OPTIMAL SIZING OF OFF-GRID HYBRID RENEWABLE ENERGY SYSTEM FOR REMOTE AREA

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ABSTRACT : Energy is one of the essential requirements to alleviate poverty and socioeconomic advancement. Most of the rural area is not under the national grid; therefore, electrification in rural area is the crying need of India. The reserve of fossil fuel is diminishing; also the price of fuel is increasing throughout the world. Environmental pollution is another important issue. Green energy is current demand for the existence of future world. For that reason, reducing carbon emission and meeting energy demands are the main topologies to plan energy systems. As India is an agricultural based country, biomass resources are available here and there is also good prospect of solar energy. The study indicates that off grid hybrid system including PV and biomass system is the most feasible solution in view of the monthly average solar radiation intensity, biomass resource availability of the design location Ujjain, Madhya Pradesh, India. The most cost effective one simulation result gives the lowest COE of $0.277kWh and lowest NPC of $125737 with a renewable fraction of 100% is configured with a 30kW PV, 15 kW Biomass generator, 50 battery and 25 kW converters. This proposed hybrid system is also environment friendly because emission is very less such as carbon dioxide 1.14kg/yr and nitrogen oxides .38kg/yr.

I. INTRODUCTION

Expanding electrification and scaling up electricity benefit is exact to both the economic and social development of India. The current condition of electrical services across India can be said to be acute, if not in a crisis mode. The instant manifestations of this crisis are severe shortcomings in:

- Access to electricity for rural and urban poor,
- Generation capacity that cannot meet peak demand,
- Reliability of supply, in terms of predictability of outages and quality of power supply.

National statistics tell a story of problems afflicting generation, transmission, and distribution of electricity. This project report examines the rural electricity sector development in India using available renewable energy sources and provides recommendations on possible reforms with a focus states: Madhya Pradesh. A hybrid renewable energy system for an isolated small community, where grid extension is considered uneconomical. The project proposed cost optimization through dynamic matching between load and equipment sizing. The HOMER software based design model developed for determining the most cost effective energy source to supply required load any given time of the day.

These reforms, combined with a focus on capacity building within and modernization of electricity infrastructure, provide a roadmap to reinvigorating India's energy sector.

The evolution of the power sector in India, the role of SEBs, and the outcomes of key rustic electrification schemes are also detailed in the report. As a result of several factors the progress of rustic electrification in developing countries is insufficient. Factors are, for instance; over-dimensioning of supply system, resulting in costly electricity, rustic-urban demographic move and poor condition for investment credits as well as absence of financial institutes.

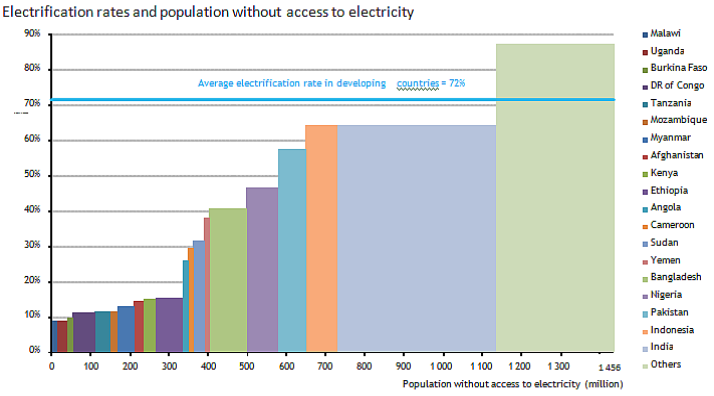


Fig 1: Electrification rates and population without access to electricity.

The challenges for rustic electrification are to:

- Expand admittance of electricity to un-electrified villages.
- Increase penetration cost in electrified villages.
- Strengthen technical and operational production of the distribution network in villages.
- Provide a sustainable model for rustic electrification.

Table 1 explains the real values for a number of indicators recorded in 1993, the status of these indicators in 2011 and the projections for 2020 made in Energy for Tomorrow's World, High-Growth Scenario A to 2020. The comparison show that future developments are often underestimated. Even the maximum projections made 20 years back, fall below the fact. What does it mean? It means that the demand for energy might increase significantly faster than expected, and if suitably conduct, energy resources and technologies should be available to meet this demand. The changes in the energy industry over the over 20 years have been significant.

