

PV/Wind Turbine Hybrid System to Power a Room Air Conditioner

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ABSTRACT; Just as other factors, electric power is an essential factor for economic and social growth. Size optimization of a PV-wind hybrid energy system decides the cost of such a system. The amount of solar energy received in any site as well as wind speeds determine electricity cost. Similarly, the real climate and weather conditions such as solar insulation, wind speed and ambient temperature effect the optimization and cost of such system.

In fact, an air conditioning load depends simultaneously on the above mentioned parameters. As so, the sizing up a of PV-wind hybrid system to power an air conditioning system should consider the local climatic characteristics and ambient temperature.

This makes the design process of such a hybrid system a site-specific, and depends upon resources availability and power demands.

The present work describes the sizing up procedures and the feasibility of utilizing a hybrid system in powering an air conditioning unit under the city of Hoon (29 N, 15 E) climatic conditions.

A monthly wind data and solar insulation data, as well as the ambient temperature for a year long period is being used in this study, which is obtained from the data collected by the local metrological center in the town of Hoon.

The objective of this work aims at optimizing the size of a PV-wind turbine system which powers an air conditioner unit. Fortunately, ambient temperature and solar energy is considered a reliable electricity power source for A/C demand. Solar powered A/C reduces the peak power demand in the mean time utilizes the environment friendly natural energy.

The tools that have been used in this research, which is a combination of energy and economic studies, are (HOMER) CODE of National Renewable Energy Laboratory USA, available in the website. (HOMER), and design program using MATLAB software.

Key words; PV, wind turbine, hybrid system, renewable energy sources.

1. INTRODUCTION

Electric power is an essential factor for economic and social growth. But availability of power is a big problem for all worlds.

There are many sources for power such as oil, natural gas, nuclear energy, solar energy, wind energy etc, but each one of these types has its own problems. In Addition to availability problem, there are other sources

of complications such as control, stability and transmission processes.

Too much energy usually lost when energy is transmitted from the place of production to its place of consumption especially in the case of small remote areas. One of the solutions for this problem is the Diesel generator. This solution has many problems, such as its weight, large noise, and high cost for operation and maintenance as well as emission penalties. Other alternative is renewable energy sources in the form of a hybrid system. Present work suggests the application a PV-wind turbine hybrid system to feed a room air conditioner.

Wind and solar energy are considered a potential electricity power source for air conditioning systems (A/C) demand. Solar and wind energy powered A/C reduces the peak power demand, in the mean time utilizes the environment friendly natural energy.

In this investigation, the recent inventor type A/C is being considered, which has features of higher performance over the conventional A/C, as the latter, is difficult to use for photovoltaic-wind turbine, because of its high power consumptions and its low efficiency.

Selection of components for the Hybrid Optimization Model for Electric Renewable Energy (HOMER) code, of National Renewable Energy Laboratory USA, is a general-purpose hybrid system which can be adapted as a design tool with reasonable accuracy.

A brief historical back ground of research work in the area of photovoltaic and wind turbine hybrid systems and its application in air conditioning, during recent years, is being carried out [1-14].

Nasr et al. (2008) [15], carried out a size optimization of a stand-alone photovoltaic (PV), a stand alone wind turbine along with a diesel generator's room air conditioner considering the characteristics of local climate and temperature for Hoon city. In their study, they presented sizing procedures

and special consideration under Melbourne's climate condition using HOMER Code. The reliability of various PV-battery size combinations was also simulated using MATLAB software. They concluded that, "excellent system performance can be predicted". Comparison between different energy sources showed that wind turbine is the best for the local weather conditions and the specific application..

Survey; shows that the hybrid PV/Wind turbine system is a common used renewable energy system. It reduces the energy cost and is a most stable system.

Methodology and design procedure for optimum PV-wind hybrid energy system configuration and control criteria for given load profile and desired reliability, in sizing and performance variables are optimized according to the defined life-cycle cost function under described constraints using HOMER CODE. Results and discussion for system optimization are presented.

