of Electricity Production by Solar PV System

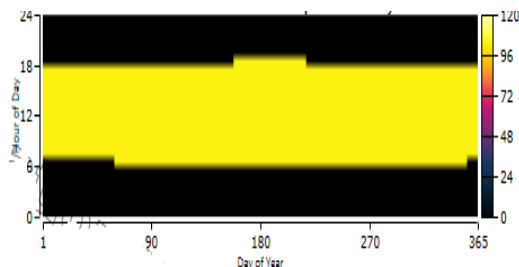


Figure7. Instantaneous Renewable Output Divided by Load

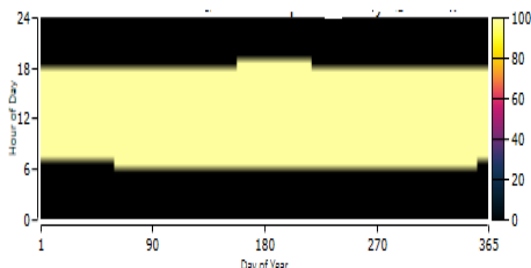


Figure8. Instantaneous Renewable Output Divided by Generation

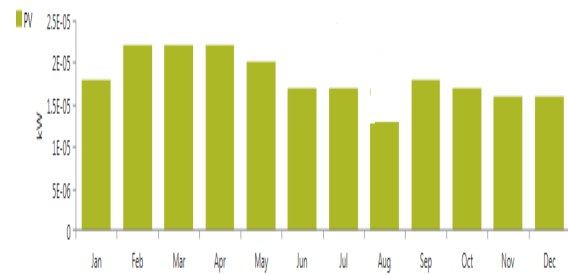


Figure 9. Monthly Average of Electricity Production by Solar PV System

A. PV: Generic Flat Plate PV

The results obtained from HOMER software for Solar PV system (Calculated for 22 years in Chennai) was shown in table-VII

Table 7. Output details for PV system

Quantity	Value
Hours of operation	4372 hrs/yr
Levelized cost	4.45 Rs/KW/hr
Capacity factor	16.8 %
Total Production	22.9 KW/hr/yr
Maximum Output	0.0151KW

B. Wind Turbine: Generic 10KW:

The results obtained from HOMER software for Wind system (Calculated for 22 years in Chennai) was shown in table-VIII

Table 7. Output details for Wind system

Quantity	Value
Hours of operation	6,007 Hrs/year
Levelized cost	4.82 Rs/year
Capacity factor	7.73%
Total Production	6773 KWh/year
Maximum Output	9.94

C. Converter:

The converter for renewable energy application is designed and analyzed [7]. The results obtained from HOMER software converter (Calculated for 22 years in Chennai) was shown in table-IX

Table 8. Output details for PV system

Quantity	Value
Hours of operation	6958 Hrs/Year
Capacity factor	61.8%
Energy out	787 KWhr/year
Energy In	828 KWhr/Year

5. Conclusion

This paper shows review of hybrid solar and wind renewable energy system for an off grid residential application in Chennai, Tamil Nadu 600003, India(13°5.0'N, 80°16.2'E) from (July 1983-June 2005) according to NASA data . The result shows that the levelized cost for solar and wind system, Number of operation hours per year, total production in a year and capacity factor for solar and wind system and converter was calculated. The load was connected to hybrid system in order to analyze the feasible solution for operating solar or wind system.By updating solar radiation, wind speed, Replacement cost, Operation and maintenance cost, capital cost for solar and wind system as inputs, the output obtained. Depending on the availability of solar and wind system, the system will obtain optimal configuration. The result was obtained by HOMER software.

