International Journal of Innovations in Engineering and Technology (IJIET)
http://dx.doi.org/10.21172/ijiet.113.09

Optimization Of Wind-Pv-Fc-Battery System

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Abstract- : One of the most important issue in designing of renewable hybrid energy systems is to size the system components optimally to meet load requirement with minimum annualized cost of system and maximum reliability of power supply. In this work, we have built and simulated a Wind-PV-FC-Battery Hybrid System using the Hybrid Optimization Model for Electric Renewable (HOMER) and compared the operational and economical parameters which are widely used in rural India.

I. INTRODUCTION

The large number of technology options and the variation in technology costs and availability of energy resources make project design decisions difficult. HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations. HOMER allows the user to input an hourly power consumption profile and match renewable energy generation to the required load. It allows a user to analyze micro-grid potential, peak renewables penetration, ratio of renewable sources to total energy, and grid stability, particularly for medium to large scale projects. Additionally, HOMER contains a powerful optimizing function that is useful in determining the cost of various energy project scenarios. This functionality allows for minimization of cost and optimization of scenarios based on various factors.

Hybrid Optimization Model for Electrical Renewable (HOMER), is a micro power optimization model, that simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. The HOMER Hybrid Optimization Modeling Software is used for designing and analyzing hybrid power systems, which contain a mix of conventional generators, cogeneration, wind turbines, solar photovoltaic, hydropower, batteries, fuel cells, biomass and other inputs.

With their advantages of being abundant in nature and nearly non pollutant, renewable energy sources have attracted wide attention. Wind power is one of the most promising clean energy sources since it can easily be captured by wind generators with high power capacity. Photovoltaic (PV) power is another promising clean energy source since it is global and can be harnessed without using rotational generators. In fact, wind power and PV power are complementary to some extent since strong winds are mostly to occur during the nighttime and cloudy days whereas sunny days are often calm with weak winds. Hence, a Wind PV hybrid generation system can offer higher reliability to maintain continuous power output than any other individual power generation systems. Fuel cell used as auxiliary source and combined with PV system can ensure a reliable supply without interruptions. For the production and uniform supply of hydrogen of fuel cell, an Electrolyzer is considered in the proposed system. Also it consists of a battery. The main power of the hybrid system comes from the photovoltaic panels and the wind turbines, while the fuel cell and batteries are used as backup units.

II. PROPOSED ALGORITHM

2.1 Watermark embedding algorithm –No watermarking embedding algorithm is used.
2.2. Watermark Extraction algorithm –No watermark extraction algorithm is used

III. EXPERIMENT AND RESULT

3.1 System Configuration

The configuration of WIND-PV-FC-BATTERY hybrid generation system considered is shown in fig. 1.

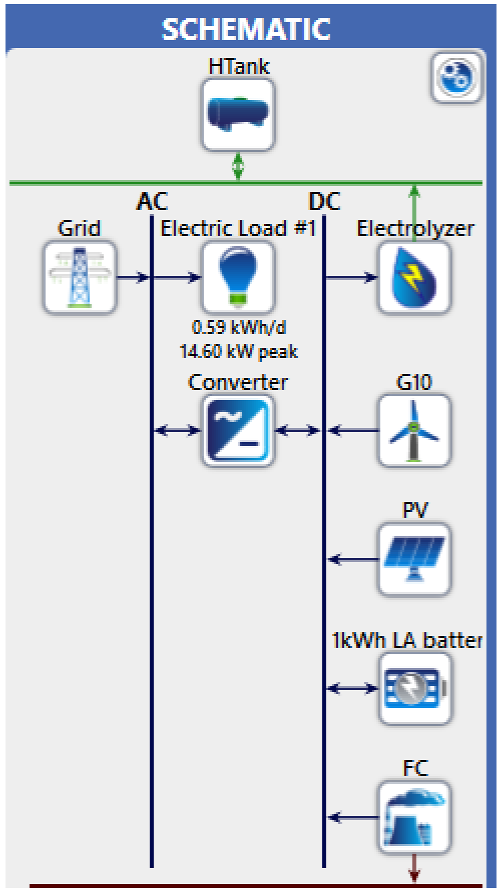

Fig. 1

In the above figure components used are as follows:-

Grid
Electric load
Converter
Fuel cell(FC)
Battery(1kwh lead acid)
Photovoltaic panel(PV)
Wind turbine(g10)
Electrolyzer
Hydrogen tank(htank)

The main objective of this paper is to optimally size of all system components in such a way that it continuously meets the load demand without any failure with possible least cost. As solar power is present during the day, load is mainly supplied by PV and the excess power charges the battery bank. When the battery state of charge (SoC) reaches its maximum SoC level then battery charging stops and electrolyzer gets activated. The hydrogen generation rate is directly proportional to current drawn by the electrolyzer. When PV power is unavailable during the night time; battery supplies the load to its minimum SoC level. After that FC started and supplies the load until PV restored again. Due to the intermittence nature of solar power, reliability analysis has been considered in this study.

