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# Experimental Analysis on Effects of Hybridizing PV - Wind Turbine System for Dual Land Use

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**Abstract:** ***As most of the renewable sources are not available for continuous use, they cannot be operated as standalone systems. There should be a grid connection to be provided along with the power generation from renewable source. Taking these factors into concern, a hybrid system is developed so as to get non-interrupted power supply off grid. Here an experimental study on effects of wind and wind turbine shadowing on pv panels is carried out using artificial illumination, shadowing and wind. The results show how the conjunction of both these renewable systems will affect the total power produced.***

## 1. Introduction

Hybrid energy systems depend on two or more types of renewable sources so as to provide the power. Even if one source is not providing power at a particular time, the other source will be dependable. The major problem one has to face while opting for a hybrid system is the effect of one resource harnessing unit on the other. Wind turbine - PV hybrid energy systems are of our interest as it merges two of the ample renewable sources together. The ultimate source for both these energies is the sun. While hybridizing two different systems to get power the resources need to be checked by their utilization, like capital cost, land area, maintenance etc. Considering land as a major factor employing solar PV and wind turbines on different land would utilize large land area. Hence using both these together in a single land area is preferred. But owing to the fact that conditions needed for each of these are different, the total amount of power may vary while both are in operation on the same land.

The wind turbine - pv array may only be installed in areas where both wind as well as sunlight is available. Hence there would be effect of wind and wind turbine on the pv arrays in the hybrid farm.

## 2. Problem Definition

The feasibility of employing pv arrays on a wind farm for a hybrid pv-wind turbine system needs to be dealt with. For that different factors require to be considered.

The amount of loss of power from pv arrays cannot be directly calculated from loss of area in the hybrid farm. It will depend on type of shading and number of hours exposed to such kind of shading. For that analysis is to be carried out on how each kind of shadows effect the pv output power. Wind effect will be there but the shadows of the wind turbines would cause fractional shading of these Solar pv arrays and may cause certain power dissipation.

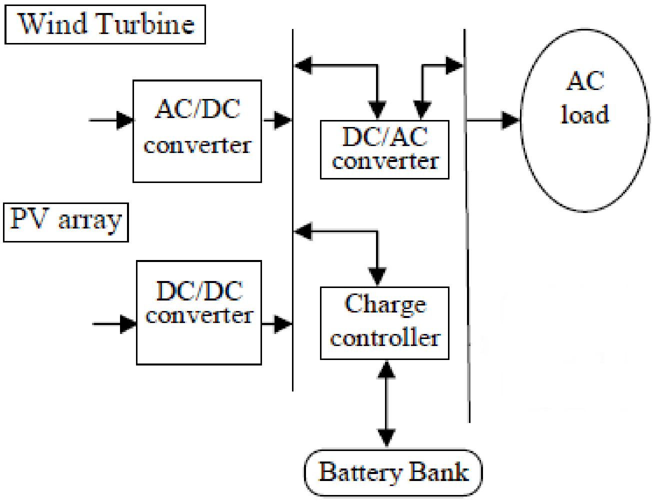


**Figure 1:** PV – Wind Turbine HRES

## 3. Methodology

Experiments are conducted on artificially illuminated solar pv panels with artificial wind at different speeds and different tilts. Fractional shadow analysis is also done with and without winds so as to know effects of fractional shadowing.

The shadow element is kept at different positions between illumination and pv panel so that effect of shadowing element at different positions from pv screen may be known. By analysing the results the overall changes in hybrid system characteristics is available by merging a wind turbine farm and solar pv arrays together for dual land use and the trend of effect of position of shadowing object on the power generated.

## 4. Experimental Setup

The experimental setup has artificially illuminated pv panels which can be tilted at different angles. The intensity of irradiation may be adjusted in the light source which is provided by halogen lamps. Solar power meter is used to measure intensity of radiation and digital anemometer to measure the wind speeds. A fan in which velocity of wind may be varied is also kept so as to replicate natural winds. A shading element of size 16 cm x 5 cm is also employed for fractional shading.