Table 1: Key indicators for 1993, 2011 and 2020

Variables	1993	2011	2020	% Growth 1993-2011
World Population, billion	5.5	7	8.1	27%
GDP, trillion USD	25	70	65	180%
TPES, Mtoe	9 532	14 092	17 208	48%

Coal, Mt	4 474	7 520	10 108	68%
Oil, Mt	3 179	3 973	4 594	25%
Natural Gas, bcm	2 176	3 510	4 049	62%
Nuclear, TWh	2 106	2 386	3 761	13%
Hydropower, TWh	2 286	3 229	3 826	29%
Biomass, Mtoe	1 036	1 277	1 323	23%
Other renewables*, TWh	44	515	1 999	n/a
Total Electricity production/year,TWh	12 607	22 202	23 000	76%
Electricity production/year, MWh per Capita	2	3	3	52%
Total CO_2 emissions/year, $GtCO_2$	21	30	42	44%
CO_2 emissions/year, tone CO_2 per Capita	4	4	n/a	11%
Energy intensity, koe/2005USD	0.24	0.19	n/a	-21%

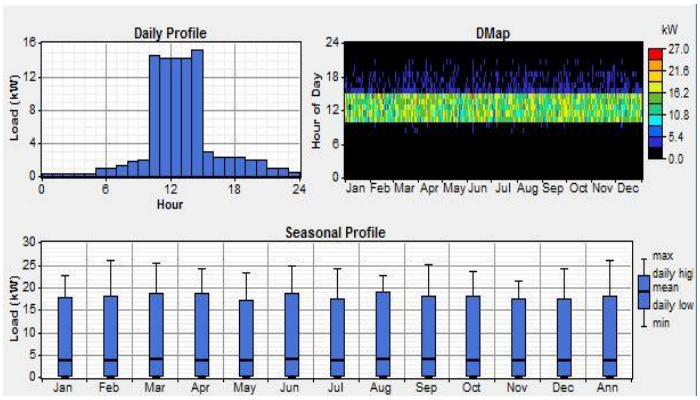
Source: World Energy Resources

Rohit Sen et. al [1]: The authors have presented a study of off-grid hybrid system configuration using HOMER for Palari village in Chhattisgarh and hybrid system installation cost is compared with conventional grid extension cost. The results obtained shows that a hybrid combination of renewable energy sources at an off grid location can be a cost effective alternative to grid extension and it is techno-economically viable and environmental friendly. Chong Li et. al [2]: The authors have presented HOMER assessment criteria and perform techno economic feasibility study of an autonomous hybrid wind/PV/battery power system for a household in Urumqi, China using HOMER. The hybrid wind/PV/battery system with 5 kW of PV array, one wind turbine of 2.5 kW, 8 unit batteries each of 6.94 kWh and 5 kW sized power converters comprises an optimal power system for the household; it reduces the total net present cost about 9% and 11% compared with PV/battery and wind/battery power systems. Mohan Kolhe et. al [3]: The authors have presented an option for rural electrification in Sri Lanka by studying off-grid hybrid renewable energy system. The system consisting of 20 kW PV, 40 kW wind turbine, 20 kW generators and 40 units of batteries is chosen as the optimal hybrid system configuration based on the HOMER optimization and sensitivity results. It can supply the electricity with 0.36 $/kWh cost of energy, which is considerably higher than the price of the grid electricity in Sri Lanka. But due to the unavailability of the national grid, this type of system offers an alternative to supply electricity for rural communities. Md. Moniruzzaman et. al [4]: The authors studied various combinations for hybrid system (PV-wind-diesel, PV-diesel, Wind-diesel, PV-wind-grid and PV-grid). HOMER software package is used to analysis the solar and wind data of a tourist spot in Bandarban, Bangladesh. Analysis of only renewable supported hybrid systems has been done along with hybrid grid connected systems. Shafiqur Rehman et. al [5]: The authors presented a feasibility study of a wind-PV-diesel hybrid power system for Rawdat Ben Habbas village in Saudi Arabia. The study found a wind-PV-diesel hybrid power system with 35% renewable fraction (26%wind and 9% solar PV) to be the feasible system with cost of energy of 0.212 US$/kWh. The proposed hybrid system was comprised of 3 wind turbines each of 600 kW, 1000 kW of PV panels, and four units of diesel generators each of 1120 kW rated power. N.M. Ijumba [6]: Renewable energy systems are increasingly being applied in areas where the grid increase is considered uneconomical. Their costs can be minimized through proper equipment sizing and load matching. This paper discusses the development of a computer programmer for determining the most cost effective energy source to supply the required load at any given time of the day.