3.2 System Components

3.2.1 Photovoltaic (PV)

Photovoltaic (PV) is a term which covers the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect. Solar irradiance data for this region is obtained from the website synergy environmental engineers (India) private limited [1].

Table 1. Monthly average irradiance data

JAN	3.24
FEB	4.92
MAR	6.32
APR	5.79
MAY	5.38
JUN	4.13
JUL	2.79
AUG	3.50
SEP	4.67
OCT	4.24
NOV	3.45
DEC	3.12

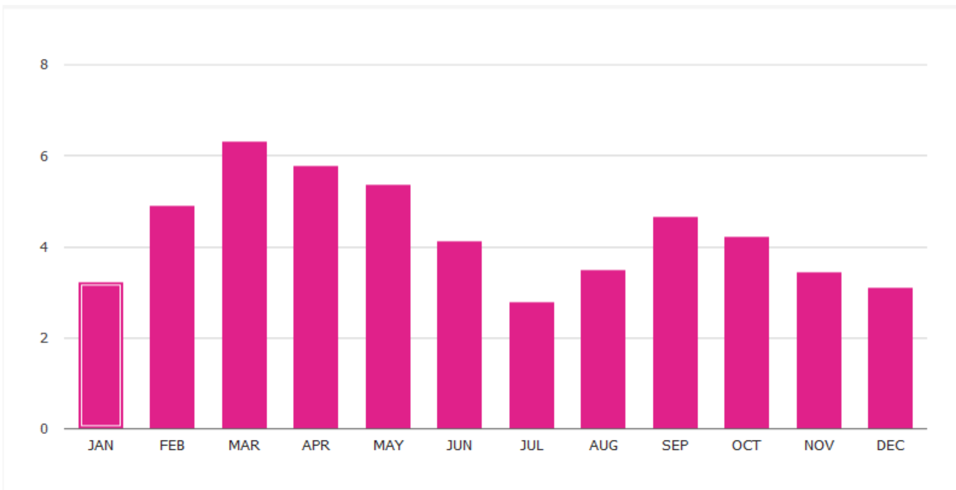

Fig. 2

3.2.2 Wind turbine

A wind turbine is a device that converts the wind's kinetic energy into electrical energy.

Wind turbines are classified by the wind speed they are designed for, from class I to class III, with A to C referring to the turbulence intensity of the wind [2].

3.2.3 Wind turbine power curve [6]

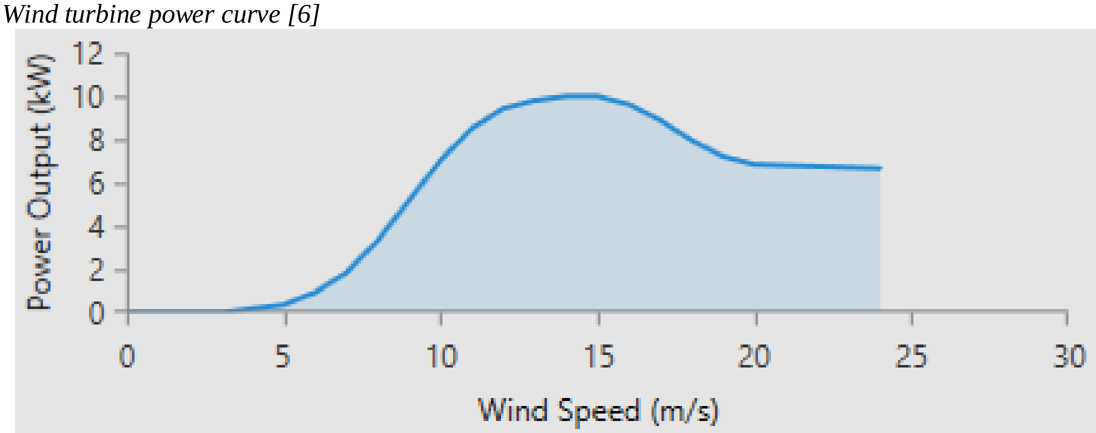

Table 2. Classification of wind turbines

Class	Avg. wind speed(m/s)	Turbulence
IA	10	16%
IB	10	14%
IC	10	12%
IIA	8.5	16%
IIB	8.5	14%
IIC	8.5	12%
IIIA	7.5	16%
IIIB	7.5	14%
IIIC	7.5	12%

