

Urban Eco-Greenergy™ Hybrid Wind-Solar Photovoltaic Energy System and Its Applications

Wen Tong Chong^{1,*}, Wan Khairul Muzammil^{1,2}, Ahmad Fazlizan¹, Mohamad Reza Hassan¹, Hamid Taheri¹, Mohammed Gwani¹, Hiren Kothari¹, and Sin Chew Poh¹

¹ Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
² Faculty of Engineering, Universiti Malaysia Sabah, Jln. UMS, 88400 Kota Kinabalu, Sabah, Malaysia
* Corresponding Author / E-mail: chong_wentong@um.edu.my, TEL: +60-1272-35038, FAX: +60-3796-75317

KEYWORDS: Hybrid renewable energy, Omni-direction-guide-vane, Wind energy, Solar energy, Vertical axis wind turbine, On-site power generation

This paper introduces the Eco-Greenergy™ hybrid wind-solar photovoltaic energy generation system and its applications. The system is an integration of the novel omni-direction-guide-vane (ODGV) with a vertical axis wind turbine (VAWT). The ODGV is designed to surround the VAWT for wind power augmentation by creating a venturi effect to increase the on-coming wind speed before it interacts with the turbine blades. In wind tunnel tests, the ODGV improves the power output of the VAWT by 3.48 times compared with a bare VAWT at its peak torque. Furthermore, the rotor rotational speed of the wind turbine increased by 182% at 6 m/s of wind speed. A solar PV panel can be mounted on the top surface of the ODGV for solar energy generation. Estimation on wind-solar energy output shows that the system can generate a total of 572.8 kWh of energy per year. By comparison, the ODGV increases the annual wind energy output by 438%. The green energy generated from the hybrid system can be used to power LED lights or other appliances (e.g., CCTV camera).

1. Introduction

In the search for cleaner ways of generating energy, numerous efforts have been carried out in the past few decades. Renewable energy researches, particularly wind and solar have been gaining popularity and recognized as potential sources for clean, inexhaustible and free energies. The concept of on-site renewable energy generation is to extract energy from renewable sources close to the populated area where energy is required. In the modern era, on-site energy extraction from renewable energy sources in urban settings is regarded as the next step in the process of reducing dependencies on the usage of conventional power generation using fossil fuels.

A hybrid system consisting of wind and solar renewable energy sources is more beneficial than a system that only depends on one source of energy. Also, the power supply from a hybrid system is more stable and reliable. In addition, optimization of hybrid renewable energy system is crucial for researchers to maximize the energy output from the system with the lowest cost and highest reliability.^{1,2} There are many discussions on the advantages of using hybrid wind-solar energy generation systems in the literature.³⁻⁵ These advantages, however,

depend on the climatic pattern and distribution of wind and solar energy resources. The benefits include:

- Supplying load demand under varying weather conditions.
- Overall costs for self-powered systems may be reduced drastically.
- High reliability without backup power sources.

Traditional methods of extracting power from the wind in urban areas using wind turbine alone is not efficient due to the uncertainty of wind speed and the turbulence generated from the surrounding buildings. Therefore, requiring methods such as increasing the oncoming wind speed before it interacts with the turbine blades.⁶⁻⁹ Moreover, for a wind turbine to be used in an urban area, issues such as the structural strength of the wind turbines, failures of blades, acoustic pollution (due to large wind turbine blades) and electromagnetic interference should be addressed.^{10,11}

Due to the advantages of a hybrid system and to further improve the performance of small wind turbines, this paper presents the urban Eco-Greenergy™ hybrid wind-solar energy generation system. The design of the system is adopted from the larger building integrated omni-

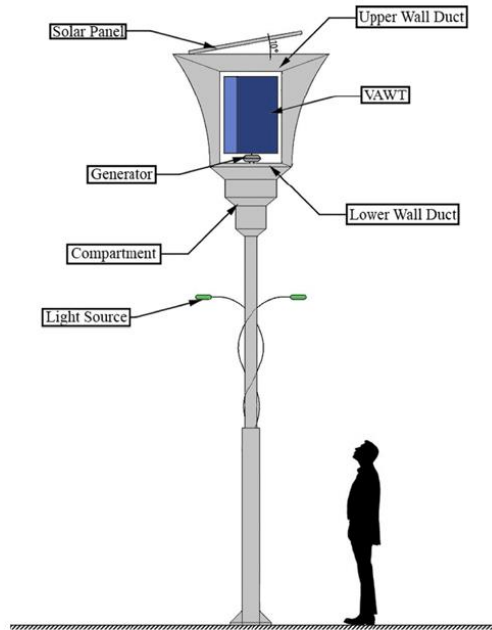


Fig. 1 Eco-Greenergy™ hybrid wind-solar energy generation system design and general arrangement (Patent no: PI 2013700243¹⁵)

