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Innovative Solar-Wind Hybrid Renewable Energy Tree: Design and Analysis

Sonu Kumar S. Koteswara Rao, ECE, Koneru Lakshmaiah Education Foundation (KLEF), Vaddeswaram 522302, Andhra Pradesh, India

Abstract

A novel concept known as a "hybrid tree" is presented in this paper, representing an innovative artificial structure designed to mimic the natural form of a tree. This unique structure features branches that support both solar modules and wind turbines, effectively harnessing renewable energy. The hybrid tree stands as an environmentally friendly and efficient power source, capable of catering to a wide range of energy needs across diverse areas, both small and large. Consequently, it emerges as an ideal solution for fostering sustainability in cities and modern societies. This research paper introduces a specific design for a 3 kW hybrid tree, which comprises 2 kW of solar panels and 1 kW of wind turbines. This particular design is planned for deployment in Vaddeswaram, Andhra Pradesh, situated at coordinates 16.26°N and 80.36°E. Notably, the hybrid tree incorporates a sophisticated two-axis tracking system, optimizing energy generation by ensuring the solar panels and wind turbines are consistently aligned with the sun and wind sources.

Introduction

Climate change stands as one of the most significant challenges facing humanity today, with potential far-reaching impacts on economic growth. To tackle these issues, the increased utilization of non-conventional or renewable energy sources emerges as a promising solution [1]. Various natural processes continuously produce renewable energy sources, such as solar energy, wind energy, and geothermal energy, which are harnessed for electricity generation [2]. Renewable natural resources like sunshine, wind, rain, waves, and geothermal energy play a crucial role in power generation, with solar, wind, hydro, biomass, and biofuels being the primary renewable energy sources [3]. However, the conventional flat or rooftop mountings of photovoltaic systems and wind turbines require extensive land area, which poses a challenge, especially in land-scarce regions like modern cities and villages in India. To address this issue, the solar-wind hybrid tree emerges as a promising alternative to conventional solar PV and wind turbine systems. These artificial structures, resembling trees, are equipped with branches on which solar modules or wind turbines are mounted. As a result, the hybrid tree visually mimics nature's elegance while generating renewable electricity, providing a harmonious blend of aesthetics and functionality. The design of the hybrid tree offers several advantages over traditional wind turbines. Its unobtrusive and visually appealing design operates silently and efficiently

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at low wind speeds, boosting overall power generation and efficiency. Researchers have presented innovative energy tree designs, such as a 36-foot-tall wind tree with 72 artificial leaves, each functioning as tiny turbines capable of silently producing a total of 3100 W of electricity. By integrating the intermittent solar irradiation and wind speed, a highly efficient and reliable system is achieved, as the two energy sources complement each other, ensuring continuous power supply.

2. Proposed solar-wind hybrid tree

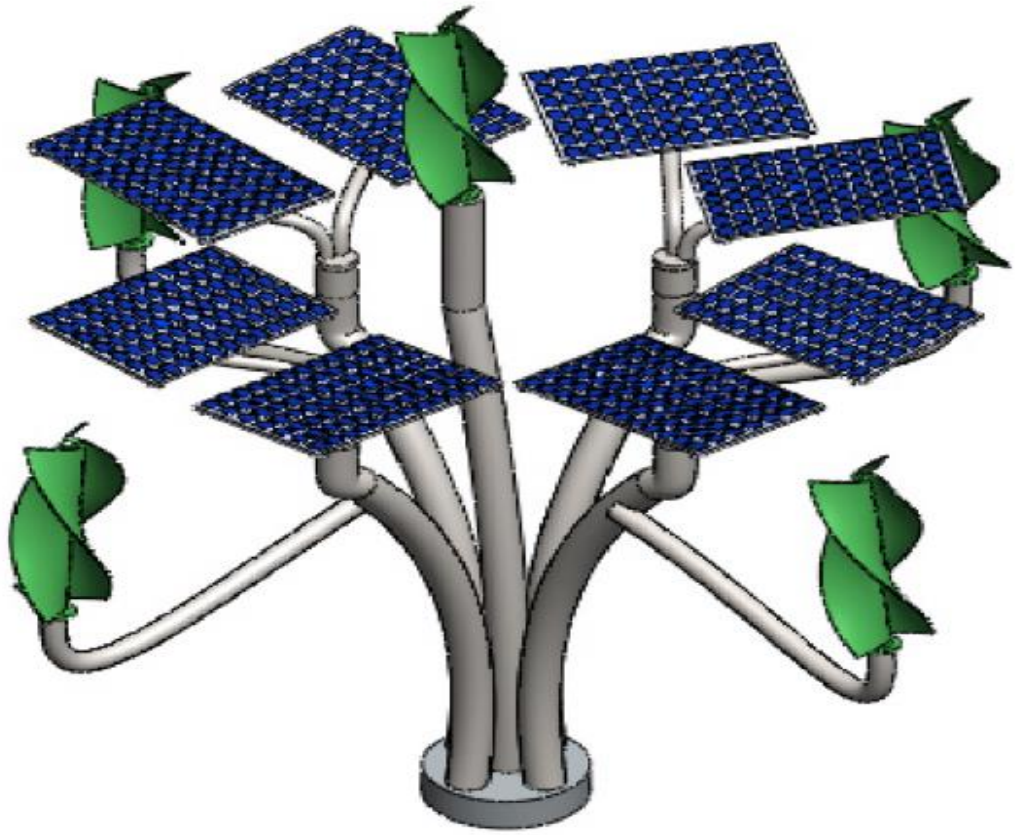

Fig. 1. Proposed design of the solar-wind hybrid tree.