Table3. Power output table [9]

Wind Speed (m/Sec)	Power output (kW)
0	0
3	0
4	0.19
5	0.37
6	0.93
7	1.85
8	3.33
9	5.19
10	7.04
11	8.52
12	9.44
13	9.81
14	10
15	10
16	9.63
17	8.89
18	7.96
19	7.22
20	6.85
24	6.67

3.3 Fuel Cell

A fuel cell is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen fuel with oxygen or another oxidizing agent [3]. Fuel cells are different from batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction, whereas in a battery the chemical energy comes from chemicals already present in the battery. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

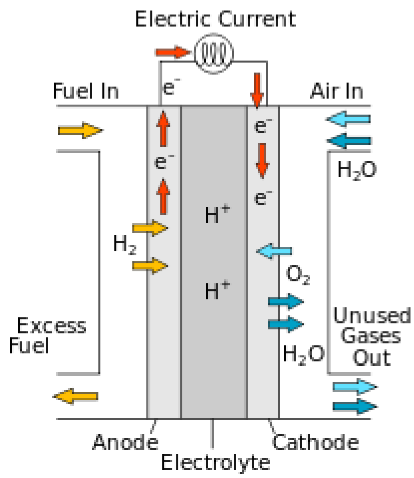

Fig. 3 Proton-conducting fuel cell

3.4 Electrolyzer

Hydrogen can be produced by the decomposition of water into its elementary components by passing the electric circuits. A water electrolyzer consists of several cells connected in series. Two electrodes of the electrolyzer are separated by electrolyte. Electrical current through the Electrolyzer enables the decomposition of water into hydrogen and oxygen by [4]:-

H2O + electricity ⟶ H2 + 1/2O2 (1)

According to the Faraday's law the amount of Hydrogen produced by rated power Pfc kW Electrolyzer in 1hour can be calculated by [8]

HYele = [(Pele x 3600) / (2 x Vele x F)] (mole/h-1) (2)

HYele = amount of hydrogen produced by electrolyzer
Pele = rated power of electrolyzer
Vele = working voltage of electrolyzer
Pfc = Rated power of fuel cell

3.5 Hydrogen tank

A Hydrogen tank (other names- cartridge or canister) is used for hydrogen storage [5].

Hydrogen energy produced by the electrolyzer provides solar energy storage in excess demand. The method of transferring the capacity of hydrogen tanks to the unit kWh is given by [7]

Etank (kWh) =Mtank (mol) x2x10- 3(kg/mol) x LHV (kWh/kg) (3)

Where,
Etank and Mtank = size of hydrogen tank in kWh
LHV = Low heat value of hydrogen in kWh/kg

3.6 Battery

Battery bank is a traditional approach to store electrical energy with high efficiency. Its discharging level cannot exceed a minimum limit defined as depth of discharge.

Battery parameters	Lead acid battery
Nominal voltage(V)	12
Nominal capacity(kwh)	1
Maximum capacity(Ah)	83.4
Capacity ratio	0.403
Rate constant(1/hr)	0.827
Round-trip efficiency (%)	80
Max. charge current(A)	16.7
Max. discharge current(A)	24.3
Max. charge rate(A/Ah)	1

3.7 Load profile

A standalone load of 0.59kWh/day energy consumption and 14.60kW peak is considered for the analysis. The daily load profile is shown in Figure 4. These load data are assumed to remain constant in each hour.