direction-guide-vane (ODGV).¹²⁻¹⁴ The ODGV was originally designed to be installed on top of a high-rise building, shrouding a vertical axis wind turbine (VAWT) that covers much of the roof area of the building. However, the large size of the system drew concerns on the structural, safety and vibration issues that would affect the building and its occupants. Furthermore, installing the system with this scale requires high capital and maintenance costs. Hence, this paper introduces a small scale Eco-Greenergy™ hybrid wind-solar system that employs the ODGV integrated with a VAWT and solar photovoltaic (PV) panel for on-site standalone energy generation. This minimizes the risks posed by the large scale system, and with reduced costs.

2. Working Principles and General Arrangement of Eco-Greenergy™ System

The Eco-Greenergy™ system combines the hybrid wind-solar energy generation and energy-saving lighting feature into one compact design. The philosophy of the system is to increase the on-coming wind speed before it interacts with the wind turbine blades. Using the principle of the venturi effect, a shroud-augmentation device called the omni-direction-guide-vane (ODGV) is used to harvest more energy from the wind by increasing the natural wind-stream speed before the wind interacts with the turbine. Fig. 1 shows the overall design of the system.

Under the ODGV, multiple lamps can be adapted and arranged for optimum illumination. The height of the pole can be designed between



Fig. 2 Eco-Greenergy™ hybrid wind-solar photovoltaic energy system

2 to 30 meters above ground level. The height and size of the system depend on the location's weather pattern and distribution of wind and solar energy resources. The system can be deployed to illuminate parks, lawns, streets or sky-gardens. In remote areas, the system can be adapted to power weather data collectors, flood monitoring systems or as emergency beacons for hikers and travelers.

To harvest wind energy from all directions, the ODGV has several guide vanes that surrounds the VAWT. The VAWT sits in the middle of the ODGV, where its driveshaft is directly connected to a generator. On top of the upper wall duct, a solar panel is strategically placed for optimum solar energy generation. The combined green energy generated from the wind and solar sources is used to power the light source. In order to minimize power consumption, the LED lamp is adapted as the light source due to its durability. A battery can be used to store energy generated from the wind turbine and solar panel. Excess energy generated from the system can be used to power other electrical appliances or fed into the grid. The compartment housing is designed to place the hybrid controller and battery. A prototype of the system installed in University of Malaya, Malaysia is shown in Fig. 2.

2.1 Omni-direction-guide-vane

The ODGV can be fitted with any form of existing or new VAWT (S-rotor, H-rotor or Darrieus or a hybrid of Darrieus and S-rotor). As shown in Fig. 3, the guide vanes are used to guide the on-coming wind stream to the optimum angle of attack of the VAWT blades. The design of the guide vanes can be adapted into various forms, i.e. curve plates or straight plates with constant or varied thicknesses. The guide vanes, together with the upper and lower wall ducts form the channels through which the wind stream passes through before the wind interacts with the turbine blades.

The cross-sectional area at the intake of the channel is preferably two times or more than the cross-sectional area at the exit. Furthermore, the upper and lower wall ducts surfaces are inclined at a fixed angle from the horizontal plane. The venturi effect created by the channels can induce a higher wind speed into the VAWT, which allows for smaller and lighter rotating wind turbine parts to be used to produce similar power output. Moreover, this eliminates or further minimizes the electromagnetic interference issue and noise level caused by the long blades of large wind turbines. The small blades of the VAWT used in the system exert less pull compared to the blades of a HAWT. Hence,

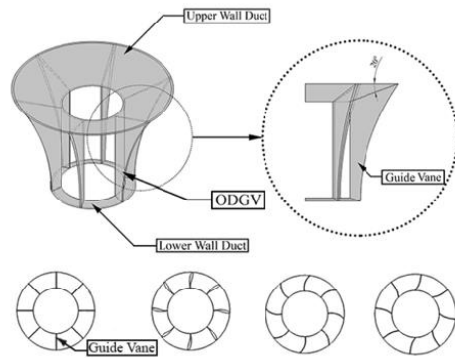


Fig. 3 Design of the omni-direction-guide-vane (ODGV) and variations of the guide vanes

the VAWT produces much lower levels of noise and vibration.¹⁰ Besides, as the VAWT is surrounded by guide vanes, the noise level of an ODGV integrated VAWT is lower than a bare VAWT.

