Renewable Hybrid Energy System for Sustainable and Economical Power Supply- A Review

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Abstract

Renewable energy sources are an "indigenous" environmental option, economically competitive with conventional power generation where good wind and solar resources are available. Hybrid plants can help in improving the economic and environmental sustainability of renewable energy systems to fulfill the energy demand. It consists of PV and solar thermal modules, wind turbine and biomass plant.A large proportion of the world's population lives in remote rural areas that are geographically isolated and sparsely populated. This paper proposed a hybrid power generation system suitable for remote area application. The concept of hybridizing renewable energy sources is that the base load is to be covered by largest and firmly available renewable sourceand other intermittent source should augment the baseload to cover the peak load of an isolated mini electric grid system.

Key words: *Renewable Energy*, *Integrated Energy Sources,* Solar PV, Wind, HOMER,*Optimization*.

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1. Introduction

Hybrid energy systems can be used to generate electricity consumed in household. This paper describes design, simulation and feasibility study of a hybrid energy system for a household in Malaysia. One year recorded wind speed and solar radiation are used for the design of a hybrid energy system. In 2004 was average annual wind speed in Kuala Terengganu is 3 m/s and annual average solar energy resource available is 5.2 kWh/m^2/day. National Renewable Energy Laboratory's HOMER software was used to select an optimum hybrid energy system. 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). The optimization study indicates that sensitivity analysis of the HOMER is shown in the overall winner which shows that the most least cost and optimize hybrid system is combination of the 2 kW PV, 1 units wind turbine with capacity 1 kW, 1 kW converter, and 24 unit batteries.

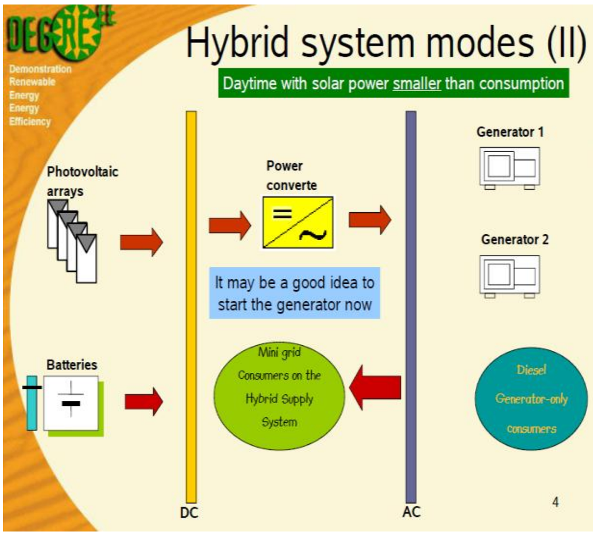

Figure 1- Hybrid energy systems Model

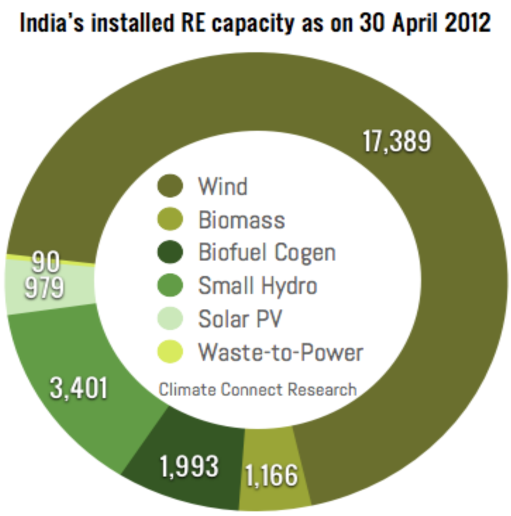

Figure 2 India's installed RE capacity (as on 30 April 2012)

The sustainable security of energy supply, led both developed and developing countries to make and implement new policies to improve efficiency in energy consumption, to adopt new alternatives like renewable energy systems. To face the economic, social, technological and environmental challenges, the need for energy conservation as well as for developing renewable technologies becomes ever more critical.