Conclusion and suggestions for future work are explored. Results showed- when compared with stand-alone PV and wind turbine systems as well as Diesel generators- that hybrid system is the best for small loads in remote areas having similar conditions to Hoon weather.

2. HYBRID PV-WIND SYSTEM

In many regions, photovoltaic power systems are widely used in smaller off-grid applications, due to reliability and simplicity reasons. However, a stand-alone solar energy system cannot provide a continuous source of energy due to the low availability during the no-sun period and the winter. This implies that in order to achieve the high energy availability required in telecommunication and lighting applications, it is necessary to oversize the solar panels

and the batteries which increases the cost and the size of the overall system.

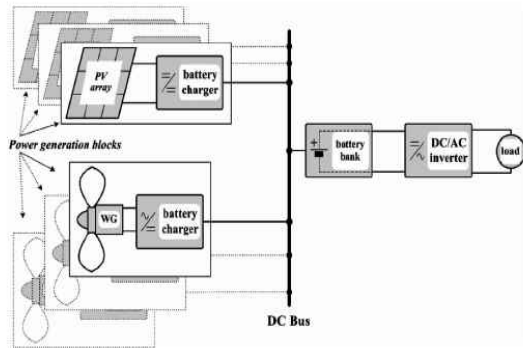


Figure (1) Hybrid PV/ Wind Energy System

Combining two or more renewable energy sources makes the system more reliable and according to the region where the system is built, system costs stay constant or slightly decreases, but the energy system sizing procedure and the operation control strategies are getting more complex. Configuration of the PV/ wind hybrid energy system depends on the wind speed and solar insulation at the site in question. The cost-effective, reliable design and appropriate operation of the hybrid systems are equally important.

3. STORAGE BATTERIES

Fixing “Average Amp-Hour per Day Load” to be supplied, designing an adequate battery storage is the next step. Begin this task by establishing the inverter losses which will occur by inputting the “Alternating Current Average Daily Load”. When we add this watt-hour total to the “Direct Current Average Daily Load” and divide the sum by the “Direct Current System Voltage” to arrive at the “Average Amp-Hour Per Day Load.”

This “Average Amp-Hour per Day Load” should be multiplied by the desired “Days of Autonomy” to determine the required battery capacity. Divide this total by the

“Discharge Limit,” or the battery’s “Maximum Depth of Discharge” (a number less than 1.0) to determine the total required battery capacity. *We should select a particular battery to be used in the system and use the specifications for that battery.* Divide the total required battery capacity by the “Battery Amp-Hour Capacity” supplied by the manufacturer to determine the number of “Batteries in Parallel” which must be purchased.

If the battery bank includes batteries connected in a series configuration, the required number of “Batteries in Series” is determined by inputting the “Direct Current System Voltage” and dividing it by the “Battery Voltage” of the battery that has been chosen. Multiply “Batteries in Series” by “Batteries in Parallel” to obtain “Total Batteries.”

4. RESEARCH TOOLS AND METHODOLOGY

The design problem of the hybrid system is non-linear. This non-linearity problem was solved using genetic algorithm. PVwind hybrid system configuration using seasonal variations instead of hourly variations defines the size of PV arrays and wind generator, according to the supply-demand criteria and then optimizes according to the costs criteria. Interdependency between sizing and operation strategy need to be taken into considerations. Size determination of the hybrid system can be reached using limited meteorological parameters. A simple iterative technique based on energy balance can be also for sizing up PVwind hybrid energy system.

Present work presents a design procedure for optimum PV-wind hybrid energy system configuration and control criteria for given load profile and desired reliability. Using simple iterative techniques, the sizing and performance variables were optimized

according to the defined life-cycle cost function under described constraints. All calculations and simulation were implemented with HOMER Code and MATLAB software.

5. HYBRID ENERGY SYSTEM COMPONENTS MODELS:

PV-wind hybrid energy system's main components are shown in figure (1). Performance models for each individual component of hybrid energy system were developed [15].

