# ECONOMICAL DESIGN OF HYBRID WIND- SOLAR POWER PLANT

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**Abstract: The two most trusted source of Renewable Energy are Wind Energy and Solar Energy, but in order to take the advantage of the complimentary characteristics of these two energy sources no sufficient research work has been carried out. Hence in this paper I like to propose optimized design for hybrid wind solar power plant in terms of number of photovoltaic modules, the height of the wind turbine and their numbers, and the turbine rotor diameter keeping the objective of reducing the cost. In the proposed design, the hybrid wind solar power plant will exploit the complementary characteristics of the energy sources and will efficiently deliver the energy throughout the year.**

**Key words: Renewable Energy, Wind turbines, solar, photovoltaic, standalone**

## INTRODUCTION:

The Global warming of the earth is protected by the Greenhouse gas emissions(GHGs).GHGs possess carbon dioxide, methane, sulphuehexa fluoride, nitrous oxide, methane, hydro fluorocarbons & per fluorocarbons. These gases allow the sunlight to enter earth's atmosphere, trap the heat radiated off the earth's surface, the planets temperature or Global warming will increase with the increase in the emission of these gases. The excessive global warming will prove fatal to the living organisms many of the researcher have concluded that as the earth's temperature increases the increase in the natural disaster is fueled by climatic change and atmospheric and ocean pattern shift.

As a part of a global effort to reduce GHGs, The Kyoto Protocol was negotiated. This Protocol establishes binding commitments on all member nations to reduce their GHGs emissions to meet their emission restrictions. This protocol introduced three flexible mechanisms, namely, 1.allows the member nations to carry out emission reduction projects in other countries to gain emission credits.2. The clean Development mechanism also allows nations to gain emission credits by financing emission reduction projects in developing countries. 3. Emission Trading, also called as Carbon Trading provides incentives for governments & companies to reduce their emission.

The Kyoto protocols, financial incentives, the carbon Emission limits and the scarcity and fast depletion of fossil fuels worldwide has made it necessary to search for alternative energy sources that will meet todays energy demand. In most of the countries of the world, world's population lives in rural and remote areas, which are less populated and geographically isolated, where there is no link of Grid. To bring development in such areas, an efficient and financially feasible methods needs to be found to provide electricity in these areas. It is concluded that, renewable wind solar energy source may be well suited for this task.

The Solar and Wind Energy Renewable energy sources are the clean, inexhaustible, unlimited and environmental friendly [1] has attracted to use renewable energy sources on larger scale [2]. The main drawback of wind and solar energy sources are their dependence on unpredictable weather and climate conditions. Considering the complementary nature of the energy sources, some of the drawbacks can be addressed by overcoming the weaknesses of one over the strength of the other [2].This brings us the concept of hybrid wind solar power plants.

The concept of having hybrid power system has gained popularity in recent years [1].this concept of energy station have proven to be more advantageous for decreasing the depletion rate of fossil fuels as well as supplying energy to the remote rural areas[3], without harming the environment. However analyzing the hybrid system is more difficult. For this reason there is a rich literature dedicated to modeling and designing hybrid wind solar power plants.

## 1. LITERATURE REVIEW

The hybrid wind/solar systems using battery banks was studied by Yang et al.[2] and developed the optimal model for designing hybrid wind solar system. The Stand alone system was developed to power to power a telecommunication station along the coast of china. The study was carried on the slope angle of the photovoltaic array to find the optimal power producing angle as well as the optimal values of the other variables like battery capacity and number of wind turbines. The annualized cost of the system was minimized while meeting the specified loss of power supply probability. The model was solved using generic algorithm and good complimentarity between wind solar energy sources was reported. Accordingly Ekren et al.[4] studied an optimal sizing procedure for similar system in Turkey.

Ahmed et al.[5] has developed a hybrid system model Th at included energy generation using fuel cell along with wind and solar power. Main energy sources were wind and solar and fuel cells were used as a backup resource, such that high quality of power can be supplied to the load even in the absence of wind and solar energy resources. Result demonstrated the system as more reliable Accordingly Onar et al.[6] also have developed the hybrid model with wind and solar energy resources. This model has proved well suited to grid independent applications.

A generic algorithm was used by Yang et al.[7] to develop an optimal sizing method for a hybrid wind/solar system which optimizes the use of battery banks configurations. This method is then used to calculate optimal system configurations that achieve a given loss of power supply probability, at the same time minimizing the annualized cost of the system.