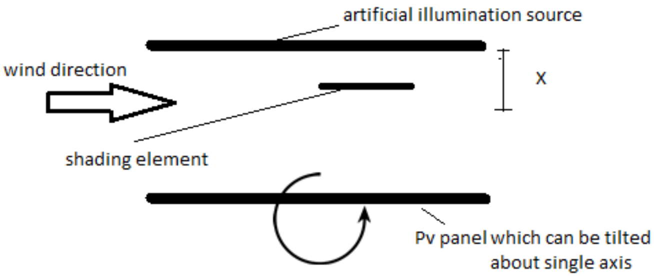


**Figure 2:** Schematic of the experimental setup

## 5. Procedure

The pv module was set up with artificial illumination. Voltage and Current readings of pv panels were taken from control board to know maximum power point at 2 values of radiation intensities (100 kW/m$^2$ and 200 kW/m$^2$). Wind of velocities 2 m/s and 4 m/s was artificially created and voltage and current readings were taken for the pv panel. Experiment was repeated for different tilt angles to study the change of maximum power with respect to tilt angle.

Ambient conditions of 34 $^0$C prevail and a relative humidity of 82 %.

In the experiment, an opaque obstruction was placed between light source and photovoltaic cell (16 cm x 5 cm) at 0 cm distance from light source and changes in power at above mentioned wind speeds were measured. Maximum power position at different tilts was also measured for these. The change of maximum power of pv with respect to distance of opaque body from the pv is noted. Graphs were plotted (V–I, Max power point v/s Tilt, Max power v/s Distance of shadowing object from pv surface).

## 6. Results and Discussion

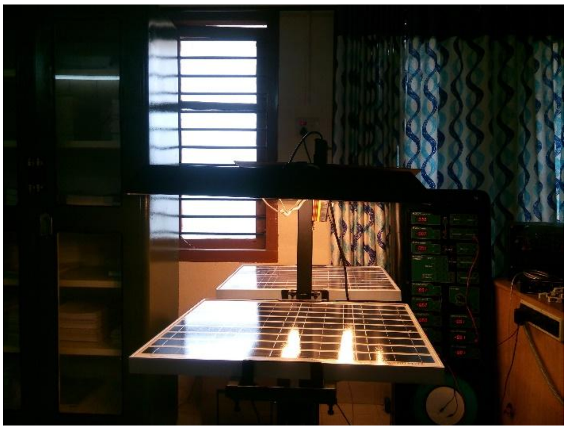

**Figure 3:** Experimental setup

The V-I as well as maximum power vs tilt angle graphs are plotted for each intensities and variations with application of two different wind speeds (2 m/s and 4 m/s) are observed. The results with a shadowing opaque body introduced in front of the source between source and pv panel at these intensities and wind speeds are plotted. The readings of maximum power of pv at different distance of opaque body from the light source is also tabulated and graph is drawn (maximum power position vs x (distance from PV screen).

The graphs were obtained with no shading at three different wind speeds of 0, 2 and 4 m/s. It is observed that there will be a small increase in voltage as wind speed increases. This increase in voltage is attributed to the decrease in temperature of the modules owing to the cooling action of the wind.

The results were obtained with wind and shadow element (16x5 cm) at different distances from screen.

The change of maximum power point with respect to each position was obtained and graphs were plotted between power and position of shadow object.

It is clear that the power decreases with the increase in value of x because of decrease in value of distance between shading object and pv screen. The current value has a major dip as distance between screen and shade increases.