Various aspects must be taken into account when working with stand-alone hybrid systems for the generation of electricity. Reliability and cost are two of these aspects; it is possible to confirm that hybrid stand-alone electricity generation systems are usually more reliable and less costly than systems that rely on a single source of energy. In various research papers, it has been proven that hybrid renewable electrical systems in off grid applications are economically viable, especially in remote locations. In addition, climate can make one type of hybrid system more profitable than another type. For example, photovoltaic hybrid systems (Photovoltaic–Diesel–Battery) are ideal in areas with warm climates.

2. Literature Summary

S. M. Hakimi et al. (2011): In this paper, a novel intelligent method is applied to the problem of sizing in a hybrid power system such that the demand of residential area is met. This study is performed for Kahnouj area in south-east Iran. It is to mention that there are many similar regions around the world with this typical situation that can be expanded. The system consist of fuel cells, some wind units, some electrolysers, a reformer, an anaerobic reactor, and some hydrogen tanks. The system is assumed to be stand-alone and uses the biomass as an available energy resource. System costs involve investments, replacement, and operation and maintenance as well as loss of load costs. Prices are all empirical and components are commercially available. In this study, we consider load growth and different types of load profile for their system. In this village, four types of loads exist such as residential, agricultural, industrial, and official loads [3].

Deepak Kumar Lal et al (2011): A large proportion of the world's population lives in remote rural areas that are geographically isolated and sparsely populated. This paper proposed a hybrid power generation system suitable for remote area application. The concept of hybridizing renewable energy sources is that the base load is to be covered by largest and firmly available renewable source(s) and other intermittent source(s) should augment the base load to cover the peak load of an isolated mini electric grid system. The study is based on modelling, simulation and optimization of renewable energy system in rural area in Sundargarh district of Orissa state, India. The model has designed to provide an optimal system configure ration based on hour-by-hour data for energy availability and demands. Various renewable/alternative energy sources, energy storage and their applicability in terms of cost and performance are discussed. The homer software is used to study and design the proposed hybrid alternative energy power system model.

The Sensitivity analysis was carried out using Homer program. Based on simulation results, it has been found that renewable/alternative energy sources will replace the conventional energy sources and would be a feasible solution for distribution of electric power for standalone applications at remote and distant locations [4].

PragyaNema et al. (2010): This paper gives the design idea of optimized PV-Solar and Wind Hybrid Energy System for GSM/CDMA type mobile base station over conventional diesel generator for a particular site in central India (Bhopal) . For this hybrid system ,the meteorological data of Solar Insolation, hourly wind speed, are taken for Bhopal-Central India (Longitude 77_{o}.23'and Latitude 23_{o}.21') and the pattern of load consumption of mobile base station are studied and suitably modelled for optimization of the hybrid energy system using HOMER software. The simulation and optimization result gives the best optimized sizing of wind turbine and solar array with diesel generator for particular GSM/CDMA type mobile telephony base station. This system is more cost effective and environmental friendly over the conventional diesel generator. It should reduced approximate 70%-80% fuel cost over conventional diesel generator and also reduced the emission of CO_2 and other harmful gasses in environments [5].

GM Shafiullah et al. (2010): Current power systems create environmental impacts due to utilization of fossil fuels, especially coal, as carbon dioxide is emitted into the atmosphere. In contrast to fossil fuels, renewable energy offers alternative sources of energy which are in general pollution free, technologically effective and environmentally sustainable. There is an increased interest in renewable energy, particularly solar and wind energy, which provides electricity without giving rise to carbon dioxide emissions. This paper presents economic analysis of a renewable hybrid system for a subtropical climate and also investigated the impact of renewable energy sources to the existing and future smart power system. Initially total net present cost (NPC), cost of energy (COE) and the renewable fraction (RF) have been measured as performances metrics to compare the performances of different systems. For better optimization, the model has been refined with sensitivity analysis which explores performance variations due to wind speed, solar irradiation and diesel fuel prices[2].