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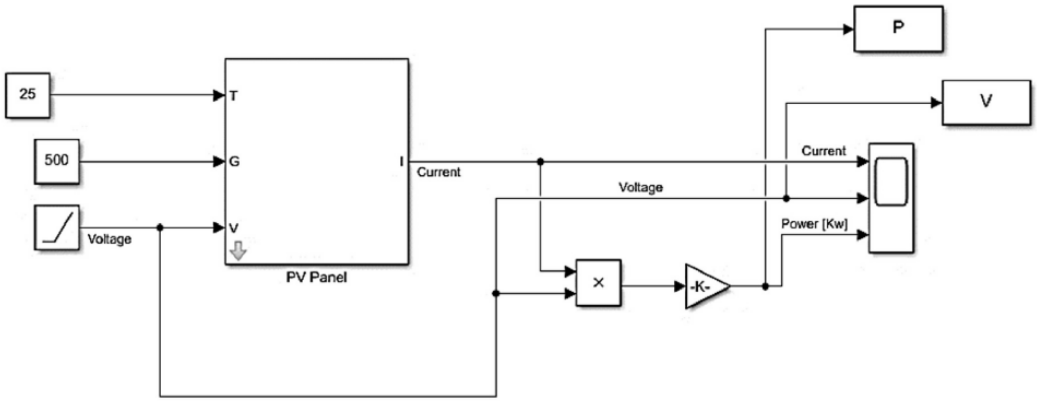

Fig. 3. Solar PV system model in MATLAB

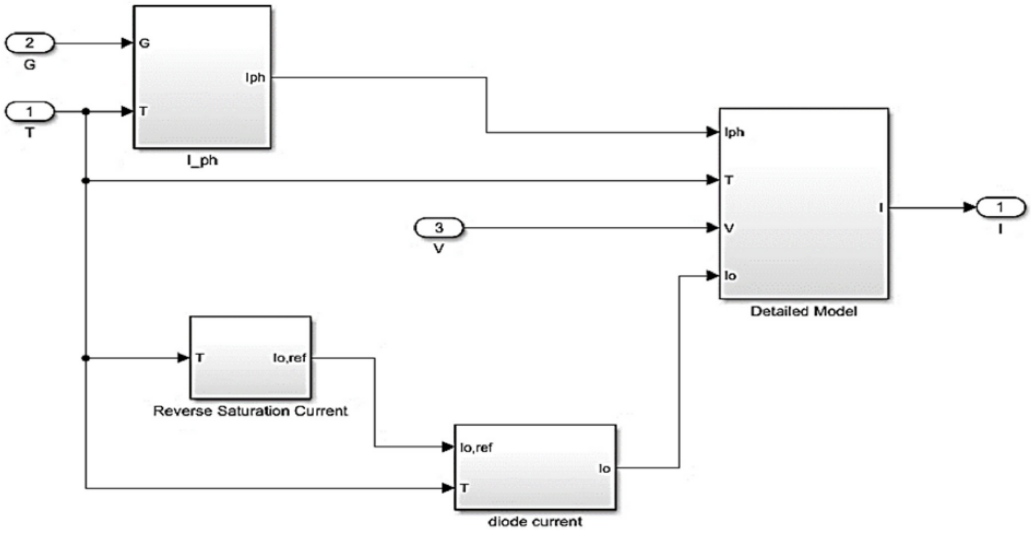

Fig. 4. PV panel model in MATLAB

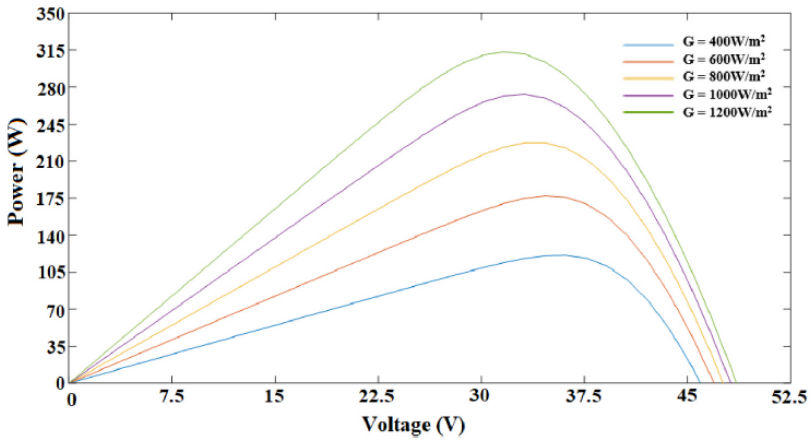

Fig. 5. *P*–V Characteristics at varying Irradiance.

