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Hybrid wind PV tree design and evaluation

Wallaaldin Abass Eltayeb

Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, 522502, India

Mail id: jarupulasomu@kluniversity.in

A B S T R A C T A: A hybrid tree is a man-made object that resembles a real tree and has branches on which solar panels or wind turbines are installed. Mobile phones, laptops, electric cars, home appliances, and lighting loads spanning small or huge regions may all be powered by it, making it the best energy source for contemporary society and sustainable cities. This study provides a 3 kW hybrid tree design, which can produce the most energy utilising a two-axis tracking system, to be put at Vaddeswaram, Andhra Pradesh (16.26 N and 80.36 E). The hybrid tree will consist of 2 kW solar and 1 kW wind. Additionally, many energy tree designs and uses that are available globally are shown. Solar panels' P-V and I-V properties were measured at various temperatures and irradiation levels. wind turbine, The study looked at power characteristics at various wind speeds and the power co-efficient at various tip speed ratios. At various tilt angles between 10 and 20, power generation research for the hybrid tree was conducted. To confirm whether the structure can bear the applied loads, structural optimisations are carried out. With the two-axis tracking system, the suggested solar-wind hybrid tree may produce 4709 kWh/year as opposed to 3763 kWh/year when solar panels are mounted at an 18.25 tilt angle.

Keywords*:* Solar-wind hybrid tree Structural optimisation Shading losses Renewable energy Power generation.

1. Introduction

One of the biggest problems or challenges that humanity is currently facing is climate change. According to the current figures, this challenge will significantly impact the economy's growth. Increased usage of non-conventional or renewable energy sources is one of the best ways to address these issues [1]. Natural processes continuously produce these unconventional sources. Solar energy, wind energy, geothermal energy, and other renewable energy sources are all used to generate electricity [2]. Renewable natural resources, including sunshine, wind, rain, waves, and geothermal energy, are used to generate power. The primary renewable energy sources are typically solar, wind, hydro, biomass, and biofuels [3]. Flat or rooftop mountings of photovoltaic systems and wind turbines require

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a large land area. Scarcity of land is one of the biggest problems in modern societies, i.e. in cities/villages in India. The solar-wind hybrid tree provides a better alternative to conventional solar PV and wind turbine systems. A hybrid tree is an artificial structure that resembles a natural tree and has branches on top of which are mounted solar modules or wind turbines. The hybrid tree can be regarded as a tree generating renewable energy electricity. The visually unpleasant photovoltaic panels and three-bladed wind turbines can be replaced with the elegance of nature's finest evolutionary energy trees. Contrary to most wind turbines, the unobtrusive design is really attractive to look at, reportedly silent and operates at low wind speeds, which has the extra benefit of boosting overall efficiency and power generation [4]. The energy trees proposed by various researchers are described below. A 36 feet tall wind tree presented by a researcher has 72 artificial leaves that are tiny turbines that spin silently on their hubs, capable of producing a total of 3100 W of electricity. As solar irradiation and wind speed are intermittent, integrating these two sources would result in a highly efficient and reliable system as they would complement each other, ensuring continuity in power supply [5]. In their work, numerous scholars have mentioned the idea of a solar tree or the arrangement of PV cells in a Fibonacci series. To lower the mounting cost, such solar cell combinations can be made on coconut, palm or other native trees [6]. A PV module system needs ten acres of land to generate 2 MW of power. Solar trees, compared to typical SPV systems installed on buildings, a tall pole-like structure would only require 1% of the available land [7]. It should be taken care that the top panels shouldn't obstruct the bottom panels to receive the most sun during the day.

2. Proposed solar-wind hybrid tree The proposed design as illustrated in Fig. 1, consists of 8 solar panels and 5 vertical axis wind turbines. Each solar panel is of a rated capacity 250 W at 100 W/m2. Each vertical axis wind turbine is of rating 200 W at 11 m/s wind speed. The total capacity of the proposed system is 3 kWp [8].