PrabodhBajpai et al.(2010): Inthis paper Decentralized distributed generation technologies based on renewable energy recourses such as Solar Photovoltaic (SPV)/ Wind Turbine Generators (WTG) address the major issues concerned with conventional diesel generators to a large extent and are therefore considered as emerging alternate power solutions to stand alone applications. Three stand alone WTG power systems using different energy storage technologies, i.e. WTG-Battery system, WTG-Fuel Cell (FC) system and WTG-FC-Battery system are optimized and compared in this paper. The analysis of such hybrid systems feeding a standalone load of 45.6 kWh/day energy consumption with a 2.3 kW peak power demand is carried out using Hybrid Optimization Model for Electrical Renewable (HOMER) software[7].

Jose´ L. Bernal-Agustı´n et al.(2009): Stand-alone hybrid renewable energy systems usually incur lower costs and demonstrate higher reliability than photovoltaic (PV) or wind systems. The most usual systems are PV–Wind–Battery and PV–Diesel–Battery. Energy storage is usually in batteries (normally of the lead-acid type). Another possible storage alternative, such as hydrogen, is not currently economically viable, given the high cost of the electrolyzers and fuel cells and the low efficiency in the electricity–hydrogen–electricity conversion. When the design of these systems is carried out, it is usually done resolve an optimization problem in which the Net Present Cost (NPC) is minimized or, in some cases, in relation to the Levelized Cost of Energy (LCE)[6].

3. Worldwide Renewable Hybrid System Installations

Table 1:The state wise installed capacity in India (as on 31-12-2009) is 10925MW.

Sr. no.	States	Installed Capacity(MW)
1	Andhra Pradesh	122.5
2	Gujrat	1711.8
3	Karnataka	1390.6
4	Kerala	27.0
5	Madhya Pradesh	212.8
6	Maharashtra	2004.4
7	Rajasthan	855.4
8	Tamil Nadu	4596.2
9	West Bengal	1.1
10	Others	3.2
11	**Total**	**10925.0**

Table 2:Year wise installations of wind solar hybrid systems and its progress in the state of Maharashtra. (As on 16/8/2011)

Sr. No.	Year	Nos. of Systems Installed& Commissioned	Capacity (KW)
1	1998-1999	1	5
2	1999-2000	7	19
3	2000-2001	4	17.95
4	2001-2002	3	25
5	2002-2003	17	77.56
6	2003-2004	15	67.65
7	2004-2005	9	65.375
8	2005-2006	14	58.564
9	2006-2007	16	126.9
10	2007-2008	9	45.4
11	2008-2009	18	50.9
12	2009-2010	13	115.05
13	2010-2011	31	307
14	2011-2012	32	431.14
Total		**189**	**1412.489**

Table 3: Installation work in progress (2011-12) [Ref.13]

Sr.No.	Name of site	Capacity(KW)		Programme/Remarks
1	Shree Kanhoba Urfa KanifnathDevsthan Trust, Madi. Tal. Pathardi, Dist. Ahmednagar	30KW(19.2KW Wind +10.8KW Solar PV)	Work in Progress	MNRE
2	ShriSai College of Engg. Parderi	50KW(32KW Wind +18KW Solar PV)	Work in Progress	MNRE
3	Swami VivekanandVidyalaya& Jr. College Parderi	10KW(6.4KW Wind +3.6KW Solar PV)	Work in Progress	MNRE

4	SantBhahinabaiJr.CollegeVaijpur	10KW(6.4KW Wind +3.6KW Solar PV)	Work in Progress	MNRE
5	JeevanVikas College of Arts,commerce and Science Vaijpur	10KW(6.4KW Wind +3.6KW Solar PV)	Work in Progress	MNRE
6	ManubaiVidyalaya, Vaijpur	10KW(6.4KW Wind +3.6KW Solar PV)	Work in Progress	MNRE
7	J.K. Jadhav College of commerce Vaijpur	10KW(6.4KW Wind +3.6KW Solar PV)	Work in Progress	MNRE
8	Mahindra Vehicle Manufacturers Ltd. Pune.	5KW(3.2KW Wind +1.8KW Solar PV)	Work in Progress	MNRE
9	Tuljabhavani Temple Trust tuljapur Dist. Osmanabad	15KW(9.6KW Wind +5.4KW Solar PV)	Work in Progress	MNRE
10	Govt. Secondary Ashram School Panbara, Dist. Nandurbar	5KW(3KW Wind +2KW Solar PV)	Work in Progress	Tribal commissioner
11	Govt. Secondary Ashram School Navapada, Dist. Dhule	5KW(3KW Wind +2KW Solar PV)	Work in Progress	Tribal commissioner
12	Govt. Secondary Ashram School Bhagdari, Dist. Nandurbar	5KW(3KW Wind +2KW Solar PV)	Work in Progress	Tribal commissioner
13	Shriram Urban Infrastructure ltd. Mumbai	50.06KW(30.6KW Wind +20KW Solar PV)	Work in Progress	MNRE
14	Thakkar Builders and developers Satara	10KW(6.6KW Wind +3.4KW Solar PV)	Work in Progress	MNRE
15	GyanVikasMandal, Tal. Sakhari dist. Dhule	50.06KW(32KW Wind +18KW Solar PV)	Work in Progress	MNRE