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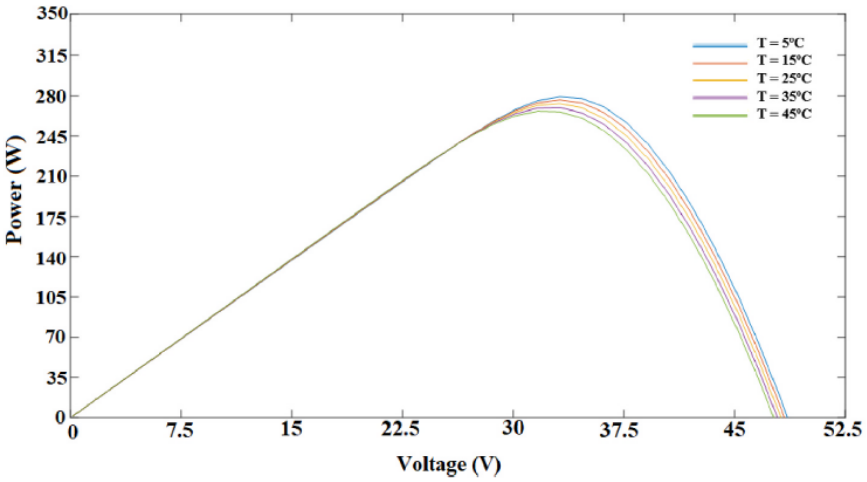

Fig. 6. *P*–V Characteristics at varying Temperature.

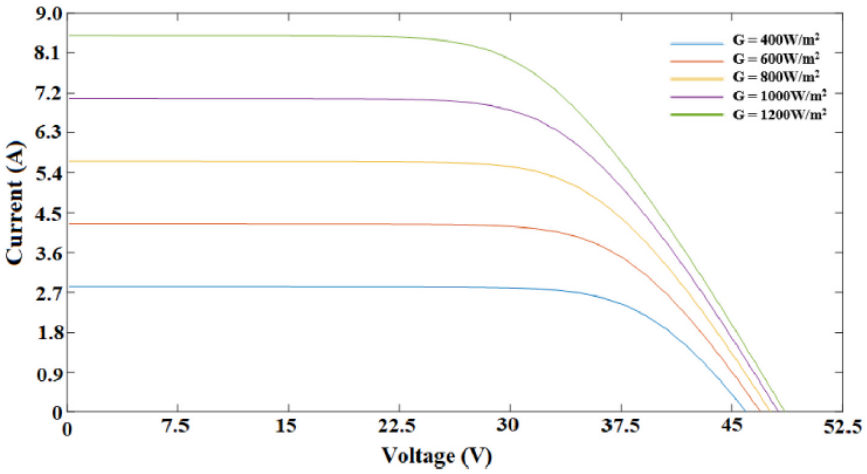

Fig. 7. I–V Characteristics at varying Irradiance.

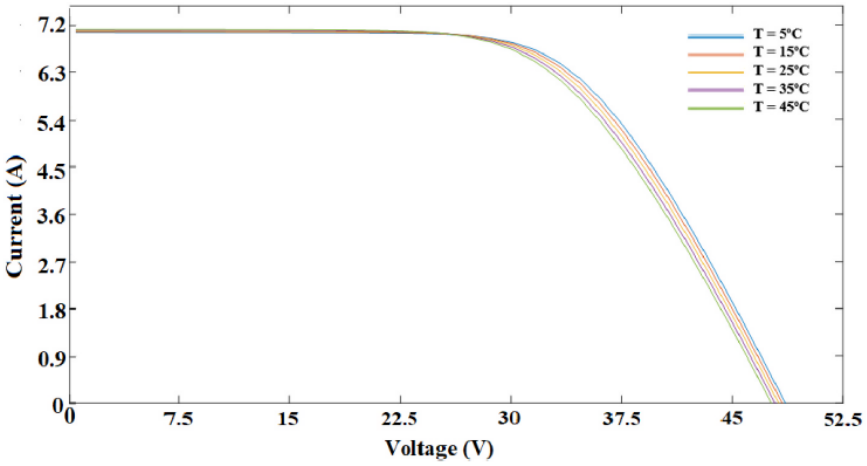

Fig. 8. I–V Characteristics at varying Temperature.