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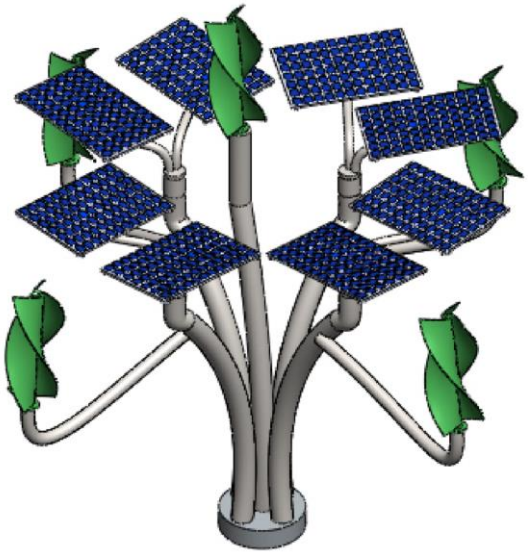

Fig. 1. Proposed design of the solar-wind hybrid tree.

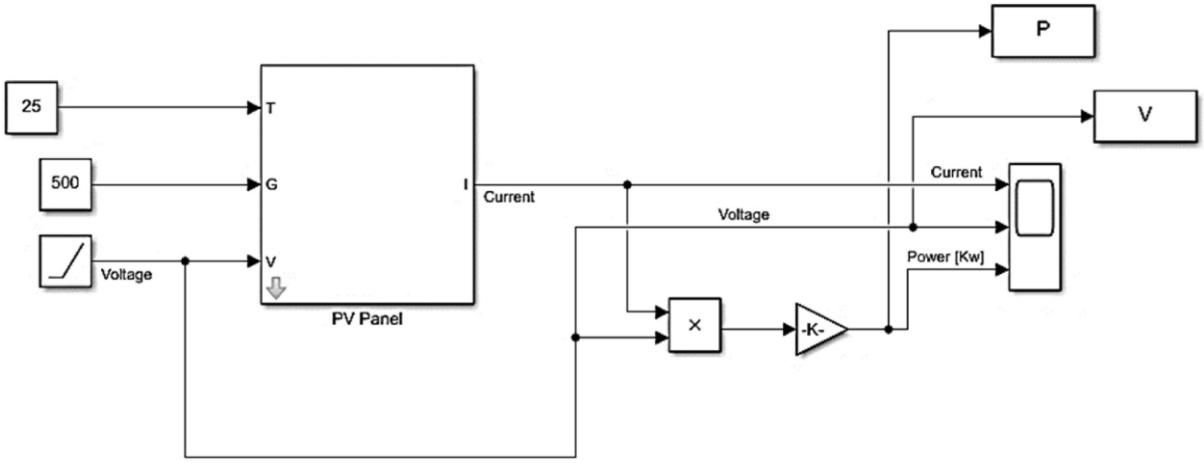

Fig. 3. Solar PV system model in MATLAB

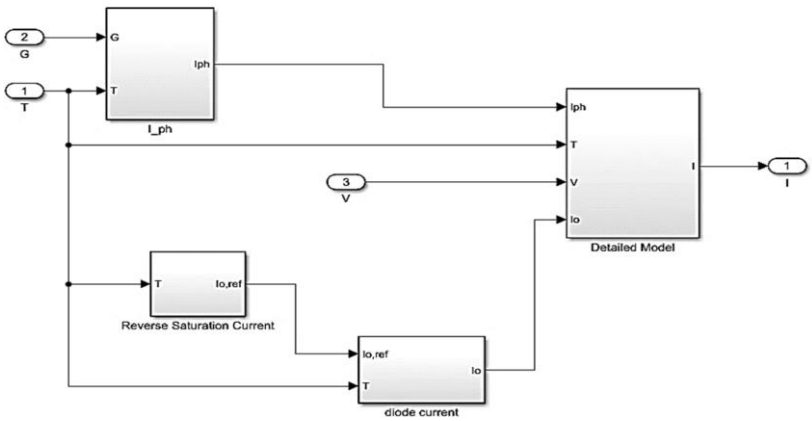

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Fig. 4. PV panel model in MATLAB

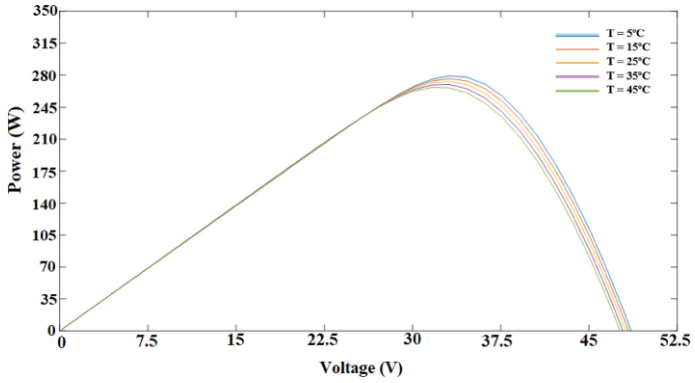

Fig. 6. P–V Characteristics at varying Temperature.