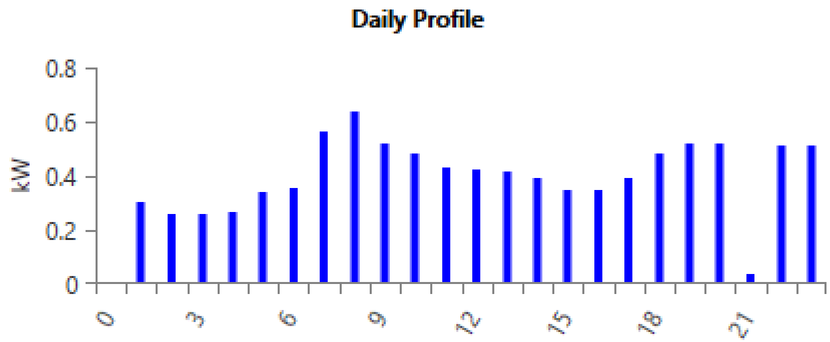

Fig. 4

3.8 Optimization and Simulation results:-

The simulations for various combinations of the systems are carried out to find out most optimal combination as shown in following figures:-

PV (kW)	G10	FC (kW)	1kWh LA battery	Grid (kW)	Electrolyzer (kW)	HTank (kg)	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)
0.00161	1		1	999,999	100		0.0635	CC	$65,252	$23.58	$1,155
0.00161	1		1	999,999	100	100	0.0635	CC	$65,252	$23.58	$1,155