4. Resources of Renewable Hybrid Energy System

Wind

The wind resource is ultimately generated by the sun, but it tends to be very dependent on location. Overmost of the earth, the average wind speed varies from one season to another. It is also likely to be affectedby general weather patterns and the time of day. It is not uncommon for a site to experience a number ofdays of relatively high winds and for those days to be followed by others of lower winds. The wind also exhibits shortterm variations in speed and direction. This is knownas turbulence. Turbulent fluctuations take place over time periods of seconds to minutes.For this study BWC Excel-R 7.5 kW DC wind turbine has been used which is manufactured by Bergey Wind power. The installation, capital and O&M cost of this turbine is respectively $17500, $15000 and zero.

Solar Radiation

Solar energy is the most promising of the renewable energy sources in view of its apparent unlimited potential. The sun radiates its energy at the rate of about 3.8 x 1023 kW per second. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.5kW/m2 at the boundary of the atmosphere. After traversing the atmosphere, a square metre of the earth's surface can receive as much as 1kW of solar power, averaging to about 0.5 over all hours of daylight.

The solar radiation resource is fundamentally determined by the location on the earth’s surface, the date, and the time of day. Those factors will determine the maximum level of radiation. Other factors, such asheight above sea level, water vapor or pollutants in the atmosphere, and cloud cover, decrease theradiation level below the maximum possible. Solar radiation does not experience the same type ofturbulence that wind does, but there can be variations over the short term. Most often, these arerelated to the passage of clouds. Figure 11 illustrates the solar radiation over a 5-day period in Decemberin Boston, Massachusetts. The initial installation cost of photovoltaic arrays may vary from $4.00 to $5.00 per Watt. For an optimum solution, the installation cost for a 1.0 kW stand-alone PV array is assumed $4500 and O&M cost is considered to be practically zero. Sizes of the photovoltaic arrays are varied 1 to 4 kW

Biomass

BiomassSources are forest or agricultural products. The resource is ultimately a function of suchfactors as solar radiation, rainfall, soil conditions, temperatures, and the plant species that can begrown.In India, fuelwood, crop residues and animal manure are the dominant biomass fuels.These are mostly used at very low efficiencies. Municipal solidwastes (MSW) and crop residues such as rice husk and bagasse can also be used for energy generation.The total potential of energy from thesesources in 1997 is estimated to be equivalent to 5.14 EJ, which amounts to a little more than a-third of the total fossilfuel use in India. The energy potential in 2010 is estimated to be about 8.26 EJ. The cost of biomass varies according to the carbon content and the location of the biomass availability.

Power Converter

A converter is required to convert AC-DC or DC-AC. The installation costs for a 1.0kW converter is $800, replacement cost is $700 and O&M cost is considered practically zero.

Grid

This proposed system is a grid-connected system in which the Grid acts as a backup power component. The grid is activated and supplies electricity when there is not enough renewable energy power to meet the load.

Batteries

Trojan L-16P type was chosen because it is a popular andinexpensive option. HOMER considered from 0-70 of thesebatteries. The valve regulated lead acid battery is rate at 6 Vand has a capacity 360 Ah. Initially cost for one battery is275$. The replacement batteries will cost another 275$. Theoperation and maintenance cost add further 3$ with aminimum life time of 8 years.