Mahmoudi et al.[8] accessed the feasibility of meeting the energy demands of a seawater green house in Oman using hybrid wind solar energy system by analyzing hourly wind speed and solar radiation measurements Elhadidy and Shaahid[9] assessed the feasibility of providing power to & meeting the load requirements of a typical commercial building using a hybrid wind solar energy system. The investigation was done with different combinations of wind energy systems, Photovoltaic panels with battery storage and diesel backup energy system. Shakya etal [10] assessed the feasibility of a grid – independent hybrid wind solar system for a region of Australia. This design featured a compressed hydrogen gas storage system. The Probabilistic approach to the model the certain nature of the load and resources is adopted and long term performance of a hybrid wind solar power system was accessed by Tina et al.[11].Dihrab and Sopian [1]proposed the hybrid wind solar(PV) system that would be used for grid connected applications as a power source in three cities in Iraq. The MATLAB Simulation was carried out, where the input parameters are determined by metrological data from three locations and the size of turbines and PV arrays. Their result showed that the hybrid system would provide sufficient energy for villages in desert and rural areas.

Kershman et al.[12] studied the design of a sea water reverse osmosis desalination plant powered by hybrid wind solar energy system to be located on Libya's coast, This was will be used to supply village with potable water. A novel method of sizing hybrid wind solar energy system using battery storage that includes design parameters both the fraction of time that the system can satisfy the load and the cost of the system was proposed by Celik.[13]. The technical and economic feasibility of using grid-connected hybrid wind-solar system to meet the energy demands in Xanthi, a city in Greece through electrical and thermal energy productions was analyzed by Bakos & Tsagas [14]. The methods of modeling and designing of Hybrid renewable energy system and issues involved in increasing penetration of such system was discussed by Desmukh and Desmukh[15].A graphical construction technique for determining optimal sizes of battery banks and the PV array in a hybrid wind/solar system was developed by Borowy & Salameh[16]. In the Optimization process only paired combinations of three subsystems were considered. Yang et al.[17,18] develop simulation model to calculate optimisied combination of PV module, wind turbine for a hybrid wind-solar system and battery bank parameters for a given loss of power supply probability. In this study, the variables like wind turbine height and PV angle are not included. In this paper, I propose the design of a hybrid standalone wind –solar power generation system that could be used for various applications in rural areas power supplies. The variables considered in this design include the number of PV modules, the wind turbine height, the number of wind turbines and the rotor diameter of the turbines. These variables are very much useful to find the optimal design of a hybrid power generation system, with the objective of maximizing power, while minimizing the cost.

## 2. The Model

**2. A) Notations: Parameters and values**. The Below Table summarizes the notation used in our model. Values for parameters are shown and variables with a "?" are a value are the decision variables in our model.

**TABLE 1: Parameters and values**

| ***Parameters*** | ***Values*** | ***Descriptions*** |
|---|---|---|
| $N_w$ | | NUMBER OFWIND TURBINES |
| $C_{wm}$ | 1000 $ | ANNUAL MAINTENANCE COST FOR WIND TURBINE |
| *H* | | WIND TOWER HEIGHT (m) |
| *R* | | RADIUS OF WIND TURBINE(m) |
| $C_{wc}$ | 50000$ | INSTALLATION AND FABRICATION COST OF WIND TURBINE(Steel cost not included) |
| *I* | 5% | REALINTREST RATE |
| $ffY_{proj}$ | 33 years | PROJECT LIFE TIME |
| $N_o$ | | NUMBE OF SOLAR CELLS |
| $C_{sm}$ | 500$ | ANNUAL MAINTENANCE+ CLEANING COST FOR SOLAR PANELS |
| $C_{sc}$ | 5000 $ | SOLAR PANEL CAPITAL COST +INSTALLATION COST |
| Rho | 1.225 $kg/m^3$ | AIR DENSITY |
| $C_p$ | 0.45 | COEFFICIENT OF PERFORMANCE |
| $V_w$ | | WIND SPEED(m/s) |
| $N_g$ | 50% | GENERATOR EFFICIENCY |
| $N_b$ | 95% | GEAR BOX BEARING EFFICIENCT |

| | | |
|---|---|---|
| $V_{oc}, V_{oco}$ | | VOLTAGE FOR OPEN CIRCUIT |
| N | 1<n> 2 | IDEALITY FACTOR |
| K | 1.38* $10^{-23}$J/K | BOLTZMANN CONSTANT |
| Q | | MAGNITUDE OF THE ELECTRON CHARGE |
| $R_s$ | | SERIES RESISTANCE(ohms ) |
| $I_{sc}, I_{sco}$ | | SHORT CIRCUIT CURRENT(A) |
| $G, G_o$ | | SOLAR RADIATION,W/m$^2$ |
| $T_o$,T | | TEMPERATURE UNDER STANDARD CONDITION(K) |
| α,β,γ | | CONSTANT PARAMETER FOR PVMODULE |