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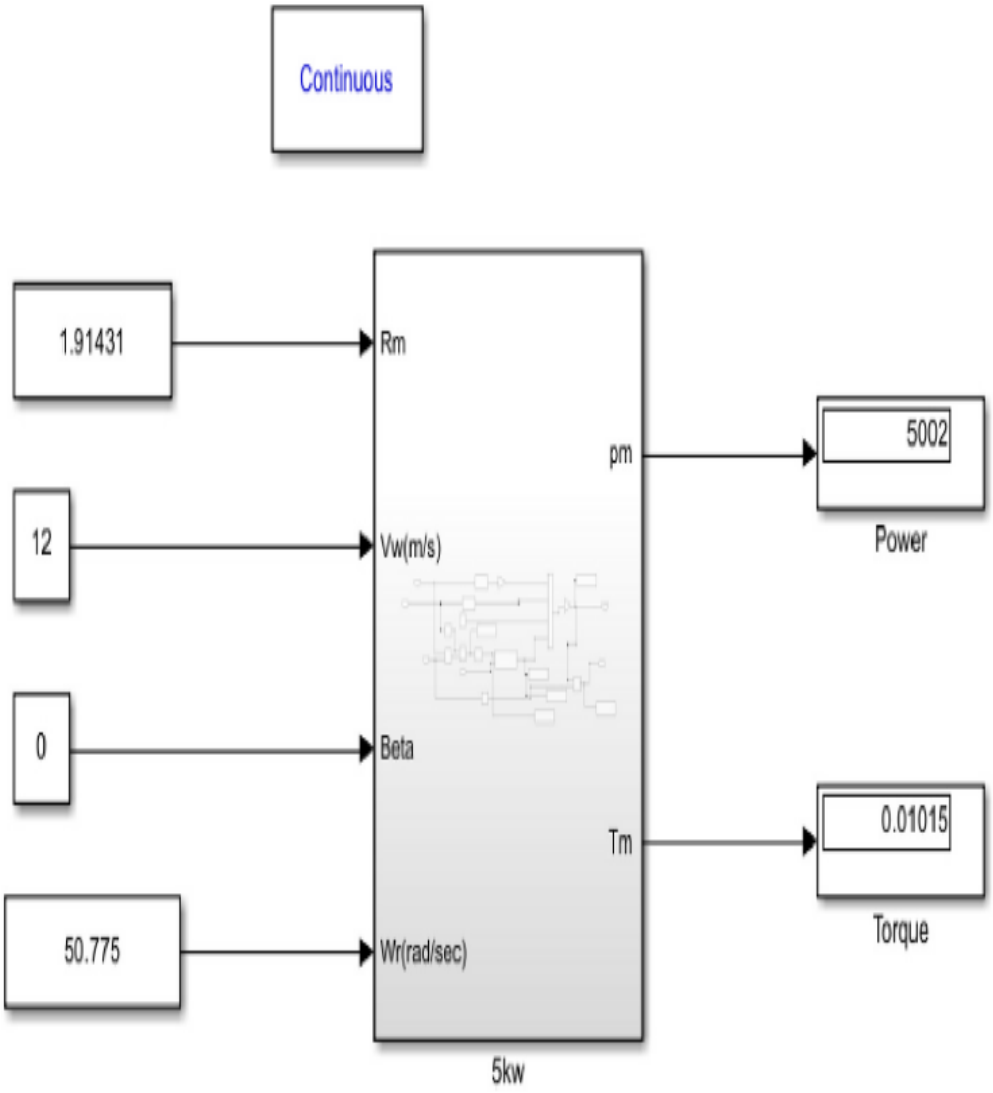

Fig. 9. Wind turbine model in MATLAB simulink.

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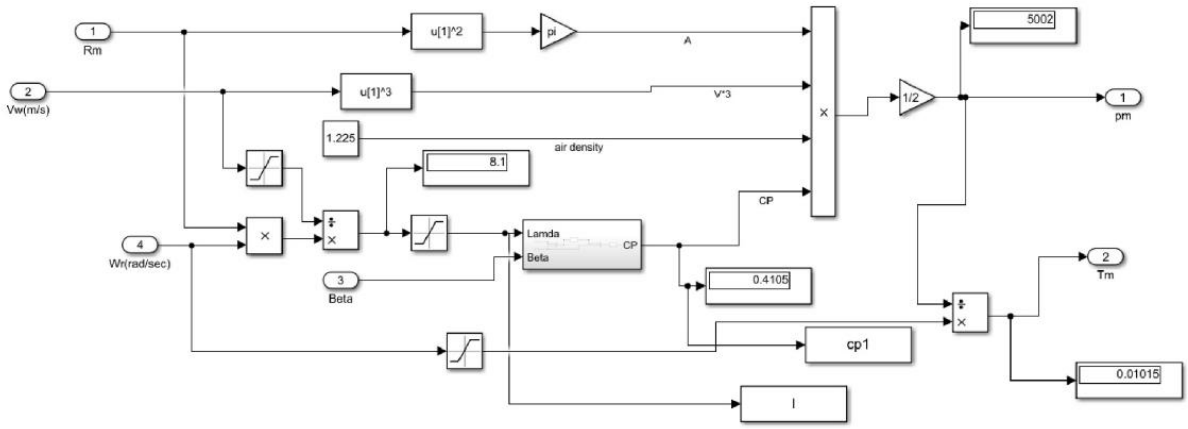

Fig. 10. Wind turbine model designed in MATLAB simulink.