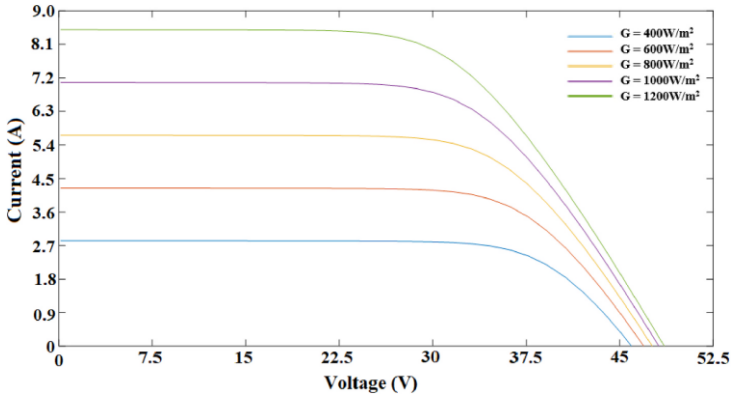

Fig. 7. I–V Characteristics at varying Irradiance.

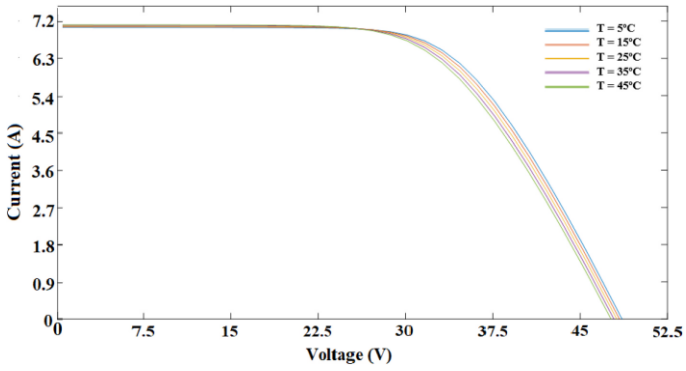

Fig. 8. I–V Characteristics at varying Temperature.

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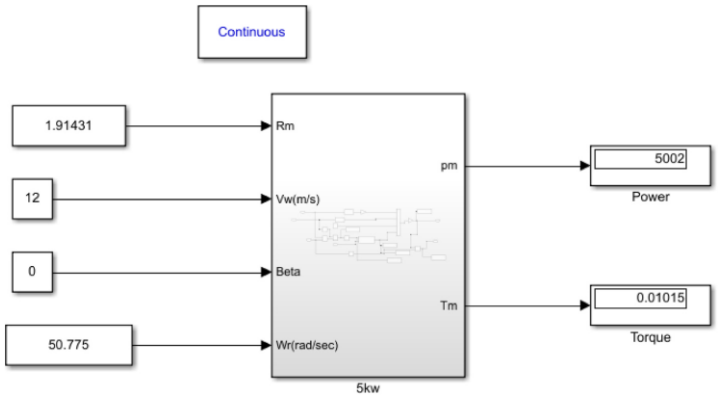

Fig. 9. Wind turbine model in MATLAB simulink.

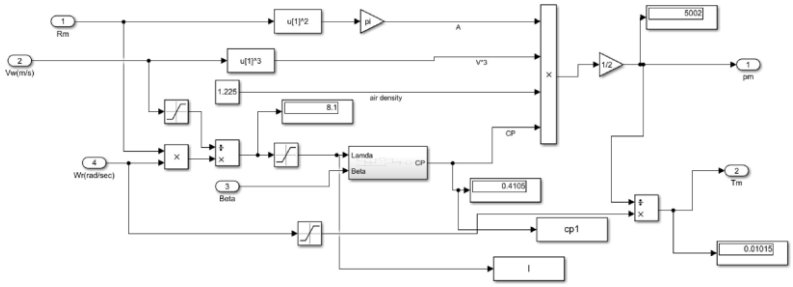

Fig. 10. Wind turbine model designed in MATLAB simulink.