**Without shading**

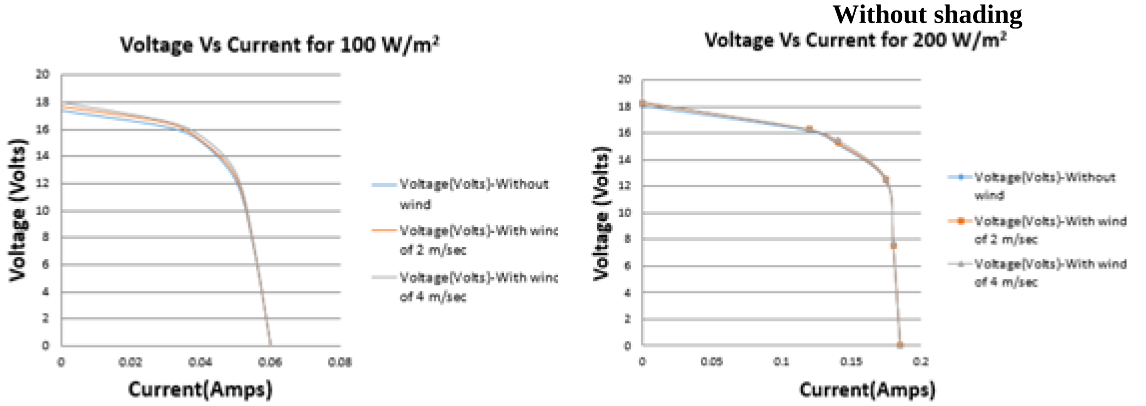


**Figure 4:** V-I characteristic graph at different wind speeds without shading

**Shadowing element at 0 distance from illumination**

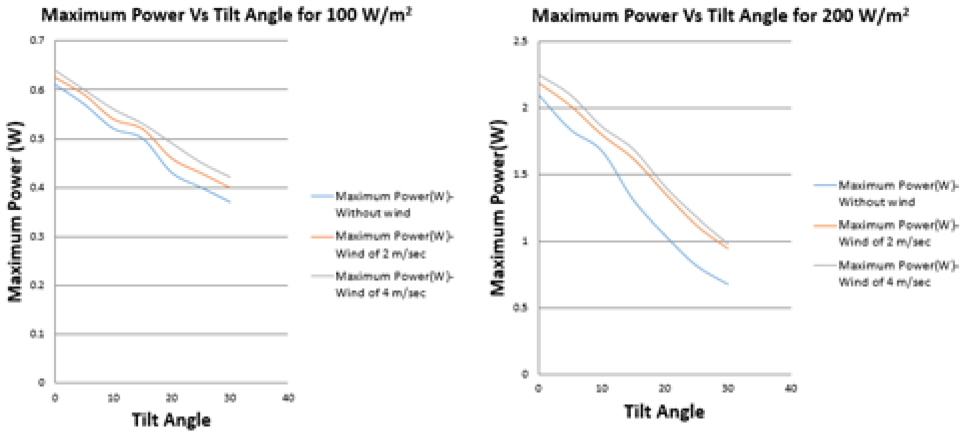


**Figure 6:** Maximum power vs tilt angle graph without shading

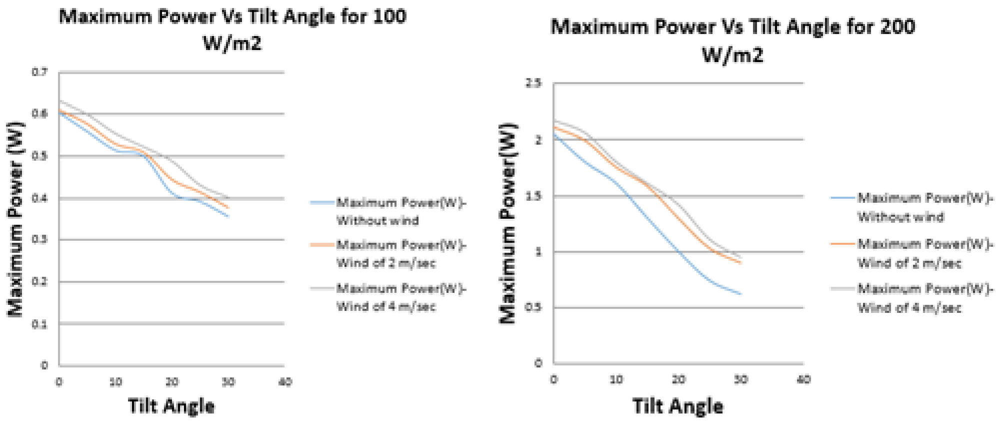


**Figure 7:** Power vs Tilt Angle with shadowing element at x=0

**Shadowing object at different values of X (distance from illumination)**

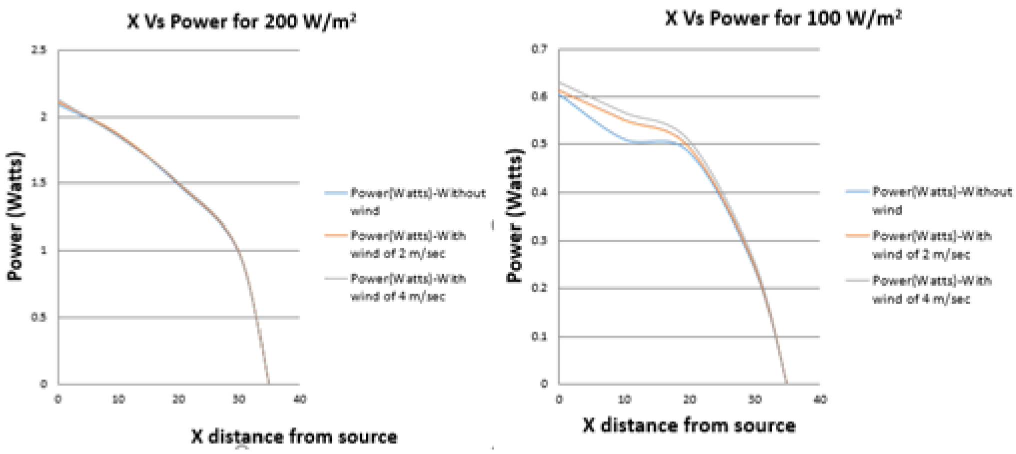


**Figure 8:** Distance of shadow object from illumination vs power graph

## 7. Comparison

It turns out that both the open circuit voltage and the fill factor decrease substantially with temperature (as the thermally

excited electrons begin to dominate the electrical properties of the semi-conductor). The short-circuit current increases, but only slightly. The effect leads to a linear relation.

$$\eta_c = \eta_{T_{ref}} \left[1 - \beta_{ref} \left(T_c - T_{ref}\right)\right] \quad (1)$$

Where,

$$\beta_{ref} = \frac{1}{T_0 - T_{ref}} \quad (2)$$

$T_{ref}$ = Reference temperature for poly silicone pv module= 25 $^0$C
$T_0$ =Temperature of pv module where its efficiency is zero= 270 $^0$C

Taking a normal reading without wind, Maximum Power Point at 39.1 $^{o}$C is 0.605 W whereas at 37.1 $^{0}$C it was found to be 0.63 W with wind speed of 4 m/s. Theoretically power would have been 0.653 W. Hence owing to the wind there will be decrease in temperature which causes efficiency of pv panel to increase. (Validated with experiments). Therefore, applying pv panels with wind turbines in a dual land use hybrid system is advantageous.

This particular Experiment can be regarded as a constant heat flux problem (100 W/m$^2$ and 200 W/m$^2$). Radiation and convection occur simultaneously hence complexity of mathematical analysis is higher. The average temperatures of modules are taken, but there would be a temperature variation throughout pv panel owing to thermal boundary layer formation (wind flow).

There is decrease in the band gap of a semiconductor with increasing temperature. It can be viewed as increasing the energy of the electrons in the material potential difference decreases.