6. COST MINIMIZATION OF HYBRID SYSTEM

In the section presented the optimal sizing methodology outputs the optimum number of WGs, PV modules, batteries and PV battery chargers, along with the optimum PV modules tilt angle and WGs installation height, comprising the set of decision variables, such that the 20-year round total system cost function, $J(x)$ (\$), is minimized. The total system cost function is equal to the sum of the total capital, $C_c(x)$ (\$), and maintenance cost, $C_m(x)$ (\$) functions [15]. Simulation function performs the system simulation in order to verify the examined system configuration fulfils the uninterrupted power supply requirement of the load during the whole year.

HOMER's fundamental capability is simulating the long-term operation of a micro power system. Its higher-level capabilities, optimization and sensitivity analysis, rely on this simulation capability. The simulation process determines how a particular system configuration, a combination of system components of specific sizes, and an operating strategy that defines the way those components work together, would behave in a given setting over a long period of time.

HOMER can simulate a wide variety of micro power system configurations, comprising any combination of a PV array, one or more wind turbines, a run-of-river hydro-turbine, and up to three generators, a battery bank, an ac-dc converter, an electrolyze, and a hydrogen storage tank. The system can be grid-connected or autonomous and can serve ac and dc electric loads and a thermal load.

Systems that contain a battery bank and one or more generators require a dispatch strategy, which is a set of rules governing how the system charges the battery bank. HOMER models two different dispatch strategies: load-following and cycle-charging. Under the load-following strategy, renewable power sources charge the battery but the generators do not. Under the cycle-charging strategy, whenever the generators operate, they produce more power than required to serve the load with surplus electricity going to charge the battery bank.

The simulation process serves two purposes. First, it determines whether the system is feasible. HOMER considers the system to be feasible if it can adequately serve the electric and thermal loads and satisfy any other constraints imposed by the user. Second, it estimates the life-cycle cost of the system, which is the total cost of installing and operating the system over its lifetime. The life-cycle cost is a convenient metric for comparing the economics of various system configurations. Such comparisons are the basis of HOMER's optimization process. HOMER models a particular system configuration by performing an hourly time series simulation of its operation over one year. HOMER steps through the year one hour at a time, calculating the available renewable power, comparing it to the electric load, and deciding what to do with surplus renewable power in times of excess, or how best to generate (or purchase from the grid) additional power in times of deficit. When it has completed one year's worth of calculations, HOMER determines whether the system satisfies the constraints imposed

by the user on such quantities as the fraction of the total electrical demand served, the proportion of power generated by renewable sources, or the emissions of certain pollutants. HOMER also computes the quantities required to calculate the system's life-cycle cost.

7. OPTIMIZATION

Simulation process models a particular system configuration; the optimization process determines the best possible system configuration. In HOMER, the best possible, or optimal, system configuration is the one that satisfies the user-specified constraints at the lowest total net present cost. Finding the optimal system configuration may involve deciding on the mix of components that the system should contain, the size or quantity of each component, and the dispatch strategy the system should use. In the optimization process, HOMER simulates many different system configurations, discards the infeasible ones (those that do not satisfy the user-specified constraints), ranks the feasible ones according to total net present cost, and presents the feasible one with the lowest total net present cost as the optimal system configuration.

The goal of the optimization process is to determine the optimal value of each decision variable that interests the modeler. A decision variable is a variable over which the system designer has control and for which HOMER can consider multiple possible values in its optimization process.

The first row in Table (1) is the optimal system configuration, meaning the one with the lowest net present cost. In this case, the optimal configuration contains one wind turbine, the 135-kW generator, 64 batteries, and a 30-kW converter. The second-ranked system is the same as the first except that it contains two wind turbines instead of one. The third-ranked system is the same as the first except that it contains fewer batteries.

The eighth- and tenth-ranked systems contain no wind turbines.

HOMER can also show a subset of these overall optimization results by displaying only the least-cost configuration within each system category or type. The results in Table (1) show that under the assumptions of this analysis, adding wind turbines and a battery bank would indeed reduce the life-cycle cost of the system. The modeler may decide that one of these suboptimal configurations is preferable in some way to the configuration that HOMER presents as optimal.