Battery Bank

The battery bank is a collection of one or more individual batteries.HOMER models a single battery as a device capable of storing a certainamount of dc electricity at fixed round-trip energy efficiency, with limits as tohow quickly it can be charged or discharged, how deeply it can be discharged withoutcausing damage, and how much energy can cycle through it before it needsreplacement. HOMER assumes that the properties of the batteries remain constantthroughout its lifetime and are not affected by external factors such as temperature.In HOMER, the key physical properties of the battery are its nominal voltage,capacity curve, lifetime curve, minimum state of charge, and round-trip efficiency.The capacity curve shows the discharge capacity of the battery in ampere-hours versusthe discharge current in amperes. Manufacturers determine each point on thiscurve by measuring the ampere-hours that can be discharged at a constant currentout of a fully charged battery.

Generators

A generator consumes fuel to produce electricity, and possibly heatas a by-product. HOMER’s generator module is flexible enough to model a widevariety of generators, including internal combustion engine generators, micro turbines,fuel cells, Stirling engines, thermo photovoltaic generators, and thermoelectricgenerators. HOMER can model a power system comprising as many as threegenerators, each of which can be ac or dc, and each of which can consume a different fuel.

The principal physical properties of the generator are its maximum and minimumelectrical power output, its expected lifetime in operating hours, the type offuel it consumes, and its fuel curve, which relates the quantity of fuel consumed tothe electrical power produced. In HOMER, a generator can consume any of thefuels listed in the fuel library (to which users can add their own fuels) or one oftwo special fuels: electrolyzed hydrogen from the hydrogen storage tank, or biomassderived from the biomass resource. It is also possible to co-fire a generatorwith a mixture of biomass and another fuel. For this study thegenerator is AC and the capital cost was considered on basisof 1000$ per 1Kw and its replacementcosts 800$. Theoperation and maintenance is 0.05$ per hour. The lifetimeof the generator is estimated at 15000 operating hours.

Inverter

The efficiencies of the inverter and rectifier were assumed to be 90% and 85% respectively for all sizes Considered. The simulations were done for each system switching the power between the inverter and the generator. Both devices were not allowed to operate in parallel. Initial and replacement cost for the converter is 700$, with no cost for operation and maintenance.

5. Software Resources for Renewable Hybrid Energy Systems

HOMER

HOMER is a micro power optimization software used in evaluating designs of both off-grid and grid-connected power systems for a variety of applications. The cost benefit analysis of a wind turbine-solar hybrid system was done using HOMER software and comparison was also made with the cost per kilowatt of central grid or utility supply. The hybrid system have a pay-back period of about thirty-three years and at current costs, central grid power is the least expensive option but may not be available to most rural households far from the grid. Hence it is necessary to supply these areas from isolated power sources.

The HOMER energy modeling software was originally developed by NREL beginning in 1992. In 2009 HOMER Energy, LLC was awarded the exclusive license to commercialize the software. The micropower optimization modeling software assists engineers and non-technical users to compare power system configurations across a wide range of applications. HOMER models the physical behavior of the power system and quantifies the total cost of installing and operating the system over its lifespan. Its graphical user interface allows users to interactively compare design options on their technical and economic merits. HOMER performs three principle tasks: simulation, optimization, and sensitivity analysis.

HOMERis primarily an optimization software packagewhich simulates varied renewable energy sources (RES) systemconfigurations and scales them on the basis of net present cost(NPC) which is the total cost of installing and operating thesystem over its lifetime. It firstly assesses the technical feasibilityof the RES system (i.e. whether the system can adequately servethe electrical and thermal loads and any other constraintsimposed by the user). Secondly, it estimates the NPC of thesystem. HOMER models each individual system configuration byperforming an hourly time-step simulation of its operation for project lifetime, including initial set-up costs (IC), componentreplacements within the project lifetime, maintenance and fuel.