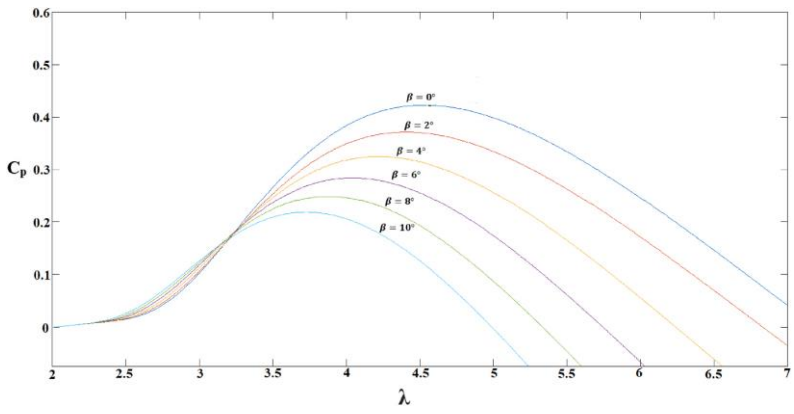

Fig. 11. Co-efficient of power vs tip speed ratio plot.

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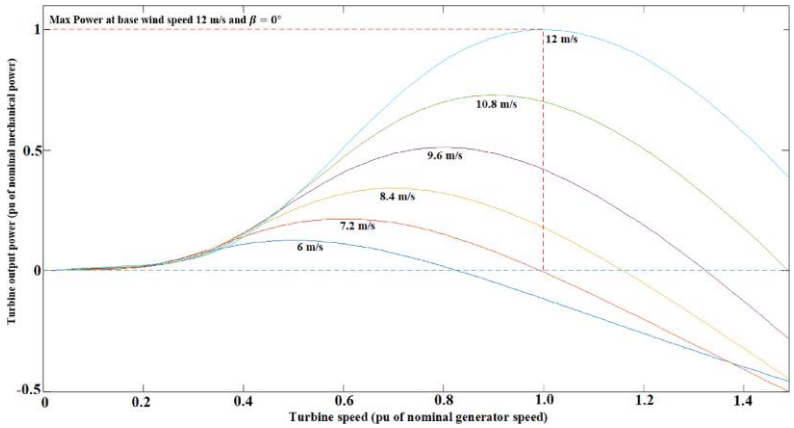

Fig. 12. Power characteristics vs wind speed plot.

3. Comparison of energy generation

The output of the hybrid system is obtained using the solar irradiance, wind speed and temperature data of the site though HOMER simulation analysis [9]. The model used in HOMER Pro for carrying out simulation studies for getting power and energy generation, is shown in Fig. 17. It consists of 8 solar panels and 5 vertical axis wind turbines. Each solar panel is of the rating 250 W at 1000 W/m2. Each vertical axis wind turbine is of rating 200 W at 11 m/s wind speed. Total hybrid tree system capacity is 3 kWp (comprising of 2 kWp and 1 kWp wind) [10]. It also consists of lead acid battery system, for energy storage. It has hybrid controller which consists of a converter and inverter. The hybrid controller output is connected with AC load. Hybrid system with both axis tracking system generate 4709 kWh/ year. While horizontal and vertical axis tracking system generate 3971 kWh/year and 4190 kWh/year respectively [11] – [12]. From Table 1 and Table 2, it can be said that, hybrid tree with two axis tracking system generate more energy than single axis tracking system or when no tracking arrangements are being made. Hybrid system with no tracking system generates maximum energy as 3763 kWh/year, when tilt angle is 18.25◦. Hence, it can be said that for fixed solar panels at this Vaddeswaram location, optimum tilt angle should be 18.25◦ [13].

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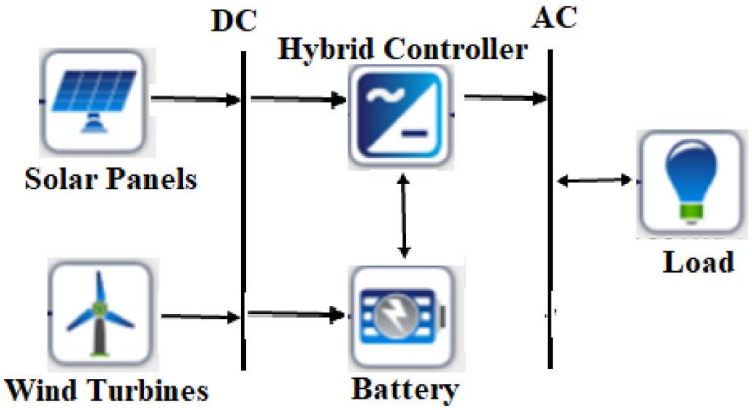

Fig. 13. Solar-Wind Hybrid system model designed in Homer Pro.