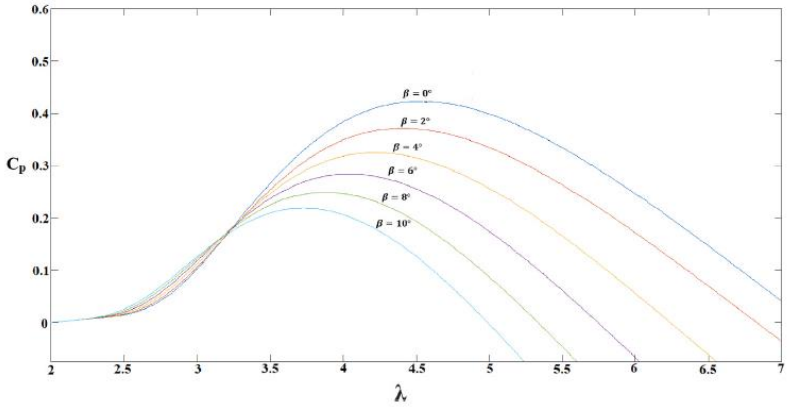

Fig. 11. Co-efficient of power vs tip speed ratio plot.

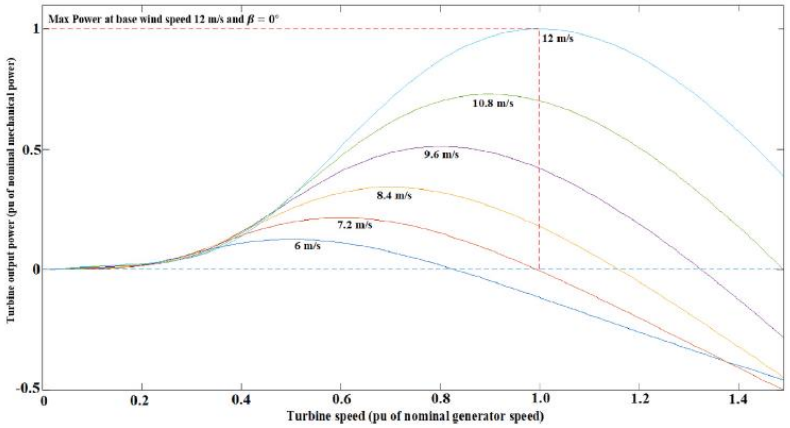

Fig. 12. Power characteristics vs wind speed plot.

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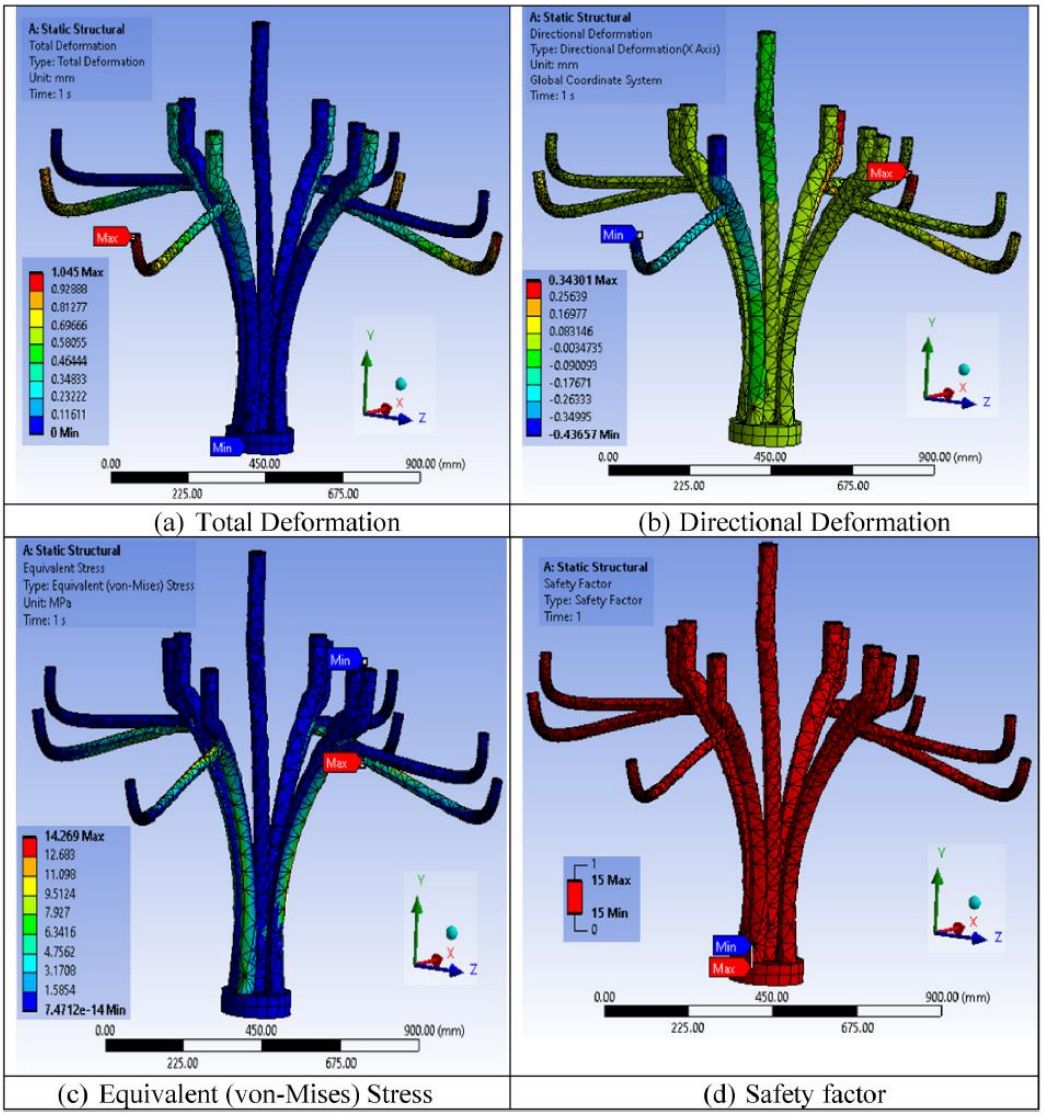