II. HYBRID SYTEM COMPONANTS

Load

The load data for design location of Ujjain, Madhya Pradesh, India are used for disgn of hybrid system. The design location has less consumer load demand because the population of the particular location is less. The per day load demand of the location is 99.7 kWh/d and peak load demand is 21.6kW.



Fi.g 2.Load profile of design loaction

PV system

Solar radiation of the design location Ujjain, Madhya Pradesh, India which has latitude 23.29 north and longitude 75.49 east is 5.33kWh/m2/day. Monthly solar global irradiation and clearance data are given in table no 2.

Table no. 2 solar resource data

Month	Clearance Data	Daily radiation
January	0.657	4.569
February	0.666	5.368
March	0.620	5.835
April	0.624	6.534
May	0.624	6.874
June	0.545	6.089
July	0.392	4.334

August	0.378	3.999
September	0.554	5.353
October	0.691	5.778
November	0.678	4.849
December	0.675	4.452

Biomass Generator

The use of biomass to supply energy has been fundamental to the development of civilization. In recent times pressures on the global environment have led to calls for an increased use of renewable energy sources, in place of fossil fuels. Biomass is one potential source of renewable energy and the conversion of plant material into a suitable form of energy, usually electricity or as a fuel for an internal combustion engine, can be fulfill using a number of different routes, each with specific pros and cons. A brief review of the main conversion processes is presented, with limited regard to the production of a fuel suitable for spark ignition gas engines[10-11].

Battery

Battery Generic 1kWh Lead Acid was chosen as battery at hybrid power generating system. Nominal voltage is 12V with 1 KWh energy storage. By means of using HOMER software, battery number is given as (0-10-20-30-40-50) to determine the optimum configuration at hybrid power generating system. Capital, replacement and maintenance and operation costs of the battery are 211$, 190$ and 10$/year respectively [7].

Converte

Converter The power produced by way of PV panel and biomass generator must be converted into AC power to be used to meet the load. Therefore, a converter is needed. Because hourly maximum load value of the Forest Observation Tower was 26.17kW, its converter power was chosen as 3kW and the efficiency was % 90. The initial cost is 600$/kW, the replacement cost is 360$/kW. Maintenance and operation cost is neglected because it costs too little. By means of using HOMER software, the converter power was chosen at (0- 10- 15-27kW) power range to determine the optimum configuration at hybrid power generating system [6].

HOMER

The Hybrid Optimization Model of Electric Renewable (HOMER) is a general purpose designing software developed by the U.S. National Renewable Energy Laboratory (NREL) in 1993 [4]. Number of software have been developed by different institutions for analyzing the hybrid energy system, for e.g. HOMER, PV system, Hybrid2 etc. among all these software HOMER is the widely used tool for hybrid system sizing [3]. This optimization software package simulates varied renewable energy sources (RES) system configuration and scales them on basis of net present cost (NPC) which is total cost of installing and operating system over its lifetime [5],[9]. HOMER can model grid-connected and off-grid hybrid systems serving the require electric loads, and comprising any combination of photovoltaic (PV) modules, wind turbines, small hydro, generators, micro turbines, fuel cells, batteries, and hydrogen storage. HOMER allows modeller to compare a number of different designs options, taking into account the technical and economic features of system configuration. The analysis and design of hybrid systems can be challenging, due to the large number of design options and the uncertainty in important parameters, such as load demand and future fuel price. Renewable power sources add further complexity because their power output may be intermittent, seasonal and the availability of renewable resources may be uncertain. HOMER keeps the accounts of such challenges. HOMER performs three principal tasks: simulation, optimization, and sensitivity analysis [6]. In the simulation process, HOMER models the performance of a particular micro power system configuration each hour of the year to determine its technical feasibility and net present cost. In the optimization process, HOMER simulates many different system configurations in search of the one that satisfies the technical constraints at the lowest net present cost. In the sensitivity analysis process, HOMER performs multiple optimizations under a wide range of input to see the effects of uncertainty or changes in the model inputs Sensitivity analysis helps to see the uncertainty or changes in the variables over which the designer has no control, such as the average wind speed, solar radiation or the future fuel price. Fig.3 shows the architecture of HOMER simulation and optimization. To use HOMER, one should provide the HOMER software with inputs, which describe technology options, component costs, sizes and resource availability. HOMER uses these inputs to simulate different system configurations, and generates results that can be viewed as a list of feasible configurations sorted by NPC. HOMER also displays simulation results in a wide variety of tables and a graph which helps in comparing different configurations and evaluates them on their economic and technical basis [6].