References

- [1] Esmail M. A. Mokheimer, Abdullah Al-Sharafi, Mohamed A. Habib and IyadAlzaharnah, "A New Study for Hybrid PV/Wind off-Grid Power Generation Systems with the Comparison of Results from Homer", International Journal of Green Energy, Vol. 12, Iss. 5, 2015, pp. 526-542.
- [2] Tao Ma, Hongxing Yang and Lin Lu, "A feasibility study of a standalone hybrid solar-wind-battery system for a remote island", Applied Energy. Vol. 121, 2014, pp. 149-158.
- [3] Mohan Kolhe, K. M. IromiUdumbaraRanaweera and A. G. B. SisaraGunawardana, "Techno-Economic Optimum Sizing of Hybrid Renewable Energy System", Annual Conference of the IEEE Industrial Electronics Society, IECON 2013 - 39th, 2013, pp. 1898-1903.
- [4] B H Khan, "Non-conventional Energy Sources", Tata McGraw-Hill Publication, India, II.
- [5] B.Kanagasakthivel and Dr.D.Devaraj, "Simulation and performance analysis of solar pv-wind hybrid energy system using Matlab/Simulink", 2015 International Conference on Computing and Communications Technologies (ICCT), Feb 2015, pp. 99-104.
- [6] P. Mazumdar, P. N. Enjeti, and R. S. Balog, "Analysis and design of smart PV modules," IEEE J. Emerg. Sel. Topics Power Electron., vol. 2, no. 3, pp.451-459, Sep. 2014.
- [7] Y. Li, Y. Zheng, S. Sheng, B. Scandrett, and B. Lehman, "Modular subpanel photovoltaic converter system: analysis and control," in Proc.2016 31st Annu. IEEE Appl. Power Electron. Conf. Expo., Mar. 20-24, pp. 417-423.
- [8] Kawamura, K. Naka, N. Yonekura, S. Yamanaka, H. Ohno, and K. Naito, "Simulation of I-V characteristics of a PV module with shaded PV cells," Solar Energy Mater. Solar Cells, vol. 75, no. 3/4, pp. 61-62, Feb. 2003.
- [9] Kusiak A, Li W, Song Z. Dynamic control of wind turbines. Renewable Energy 2010;35(2):456-63.
- [10] Kusiak A, Song Z. Design of wind farm layout for maximum wind energy capture. Renewable Energy 2010;35(3):685-94.
- [11] Nema P, Nema RK, Rangnekar S. A current and future state of art development of hybrid energy system using wind and PV-solar: a review. Renewable and Sustainable Energy Reviews 2009; 13(8):2096-103.
- [12] Bilal BO, Sambou V, Ndiaye PA, Kebe CMF, Ndongo M. Optimal design of a hybrid solar-wind-battery system using the minimization of the annualized cost system and the minimization of the loss of power supply probability (LPSP). Renewable Energy 2010;35(10):2388-90.
- [13] Yang H, Lu L, Zhou W. A novel optimization sizing model for hybrid solar-wind power generation system. Solar Energy 2007; 81:76-84.
- [14] Rajan Kumar and Bhim Singh. BLDC Motor driven Solar PV Array fed water pumping system employing zeta converter. IEEE Transaction on Industrial Applications, Vol.52, No.3, May/June 2016. P.No-2315-2322
- [15] Geoffrey J. May, Alistair Davidson, Boris Mohahov. Lead Batteries for utility energy storage: A Review. Journal of Energy Storage Vol.15, Feb 2018, Pg-145-157.
- [16] David.A.J. Rand, Patrick T. Moseley. Energy Storage with Lead acid batteries. Electrochemical

Energy storage for Renewable sources and grid balancing. 2015, Pg-201-222.

[17] A.Nami, F. Zare, A. Ghosh and F. Blaabjerg, "Multioutput DC-DC converters based on diode-clamped converters configuration: Topology and control strategy", IET Power Electron., vol. 3, pp. 197-208, 2010.

[18] A.Nahavandi, M.T. Hagh, M.B.B. Sharifian and S. Danyali, "A Nonisolated Multiinput Multioutput DC-DC Boost Converter for Electric Vehicle Applications," IEEE Transactions on Power Electronics, vol. 30, pp. 1818-1835, April 2015.

[19] M. A. Guerrero, E. Romero, F. Barrero. M.I. Milanés and E. Gonzalez, "Overview of Medium Scale Energy Storage Systems", Compatibility and Power Electronics, 2009.

[20] J. Marquez and F. Manzano, "A Methodology for Optimizing Standalone PV-system Size Using Parallel-connected DC/DC Converters", IEEE Trans. on Ind. Electron., Vol. 53, Iss. 7, 2008.

[21] S. K. Kollimalla, M. K. Mishra, and N. L. Narasamma, "Design and Analysis of Novel Control Strategy for Battery and Supercapacitor Storage System" on IEEE Transactions on Sustainable Energy, vol. 5, no.4, pp. 1137-1144, October 2014.

[22] Hredzak, V. G. Agelidis and G. D. Demetriades, "A Low Complexity Control System for Hybrid DC Power Source Based on Ultracapacitor- Lead-Acid-Battery Configuration" on IEEE transactions on Power Electronics, vol. 29, no.6, pp. 2882-2891, June 2014.

[23] J. M. A. Curti, H. J. Xiaoliang, R. H. Minaki and H. Yoichi, "A Simplified Power Management Strategy for a Battery/Supercapacitor Hybrid Energy Storage System Using the Half-Controlled Converter" on 38th Annual Conference on IEEE Industrial Electronics Society (IECON) 2012, pp. 4006-4011, October 2012.