Fig. 13. Static structural analysis of the proposed hybrid tree structure (a) total deformation (b) directional deformation (c) equivalent von-mises stress and (d) safety factor.

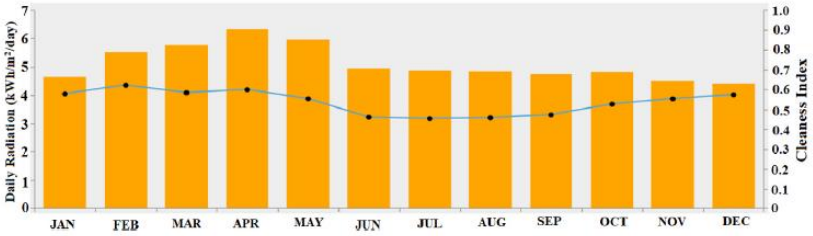

Fig. 14. Solar Irradiance plot for full year.

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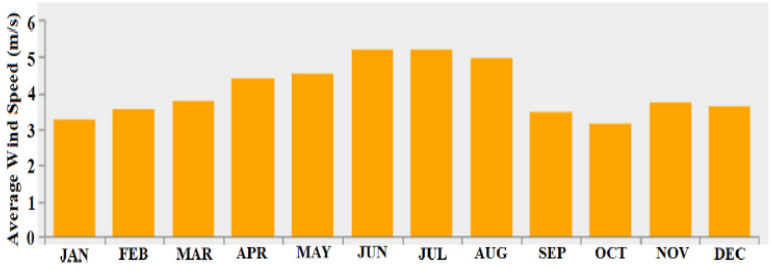

Fig. 15. Wind Speed plot for full year.

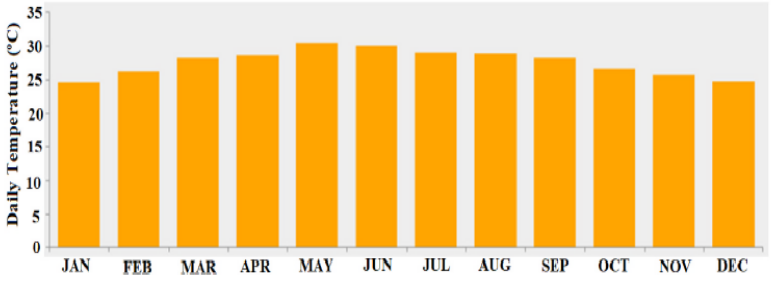

Fig. 16. Temperature plot for full year.

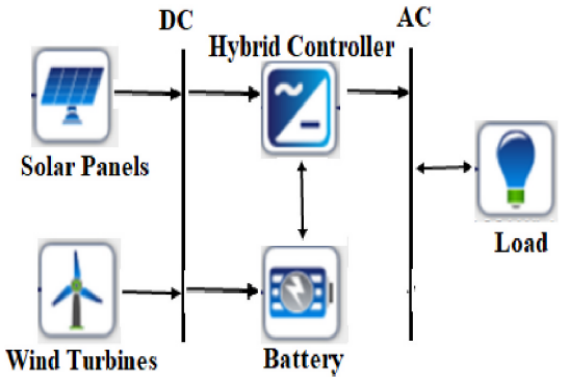

Fig. 17. Solar-Wind Hybrid system model designed in Homer Pro.

Table 1
Energy Generation for hybrid tree with tracking systems.

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/year)	Energy Generation from wind side (kWh/year)	Total Energy Generation (kWh/year)
10	3137	601	3738
10.5	3140	601	3741
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

requirements are significant obstacles that have a negative impact on its wide public acceptance. The high structural material requirements mostly account for the high expense of the existing hybrid tree designs.