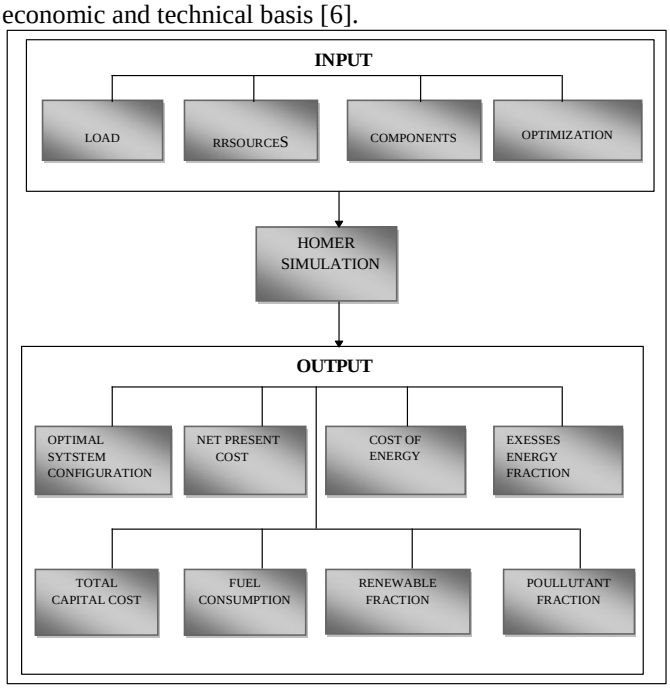


Fig.3. Architecture of HOMER simulation and optimization

III. RESULTS AND DISCUSSION

This section deals with the result and analysis. The optimization results are presented for PV/Biomass hybrid system, which is followed by outcomes of the sensitivity analysis. The proposed system is considered at 5.3300 kWh/m2/day global solar radiation. The environmental aspect of system configuration is also considered by performing emission analysis. The proposed PV/Biomass hybrid system model is shown in fig.5.1

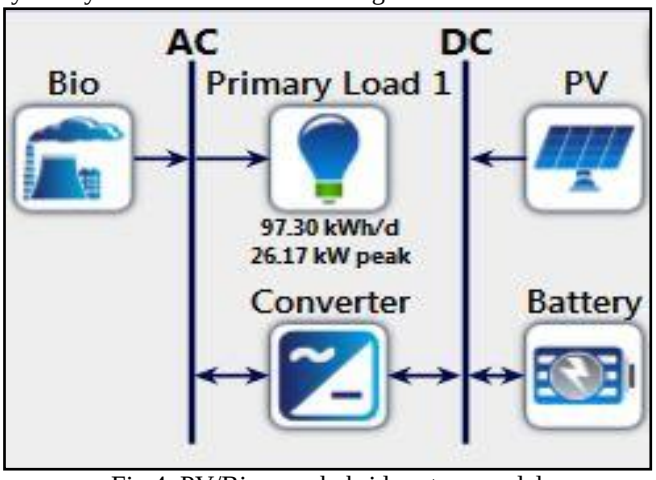


Fig 4. PV/Biomass hybrid system model

HOMER performs simulations with respect to a number of inputs given. It identifies the best hybrid system configuration based on several combinations of equipment and their cost and ranks them in ascending order on the basis of least net present cost (NPC). In fig.5.2

Architecture						Cost				System
PV (kW)	Bio (kW)	Battery	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)
30.0	15.0	50	25.0	CC	$0.277	$125,737	$4,438	$69,000	100
35.0	15.0	50	25.0	CC	$0.279	$126,632	$4,039	$75,000	100
40.0	15.0	50	25.0	CC	$0.281	$127,499	$3,637	$81,000	100
30.0	15.0	45	25.0	CC	$0.281	$127,730	$4,676	$67,950	100
40.0	15.0	45	25.0	CC	$0.281	$127,750	$3,739	$79,950	100

Fig 5. simulation result of hybrid model.