Table (1) Categorized optimization results table.

	FL30	Gen (kW)	Batt. (kW)	Conv. (kW)	Initial Capital	Total NPC	COE (\$/kWh)	Diesel (L)	Gen (hrs)
   	1	135	64	30	\$216,500	\$849,905	0.273	75,107	4,528
   		135	64	30	\$86,500	\$885,175	0.284	101,290	5,528
		135			\$0	\$996,273	0.320	132,357	8,760
 	1	135			\$130,000	\$1,130,637	0.363	127,679	8,740

In the overall list shown in Table (2), Appendix, the top-ranked system is the least-cost configuration within the wind-diesel-battery system category. Similarly, the eighth-ranked system is the least-cost configuration within the diesel-battery system category.

The initial investment of \$216,500 for the optimal system leads to a savings in net present cost of \$146,000 compared to the existing diesel system, shown in the third row. (Note that the diesel-only system has a capital cost of zero value, because the existing diesel generator requires no capital investment.) The optimization results tables allow this kind of comparison because they display more than just the optimal system configuration. The overall optimization results table in particular tends to show many system configurations whose total net

present cost is only slightly higher than that of the optimal configuration.

Table (2) Overall optimization results table showing system Configurations sorted by total net present cost

	FL30	Gen (kW)	Batt.	Conv. (kW)	Initial Capital	Total NPC	COE (\$/kWh)	Diesel (L)	Gen (hrs)
   	1	135	64	30	\$ 216,500	\$ 849,905	0.273	75,107	4,528
   	2	135	64	30	\$ 346,500	\$ 854,660	0.274	54,434	3,350
   	1	135	48	30	\$ 200,500	\$ 855,733	0.275	78,061	4,910
   	2	135	48	30	\$ 330,500	\$ 856,335	0.275	57,654	3,685
   	2	135	32	30	\$ 314,500	\$ 873,322	0.280	62,394	4,139
   	2	135	96	60	\$ 401,000	\$ 878,370	0.282	48,139	2,603
   	2	135	64	60	\$ 369,000	\$ 880,421	0.282	52,999	3,195
   		135	64	30	\$ 86,500	\$ 885,175	0.284	101,290	5,528
   	1	135	96	30	\$ 248,500	\$ 887,379	0.285	74,193	4,346
   		135	48	30	\$ 70,500	\$ 888,528	0.285	104,009	6,067
   	1	135	32	30	\$ 184,500	\$ 889,688	0.285	85,310	5,615
   	2	135	96	30	\$ 378,500	\$ 890,504	0.286	52,442	3,136
   	2	135	48	60	\$ 353,000	\$ 891,896	0.286	57,316	3,615
   	2	135	32	60	\$ 337,000	\$ 905,959	0.291	62,312	4,080
   	2	135	128	60	\$ 433,000	\$ 907,508	0.291	45,596	2,226
   	1	135	64	60	\$ 239,000	\$ 911,667	0.292	77,753	4,613
   		135	96	30	\$ 118,500	\$ 912,410	0.293	101,003	5,330

8. SENSITIVITY ANALYSIS

Sensitivity analysis process, in which HOMER performs multiple optimizations, uses different set of input assumptions. A sensitivity analysis reveals how sensitive the outputs are to changes in the inputs.

One of HOMER's most powerful features is its ability to do sensitivity analyses on hourly data sets such as the primary electric load or the solar, wind, hydro, or biomass resource. HOMER's use of scaling variables enables such sensitivity analyses. Each hourly data set comprises 8760 values that have a certain average value. But each hourly data set also has a corresponding scaling

variable that the modeler can use to scale the entire data set up or down. For example, a user may specify hourly primary load data with an annual average of 120kWh/day, and then specify 100, 150, and 200 kWh/day for the primary load scaling variable. In the

course of the sensitivity analysis, HOMER will scale the load data so that it averages first 100 kWh/day, then 150 kWh/day, and finally, 200 kWh/day. This scaling process changes the magnitude of the load data set without affecting the daily load shape, the seasonal pattern, or any other statistical properties. HOMER scales renewable resource data in the same manner. For purpose of this study, the load profile is taken as shown in figure (2).