Fig.5 Optimization results for Wind-Pv-Fc-Battery hybrid system

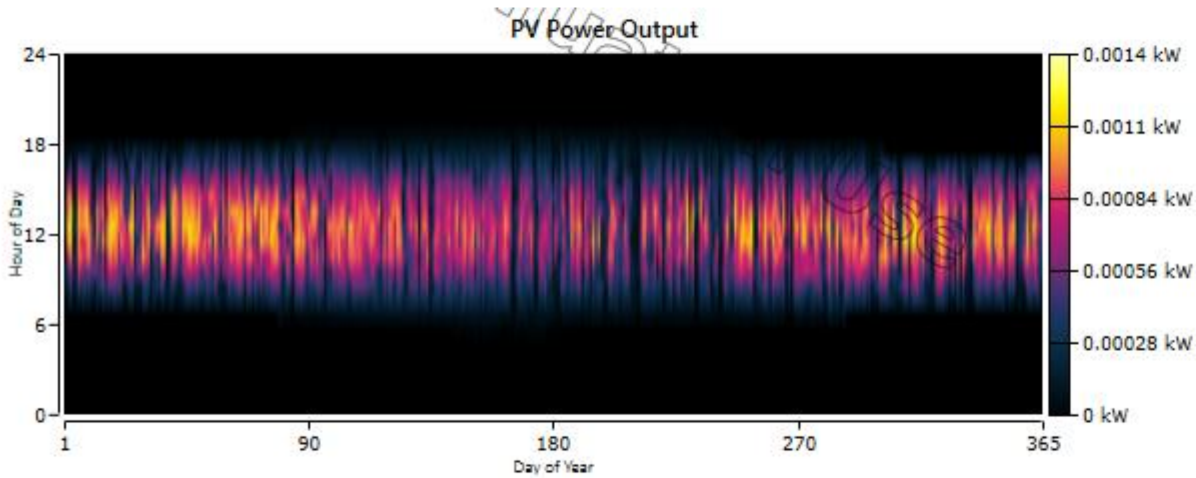

Fig. 6 PV output simulation result

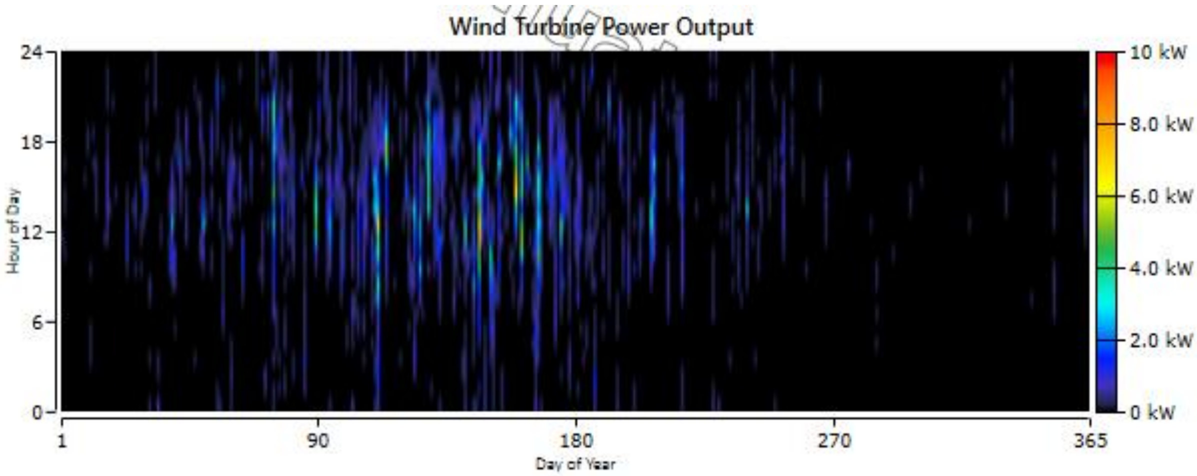

Fig.7 wind turbine power output simulation result

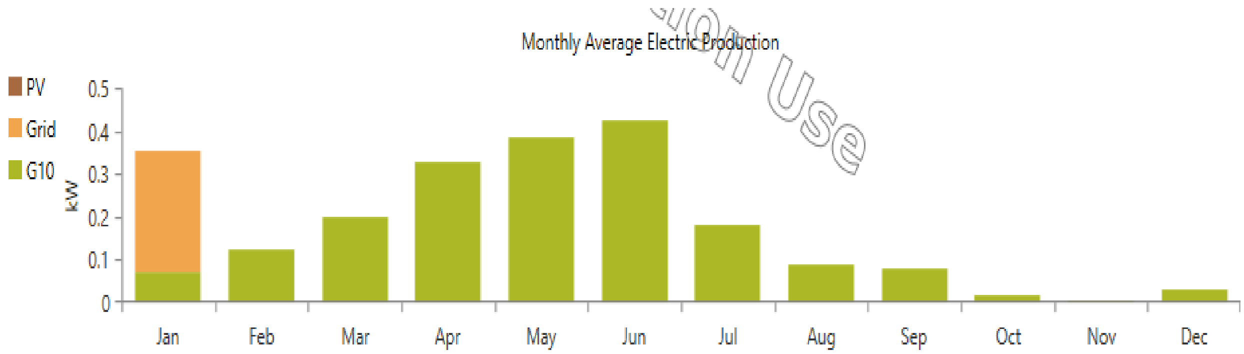

Fig.8 Monthly average electric production simulation result

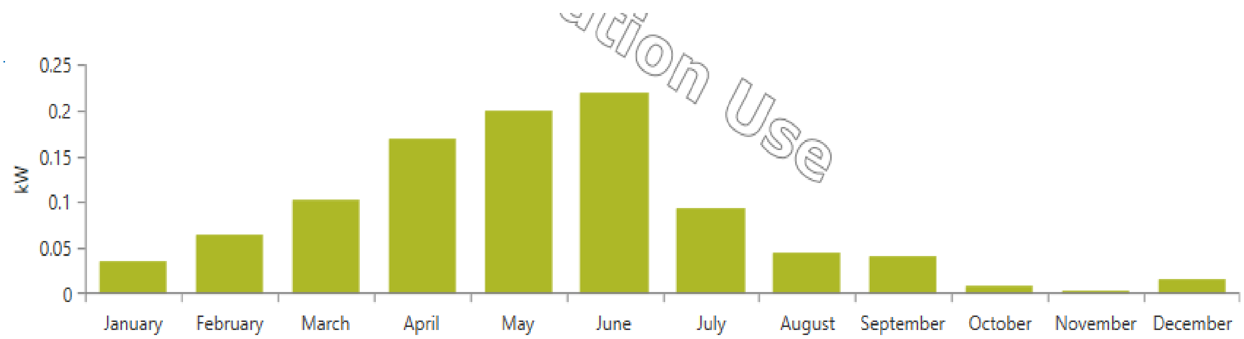

Fig.9 Simulation output Monthly Hydrogen production

The optimized results shows the least operating cost of the system which comes out to be Rs 84,962 only. Total net present cost of the system is Rs 47, 999, 37.12. 65% of total electrical energy is produced by photovoltaic and remaining 35% by wind turbine. The total electric production of the system is 1626kWh/yr. Fig. 10 shows the simulation output result of monthly hydrogen production.