## 2. B) EQUATIONS

### 2. B.1 OBJECTIVE FUNCTION

It consists of our Total costs (wind &solar), Including maintenance costs and capital costs, and considers the interest rates over the project lifetime.

CostWind+CostSolar……………. (1)

The equation (1) shows our objective function which we aim to minimize.

### 2. B.2 DEMAND CONSTRAINT

The Power Generated by both sources is considered over a 12 month period under different weather conditions like higher solar radiation in summer and high wind in Winter.

**$P_o$wind+$P_o$solar >=$P_{demand}$**……………… (2)

The equation (2) ensures that our model meets the power demand of the load using the power generated from the hybrid system- both from wind turbines and solar arrays

### 2. B.3 Overall costs

Cost Wind=$N_w C_{wm}$ +0.1$\frac{h}{10}$ -1+1 N.2, 449r2.7 +C. $\frac{i*(1+i)^{\gamma proj}}{(1+i)^{\gamma proj}-1}$………………………………….... (3)

Cost Solar=$N_s C_{sm}$+$N_s C_{sc}$.$\frac{i*(1+i)^{\gamma proj}}{(i+1)^{\gamma proj}-1}$…….. (4)

The equation (3) gives the cost incurred from operating and maintaining the wind turbines, this equation incorporates the costs of increasing the height of the wind turbines and the rotor diameter. These costs are multiple of the number of wind turbine installed, $N_w$. equation (4) gives the cost incurred as a function of the design and placement of the solar arrays, where the cost includes the capital invested and maintenance costs. This cost is multiple of the optimal number of solar arrays.

### 2. B.4 Height and Radius Constraints

h=100……………………… (5)

r =0.3*h…………………… (6)

Equation (5) limits the height of the wind turbine to 130 meters, while equation (6) limits the rotor radius to 30 percent of the tower height.

### 2. B.5System Generated Power Output

$P_o$wind = $N_w$ .1+.814ln$h$-*1.92*0.5 X rho X* $\pi r^2\ c_p\ V_w^2 N_g N_h$ …..…………………….. *(7)*

Equation (7) indicates the expected total output power generated by the total number of wind turbines in the design. This equation includes the effect of the turbine height and diameter. The overall power output generated by the solar array is expressed by equation (8); This model is based on the Yang et al[2] in the analysis of a hybrid wind solar power generation system

$$P_o\ \text{Solar}= N_s\ \frac{\frac{nKT^{V_{oc}}}{q}\ q^{-\ln nKT^{V_{oc}}+0.72}}{1+\frac{V_{oc}}{q}} * 1\text{-}\frac{\frac{R_S}{v}}{\frac{I_{oc}}{sc}} * I_{sco} * \frac{G^{\frac{nKT}{\alpha}}}{G_o} * \frac{V}{1+\beta ln\frac{G}{G_o}} * \frac{T_o}{T} * \gamma \quad \text{……………………………………..} (8)$$

## 3. DISCUSSION AND RESULTS

Hybrid model was simulated using GAMS keeping the objective of minimizing the costs, while meeting the specified load. The main focus in this study is to test for good complementary characteristics between the wind and solar power system and to access the feasibility of using such a hybrid system to power different application in rural. And also to find optimal number of wind turbines and solar arrays to meet the load, as well as the optimal wind turbine height and rotor diameter. It is to be noted that the test was first time conducted considering wind speed and solar radiations constant over the year. In this test, at a given electrical load, our models choose to install wind turbines only, no matter what the load, without the use of photovoltaic. This is natural, since wind turbines would generate the same amount of electricity at the cheaper price, as solar arrays are quite costly, so the model would avoid solar arrays to minimize the costs. This means model went against our hybrid concept, and choose to have one system only. However, this shows that we need a hybrid system only to take advantage of their complementary characteristics, because wind and solar radiations are not constant over the year as we specified in our test; When there is a shortage of wind in summer, there is an abundance of solar radiation, which means that wind turbines may not be able to meet demand on their own in summer and may require another source to make up the loss in power generation. In order to test this along with the feasibility of the hybrid system for different application. We tested our model based on the weather generated data. Below fig 1.shows the solar radiation and the wind speed as a percentage of the maximum attainable from each resource separately, over the course of the year. The generated data was plotted and best fit line was drawn.