Table 1 Energy Generation for hybrid tree with tracking systems.

TABLE 2 ENERGY GENERATION FOR HYBRID TREE WITH TRACKING SYSTEMS

Tracking Type	Tracking Type Energy Generation from solar side (kWh/year)	Energy Generation from wind side (kWh/year)	Total Energy Generation (kWh/year)
Horizontal Axis Tracking system	3370	601	3971
Vertical Axis Tracking System	3589	601	4190
Two Axis Tracking System	**4108**	601	**4709**

Table 2 Energy Generation for hybrid tree without tracking system but PV panels fixed at different tilt angles.

Tilt Angle	Energy Generation from solar side (kWh/yr)	Energy Generation from wind side (kWh/yr)	Total Energy Generation (kWh/yr)
10	3137	601	3738
10.5	3140	601	3741

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11	3143	601	3744
11.5	3145	601	3746
12	3148	601	3749
12.5	3150	601	3751
13	3152	601	3753
13.5	3153	601	3754
14	3155	601	3756
14.5	3157	601	3758
15	3158	601	3759
15.5	3159	601	3760
16	3160	601	3761
16.45	3160	601	3761
16.5	3160	601	3761
17	3161	601	3762
17.5	3161	601	3762
18	3162	601	3763
18.25	3162	601	3763
18.5	**3162**	**601**	**3763**
19	3161	601	3762
19.5	3161	601	3762
20	3160	601	3761

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CONCLOUSION

The concept of a solar-wind hybrid tree is gradually gaining acceptance since it can generate more energy while taking up less area on the ground. Its widespread public adoption is negatively impacted by knowledge gaps, considerable shading losses, and greater structural material requirements. The high cost of the current hybrid tree designs is primarily due to the high structural material needs. The presentation of the various energy tree designs and uses that are accessible around the world was one of the objectives of this review. It was suggested to build a 3 kWp hybrid tree in Vaddeswaram, Andhra Pradesh, which is situated at 16°26′50″ N and 80°36′42″ E. The suggested design has the potential to produce more energy while having a lesser demand for structural materials. With a factor of safety of 2, the hybrid tree's structural design was optimised for wind loads up to 150 kmph. Using pertinent characteristic equations created based on an electrical equivalent circuit, a mathematical model of SPV is presented. The results are shown under different conditions of irradiance in the range of 400 W/m^2 to 1200 W/m^2 and temperature in the range of 5 C^o to 45 C^o. The output characteristics P-V and I-V curves of SPV are obtained. A thorough mathematical model of the wind turbine system is also created, and using MATLAB simulation analysis, output characteristics are determined for a variety of input factors, such as wind speed up to 12 m/s and pitch angle. The Cp versus features for values from It has been simulated from 0 to 10. Additionally, the turbine output power simulation results for different wind speeds are shown. The HOMER simulation study yielded the annualised total power generation from the solar wind hybrid tree with and without tracking, panels at fixed angles between 10 and 20 tilt angles. The suggested solar-wind hybrid tree was shown to be capable of producing up to 4709 kWh/year using a two-axis tracking system or 3763 kWh/year when solar panels are placed at an 18.25 tilt angle. With a two-axis tracking system, the solar component can produce up to 4108 kWh per year, and when the solar panels are fixed at an 18.25 tilt angle, they can produce up to 3162 kWh per year. The wind turbines' yearly energy output was 601 kWh/year were discovered. Additionally, it was discovered that the hybrid tree system generates at its highest levels in April. The design method described in the research can be utilised to build a hybrid tree that takes into account many concerns while being applicable to a number of different geographic regions. Future research can focus on attempting to lessen the net weight of hybrid trees utilising lightweight materials like Fiber-Reinforced Plastic, which facilitates installation and shipping. The output characteristics of the wind turbine at higher wind speeds, i.e. larger than 12 m/s, can be studied by the researcher.

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