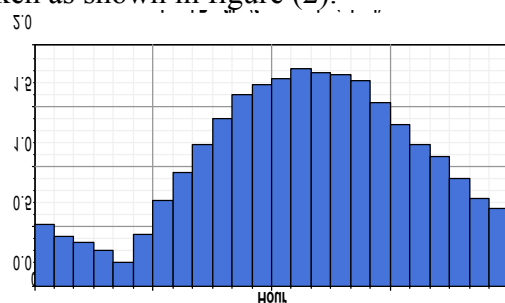


Figure (2) Load profile for present case-study

9. RESULTS AND DISCUSSION

The proposed method has been applied to the design of a stand-alone hybrid PV/WG system in order to power supply a room air conditioner -31.5 kW h per day - located in Hoon city geographical coordinates defined as; Latitude: 29.13° N, Longitude: 15.57° E and Altitude: 260 m (approx.) above sea level.

Technical characteristics and related capital and maintenance costs of the hybrid system devices, were input to the optimal sizing procedure. The installation cost has been included in the capital cost of the devices, while the maintenance cost of each unit per year has been set at 1% of the corresponding capital cost, and life time of system as 20 years.

9.1 Systems optimization

The hybrid system optimization results are shown in Table (3), from this table it is clear that hybrid system is less costly than other systems at the same components capital cost

Figures (3), (4), and (5) present the annual and daily power production for hybrid PV/Wind system and gives more power production and less number of battery storage than other systems.

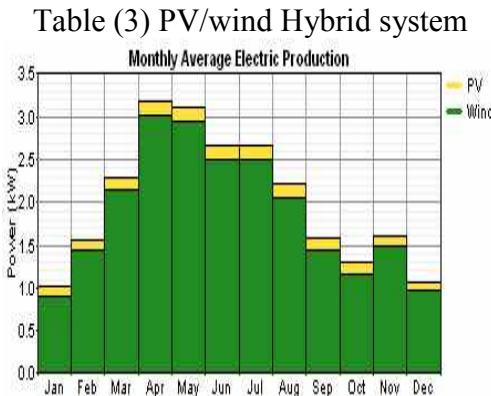


Figure (3) Annual Power Production

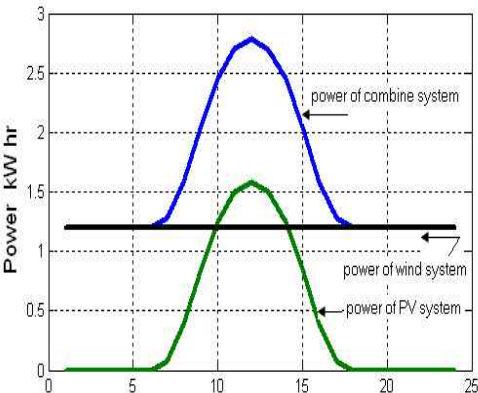


Figure (4) Daily Electric Energy Production

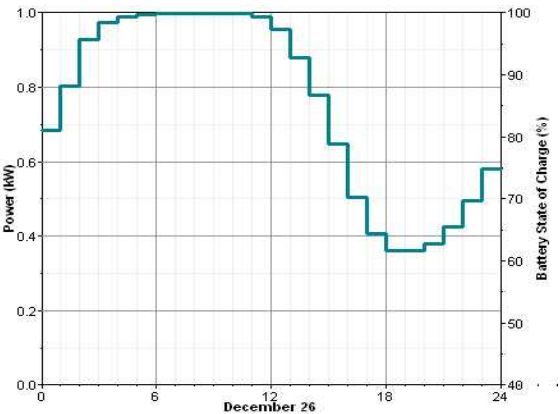


Figure (5) Daily Battery State Of Charge.