IV. CONCLUSION

The goal of this study is to show that WIND-PV-FC-BATTERY hybrids if designed optimally can be more efficient, economic and ecofriendly in meeting the energy needs of remote areas. As the wind speed increases during the night, the saving would be much higher and this system proves to be a better option to provide cost effective and clean electricity. The results of this study can be used for deployment of WIND-PV-FC-BATTERY hybrid system to supply cost effective electricity to customers while protecting the environment in remote locations

V. REFERENCES

[1] B Corona, M. Nakano, H. Pérez, "Adaptive Watermarking Algorithm for Binary Image Watermarks", Lecture Notes in Computer Science, Springer, pp. 207-215, 2004.
[2] A A Reddy and B. N. Chatterji, "A new wavelet based logo-watermarking scheme," Pattern Recognition Letters, vol. 26, pp. 1019-1027, 2005.
[3] P. S. Huang, C. S. Chiang, C. P. Chang, and T. M. Tu, "Robust spatial watermarking technique for colour images via direct saturation adjustment," Vision, Image and Signal Processing, IEE Proceedings -, vol. 152, pp. 561-574, 2005.
[4] F. Gonzalez and J. Hernandez, " A tutorial on Digital Watermarking ", In IEEE annual Carnahan conference on security technology, Spain, 1999.
[5] D. Kunder, "Multi-resolution Digital Watermarking Algorithms and Implications for Multimedia Signals", Ph.D. thesis, university of Toronto, Canada, 2001.
[6] J. Eggers, J. Su and B. Girod," Robustness of a Blind Image Watermarking Scheme", Proc. IEEE Int. Conf. on Image Proc., Vancouver, 2000.
[7] Barni M., Bartolini F., Piva A., Multichannel watermarking of color images, IEEE Transaction on Circuits and Systems of Video Technology 12(3) (2002) 142-156.
[8] Kundur D., Hatzinakos D., Towards robust logo watermarking using multiresolution image fusion, IEEE Transcations on Multimedia 6 (2004) 185-197.
[9] C.S. Lu, H.Y.M Liao, "Multipurpose watermarking for image authentication and protection," IEEE Transaction on Image Processing, vol. 10, pp. 1579-1592, Oct. 2001.
[10] L. Ghouti, A. Bouridane, M.K. Ibrahim, and S. Boussakta, "Digital image watermarking using balanced multiwavelets", IEEE Trans. Signal Process., 2006, Vol. 54, No. 4, pp. 1519-1536.
[11] P. Tay and J. Havlicek, "Image Watermarking Using Wavelets", in Proceedings of the 2002 IEEE, pp. II.258 – II.261, 2002.
[12] P. Kumswat, Ki. Attakitmongcol and A. Striaew, "A New Approach for Optimization in Image Watermarking by Using Genetic Algorithms", IEEE Transactions on Signal Processing, Vol. 53, No. 12, pp. 4707-4719, December, 2005.
[13] H. Daren, L. Jifuen,H. Jiwu, and L. Hongmei, "A DWT-Based Image Watermarking Algorithm", in Proceedings of the IEEE International Conference on Multimedia and Expo, pp. 429-432, 2001.
[14] C. Hsu and J. Wu, "Multi-resolution Watermarking for Digital Images", IEEE Transactions on Circuits and Systems- II, Vol. 45, No. 8, pp. 1097-1101, August 1998.
[15] R. Mehul, "Discrete Wavelet Transform Based Multiple Watermarking Scheme", in Proceedings of the 2003 IEEE TENCON, pp. 935-938, 2003.
[16] http://www.synergyenviron.com
[17] "Appendix II IEC Classification of Wind Turbines". Wind Resource Assessment and Micro- siting, Science and Engineering. Retrieved 29 August 2018.
[18] Khurmi, R. S. Material Science.
[19] Santarelli, M., Cali, M., Macagno, S. (2004) 'Design and analysis of stand-alone hydrogen energy systems with different renewable sources', International Journal of Hydrogen Energy 29(15), pp. 1571–86
[20] International hydrogen fuel and pressure vessel forum 2010 Archived 2012-09-05 at the Wayback Machine.
[21] www.homerenergy.com
[22] Mamadou Lamine Doumbia, Kodjo Agbossou, 2009. Photovoltaic/Wind Energy System With Hydrogen System, pp. 249-265
[23] Santarelli, M., Cali, M., Macagno, S. (2004) 'Design and analysis of stand-alone hydrogen energy systems with different renewable sources', International Journal of Hydrogen Energy 29(15), pp. 1571–86 homerenergy.com