Current slightly increases as electrons get more mobility due to temperature increase. For Poly silicon pv cells maximum efficiency available at 25 $^{0}$C is 20% (manual for insight pv panel) so from theoretical model efficiency at 39 $^{0}$C should be 4.8%.

By Experiment,

$$Efficiency = \frac{Maximum\ theoretical\ output\ power}{input\ power}$$

$$\frac{V \times i}{I \times As} = 0.453 = 4.53\%$$

$A_s = 15.5cm \times 4.4\ cm$

But comparing the maximum actual power obtained,
Efficiency from experiment = 2.81 %

$$\text{Fill factor} = \frac{voltage \times current\ (at\ maximum\ power\ point)}{open\ circuit\ voltage\ \ x\ short\ circuit\ current}$$

Hence fill factor = 62.6 %.

Partial shading of wind mills will cause decrease in power due to decrease in intensity of light falling at pv arrays. For small shading areas, distance of shading object from the pv panel plays an important role in power generated. The bypass diode may be used if there is significant reduction in power of pv cells owing to shading which results in reduction of current and hence reduction in power.

## 8. Conclusion

Hybrid systems are able to provide continuous power without depending on the grid for electricity. Before installing hybrid systems availability of the resources should be ensured. The major problem associated with their hybridization is that the individual resources may reduce performance of the other thereby reducing the total efficiency. In the present case land resource, could be used more efficiently by installing pv arrays on a wind turbine farm, so that more energy is available as compared to a standalone wind farm.

From the experiments, it is clear that though shading causes power loss in the pv panels the cooling effect of wind which on an average in a wind farm is 35 to 50 miles per hour is much significant and increases the power owing to increase of potential difference. Thus, Wind turbine – PV hybrid farm is suitable and preferred. While taking into consideration shading losses the distance between screen and shading object is also of prime importance along with the extent of shadows.

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