N0. of WTG	No. of PV	Batter y	cost (\$)
5	4	8	43,003
4	12	8	44,105
5	6	8	44,965
3	20	8	45,209
4	14	8	46,068
5	8	8	46,927
5	4	16	47,139
3	22	8	47,170
6	2	8	47,785
4	16	8	48,03

Finally the above results (renewable energy sources) were compared with a diesel generator system (classic energy sources). Table (6) shows the diesel generator 2.3 kW size with battery storage, one generator is enough to the power required, but the load is often less than 2.3 kW so that we used the

battery storage, also the system with the battery has smaller cost than the generator alone which means fuel saving.

Table (6) Results for diesel generator system

No. of Generator	No. of Battery	cost \$
1	8	71,353
1	16	74,162
1	0	76,505
1	24	78,988
1	32	85,848

Figure (6) present the daily power production by diesel generator. The system gives more stability compared to above systems as illustrated in figure (7). Generally speaking the system is the most expensive compared to other systems and more problems for operation and maintenance in addition to emission. The comparison between all systems is shown in figure (8).

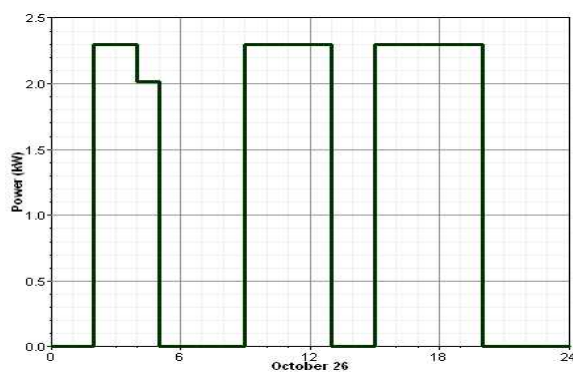


Figure (7) Daily Electric Energy Production

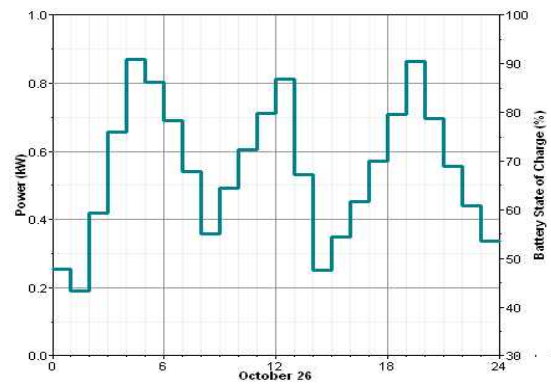


Figure (8) Daily Battery State of Charge

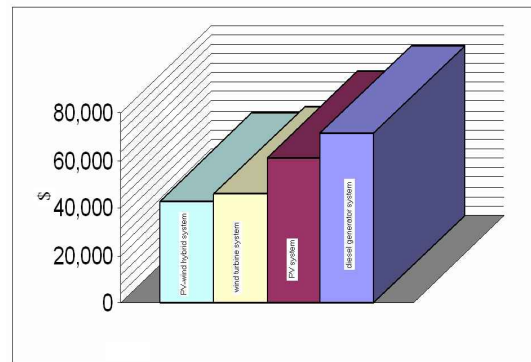


Figure (9) Comparison between different systems performance

11. CONCLUSIONS

Results obtained from this investigation show that, given the availability of renewable energy resources in a specific location, and their distribution profiles during the day and the year long, the renewable energy technologies and systems are the best choice over other conventional energy resources and systems. This is not only true from the economic point of view, in addition to its being environment friendly. It becomes clearer when air conditioning field is considered.

Present investigations were based on the weather conditions of Hoon city (29 N, 15

E), and concentrated on sizing up and optimization a PV- wind turbine hybrid system, for 20 years life-time, to power (a room air conditioner). The tool used for this is HOMER software.

Finally the simulation programs showed the hybrid system superiority over diesel generator; this is because its utilization of two different renewable energy resources, as well as low wind turbine capital cost and PV running cost.

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