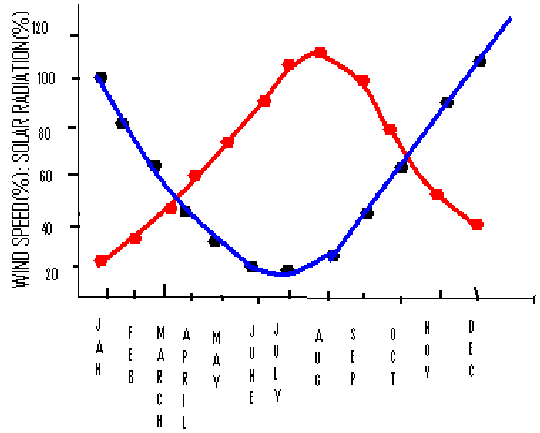


***FIG1.RESOURCES AS A PERCENTAGE OF THEIR MAXIMUM OVER THE YEAR***

Figure 1 suggests a need for a complementary relationship between the wind & solar systems as it shows a negative correlation between the two resources. Our model was then used to measure the power output of the individual energy system components and their combined total output. Using our generated weather data shown in figure-1. The result of these power output calculations are shown in below figure2.

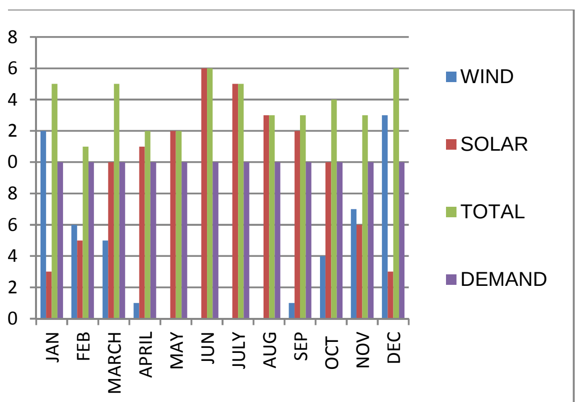


FIGURE 2: POWER GENERATED FROM SYSTEM COMPONENT ACROSS A YEAR

This figure also shows the demand line for a certain application with a load of 10kW, which my model was able to meet. The design of the system is listed for three different applications, considered to be remote and not grid connected. One of the applications, a remote home not connected to the grid, was used in figure 2.

Another two applications, a remote weather station, which requires an estimated 5kW and a remote village which requires an estimated 100kW. In corporating the different loads in our model, as well as the weather conditions, gave us the design parameters for the different applications, shown in below table 2.

| Applications | $N_s$ | $N_w$ | r | H | Annual cost |
|---|---|---|---|---|---|
| Weather station | 2 | 1 | 10 m | 34m | 5107.362 |
| House | 3 | 1 | 15 m | 52m | $147.545 |
| Village | 26 | 2 | 30 m | 100 m | $1084.726 |

## 4. Conclusion

The Study was focused on minimizing costs on designing a model that would allow us to find optimal system design parameters of a hybrid solar wind system taking in to consideration the number of solar arrays and wind turbines as well as the wind turbine rotor diameter and height. The objective was to meet the load of different applications using our optimally designed hybrid system. Using generated weather data our model had test for the presence of a potential complementary relationship between wind and solar energy system under similar weather conditions. Many different applications were considered, and the optimal design parameters for each application were found, meaning the optimal design parameters for each application were found, which means the optimum number of solar arrays and wind turbines as well as the optimum rotor diameter and height. After conducting various tests, a complimentary relationship between both individuals system was visible in our results. In Summer time, when solar radiation is abundant and there is little wind energy, solar arrays supply most of the required energy. In wintertime when wind velocities are higher and there is less solar radiation, it is the wind turbines that supply most of the required energy, thus providing clear evidence of complimentary relationship between the two sources

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