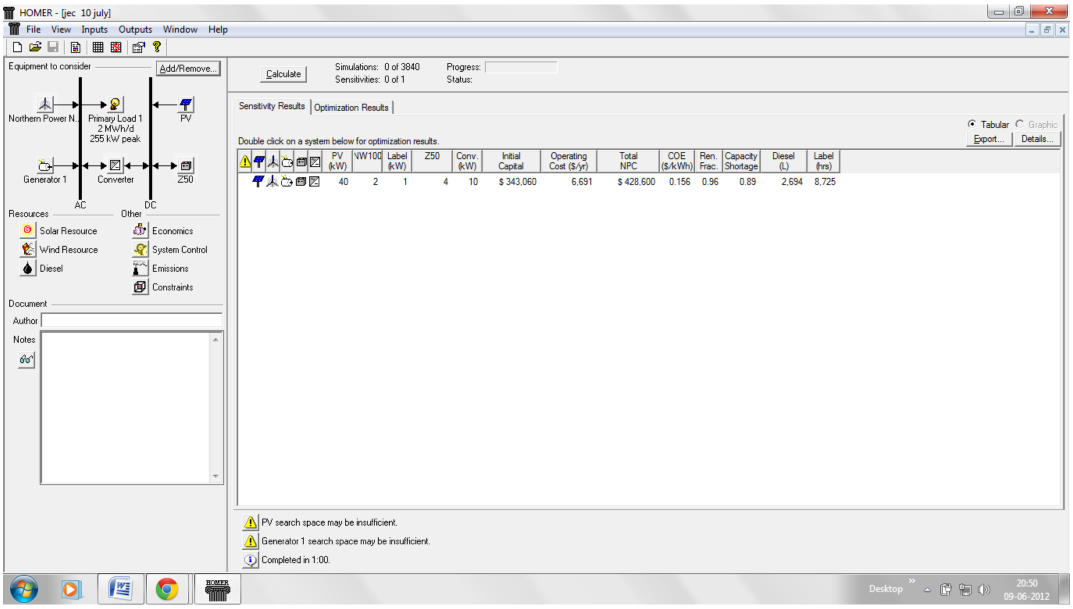

Figure 3 Homer display window

The goal of the optimization process is to determine the optimal value of eachdecision variable that interests the modeller. A decision variable is a variable overwhich the system designer has control and for which HOMER can consider multiplepossible values in its optimization process. Possible decision variables inHOMER include:

- The size of the PV array.
- The number of wind turbines.
- The presence of the hydro system.
- The size of each generator.
- The number of batteries.
- The size of the ac–dc converter.
- The size of the electrolyzer.
- The size of the hydrogen storage tank.

LINDO

LINDO Software used for Different types of renewable energy model has been used in LINDO software for the determination of minimum cost of energy (COE) after the integration of the models. Such type of models are Summer Model (Lighting and Cooking), Winter Model (Lighting and Cooking), Domestic Model for Fan, TV, etc. application, Agriculture Model for irrigation and Motive/Industry Model for small-scale industry purposes. Among these models, the cost of energy has been obtained, which is different in each type of the model with the condition of feasible solution only. LINDO Systems developed a collection of software packages that facilitate building and solving optimisation models. Linear, non-linear and integer optimisation tools are used by companies interested in addressing questions related to profit maximisation, cost minimisation, production planning, transportation, finance, portfolio allocation, capital budgeting, blending, scheduling, inventory, resource allocation and other.

6. Conclusion

This paper has included the most relevant papers on the design, simulation, control, and optimization of the hybrid systems. As a result of this review, we determined that the most frequent systems are those consisting of a PV Generator and/or Wind Turbines and/or Diesel Generator, with energy storage in lead-acid batteries.

The main criterion for sustainable development is that all key factors interacting within a global system should be in equilibrium. For a sustainable material development it needs optimum combination between three factors economy, ecology and energy. Homer software was used todetermine the optimum hybrid configuration.

The diversity of loading cases, geometry and material characteristics together with the new solution methods motivates to continue research. The review of these and earlier publication allow to conclude that, the crane hook, need a more extensive investigation since a very few articles in this field have been published yet.

Many researchers investigated into stress analysis of crane hook but no contribution in the field of critical stress point location in terms of angle measured has been made till now. This may be of practical value during the initial stage of the hook design and needs further investigation.

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