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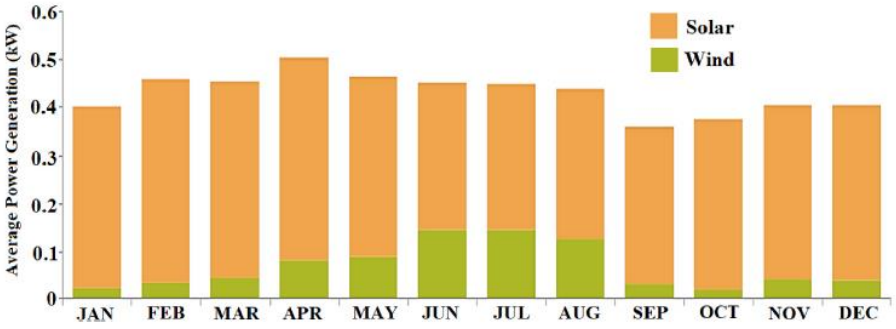

Fig. 18. Monthly average power generation for full year when solar panel fixed at 18.25°.

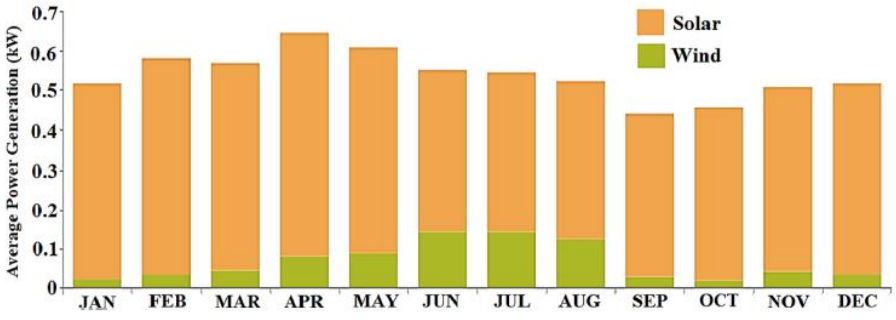

Fig. 19. Monthly average power generation for full year for two axis tracking system.

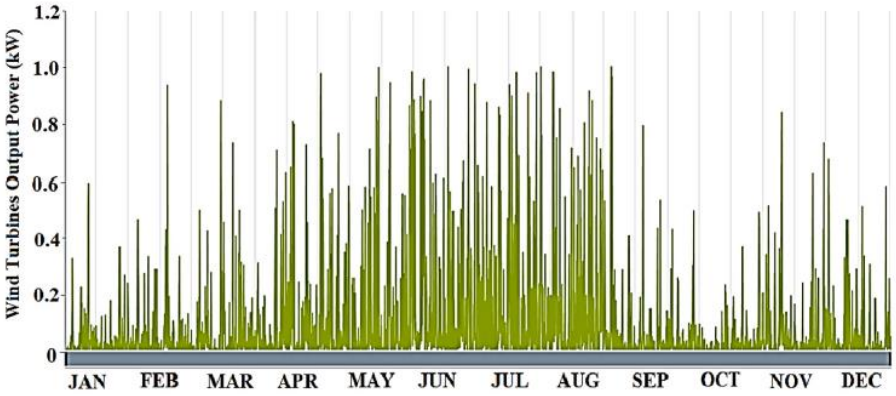

Fig. 20. Instantaneous Power generation from wind part for full year.

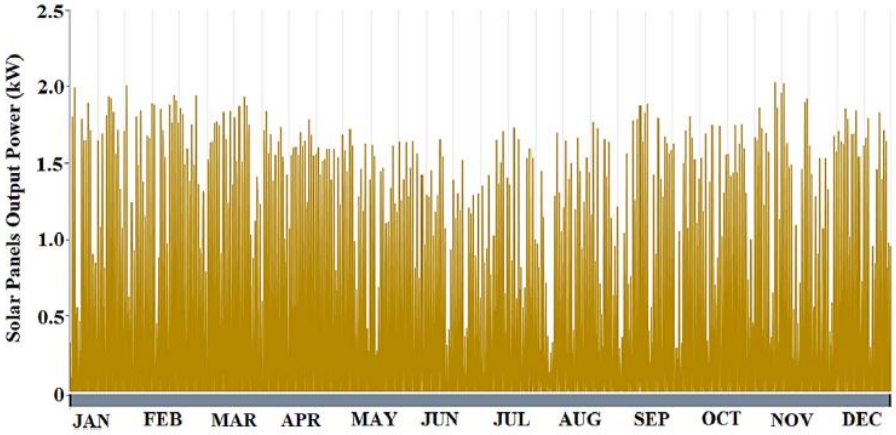

Fig. 21. Instantaneous Power generation from solar part for solar panel fixed at 18.25° for full year.