A list has been presented for different configurations. Five hybrid configurations have been selected for PV/Biomass/Battery connected load. The first configuration which is the most cost effective one gives the lowest COE of $0.277kWh and lowest NPC of $125737 with a renewable fraction of 100% is configured with a 30kW PV, 15 kW Biomass generator, 50 battery and 25 kW converters. The operating and initial cost is $4438 and $69000 respectively. The PV/Biomass/Battery hybrid system is analysis on various parameters such as.

- Cost summary
- Cash flow
- Compare economics
- Electrical
- Fuel summary
- Biomass generator
- Renewable penetration
- Generic battery
- SPV system
- Convertor
- Emission

IV. CONCLUSION

India is running in the crisis zone of power shortage. The installation of the power generating plant in a rural area is very costly because of transmission losses, transportation cost, less revenue, etc. Due to all thus problem renewable energy is the best alternative to electrify the rural /remote locations. The feasibility of utilization of biomass resources, a waste product in the village of the N–E Indian state Madhya Pradesh, gasifire-generator unit for power generation purpose in hybrid model has been tried to be explored in this proposed work. Keeping in view the exploitation of this unused potential, an optimized off- grid solar PV/biomass combined energy system has been developed for typical village in the state where the supply of electricity is always a critical issue. It is perceived from the study that greater energy production (100%) of the optimized hybrid plant comes from PV/Biomass hybrid system.

REFERANCES

[1] Report prepared for Industry Canada by the Delphi Group, “Unleashing the Potential of On-Grid Photovoltaic in Canada. An Action Plan to make PV an Integral Component of Canada’s Energy Future," available online: http://www.ic.gc.ca/epic/site/reiier.nsf/ en/h_nz00017 e.html. Retrieved February 2009.

[2] Chong Li , Xinfeng Ge , Yuan Zheng , Chang Xu , Yan Ren , Chenguang Song ,Chunxia Yang, “Techno-economic feasibility study of autonomous hybrid wind/PV/battery power system for a household in Urumqi, China”, Energy,vol.55,pp. 263-272, 2013.

[3] Mohan Kolhe, K. M. Iromi Udumbara Ranaweera, A. G. B. Sisara Gunawardana, “Techno-Economic Optimum Sizing of Hybrid Renewable Energy System”, Industrial Electronics Society, IECON - 39th Annual Conference of the IEEE, pp.1898-1903, 10-13 Nov. 2013.

[4] Md. Moniruzzaman, Samiul Hasan, “Cost analysis of PV/Wind/Diesel/Grid connected hybrid system”, International Conference on Informatics, Electronics, IEEE conference, 2012.

[5] Shafiqur Rehman, Md. Mahbub Alam, J.P. Meyer, Luai M. Al-Hadhrami,“Feasibility study of a Wind-PV-diesel hybrid power system for a village”, Renewable Energy, 38, pp. 258-268, 2012.

[6] Nurul Arina bte Abdull Razak, Muhammad Murtadha bin Othman, Ismail Musirin, “Optimal Sizing and Operational Strategy of Hybrid Renewable Energy System Using HOMER”, The 4th International Power Engineering and Optimization Conf. (PEOCO2010) Shah Alam, Selangor, Malaysia, pp. 23-24 June 2010.

[7] Getachew Bekele, Bjorn Palm, “Feasibility study

for a standalone solar-windbased hybrid energy system for application in Ethiopia", Applied energy, vol.87, pp.487-495,2010.

[8] N.M.Ijumba, "Optimized application of renewable energy sources in rural electrification" 1999, IEEE

[9] Yashwant Sawle, and S. C. Gupta. "Optimal sizing of photo voltaic/wind hybrid energy system for rural electrification." In Power India International Conference (PIICON), 2014 6th IEEE, pp. 1-4. IEEE, 2014.

[10] Sawle, Yashwant, S. C. Gupta, and Aashish Kumar Bohre. "PV-wind hybrid system: A review with case study." Cogent Engineering 3.1 (2016): 1189305

[11] Y. Sawle, S. C. Gupta, A. K. Bohre Optimal sizing of standalone PV/Wind/Biomass hybrid energy system using GA and PSO optimization technique, 1st International Conference on Power Engineering Computing and CONtrol (PECCON-2017) 2n d- 4th March 2017.