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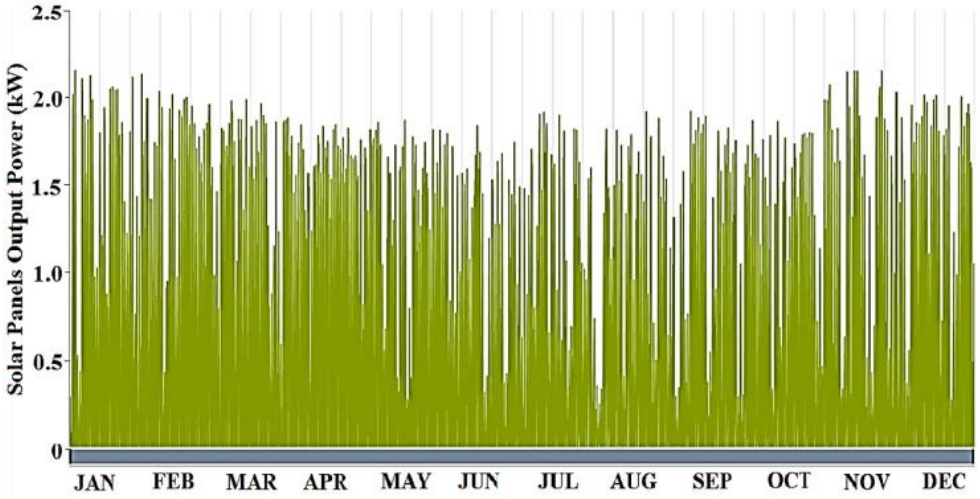

Fig. 22. Instantaneous Power generation from solar part for full year with two axis tracking system.

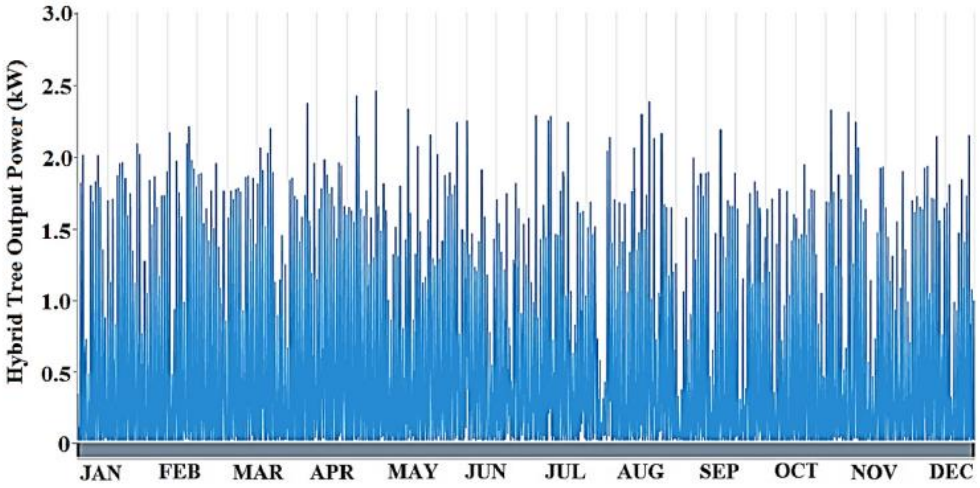

Fig. 23. Instantaneous Power generation from solar-wind hybrid tree for full year when solar panels are fixed at 18.25°.

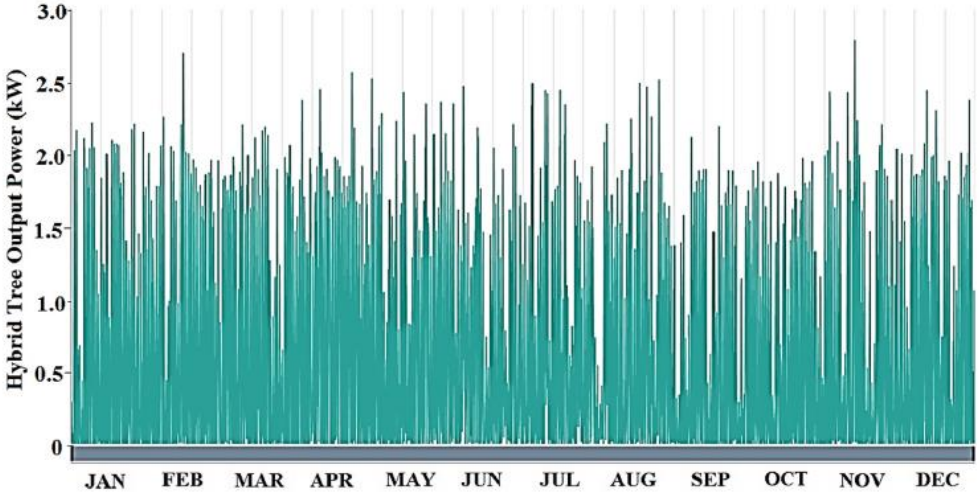

Fig. 24. Instantaneous Power generation from solar-wind hybrid tree for full year with two axis tracking system.

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