3. Methodology

To assess the energy output of the hybrid system, the performance of the ODGV was evaluated in a wind tunnel testing. The estimation of energy output from the hybrid wind-solar system was calculated from the acquired meteorological data from Sepang, Malaysia. As a case study, the Eco-Greenergy™ hybrid wind-solar photovoltaic energy system is assumed to be installed on the top of a 150 m building in an urban area. The system has two 15 W LED lights to illuminate its surroundings. The following sub-sections describe the methodology of the wind tunnel testing, as well as the calculation of the energy output of the hybrid wind-solar system.

3.1 Experimental study of the omni-direction-guide-vane

The experiment was conducted to show that the ODGV fitted on the hybrid wind-solar energy generation system can improve the performance of the wind turbine. In the following sub-sections, the ODGV design to be used in the experiment is presented and the methodology carried out in the wind tunnel testing is described.

3.1.1 Design of the ODGV

The ODGV outer diameter was 1000 mm, the inner diameter was 540 mm and the height was 450 mm. The ODGV shown in Fig. 4 has four pairs of guide vanes to form channels which will guide the wind stream towards the wind turbine. The guide vanes for each pair are tilted at angles of 55° and 20°, as shown in Fig. 5.

At equal spacing, each of the guide vane pairs are positioned around the tapered central cylinder. The four channels are designed to guide the oncoming wind stream towards the wind turbine at 0°, 90°, 180° and 270° positions. The placement of guide vanes at the outer radial band of the tapered cylinder permits the wind turbine to capture wind energy from every direction. Thus, yaw mechanism can be omitted.

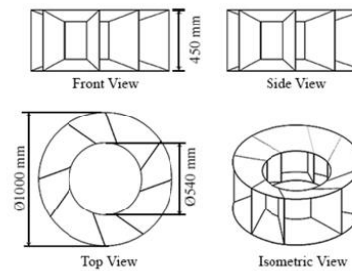


Fig. 4 Omni-Direction-Guide-Vane¹³

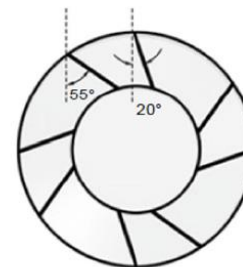


Fig. 5 Guide vanes angles¹³

3.1.2 Initial test

A preliminary test was carried out to simulate swirling and turbulent airflow similar to the real world environment. Three industrial fans were placed to simulate wind flow from three different directions, i.e. 0°, 30° and 60°. The fans were arranged in parallel. A Wortmann FX 63-137 5-bladed VAWT was enclosed by an ODGV model with dimensions shown in Fig. 4. The results from the preliminary test showed that the wind turbine rotor rotational speed was increased by about two times more when the ODGV was in place. This proves that the ODGV has positive effects on the wind turbine performance. Thus, further tests in a wind tunnel were carried out to thoroughly examine the ODGV.

3.1.3 Wind tunnel testing

The wind tunnel test was conducted at the Aeronautics Laboratory of University Teknologi Malaysia. Similarly, the ODGV integrated VAWT from the preliminary test were used in the wind tunnel test. The wind tunnel experimental set-up is shown in Fig. 6. Two types of configurations were tested, i) a bare vertical axis wind turbine without ODGV, and ii) an ODGV integrated vertical axis wind turbine.

To assess the self-starting behavior of the wind turbine for both of the configurations, the wind speed in the wind tunnel was increased gradually until the rotor started to rotate. The wind turbine was in free-running condition where the rotor was only subjected to inertia and bearing friction. No external loads were applied during the self-start assessment. Consequently, evaluations on the power generated and the rotational speed of the wind turbine for both configurations were carried out. In order to conduct the test, the wind speed was fixed at 6 m/s. An

Link to full text articles :

<http://link.springer.com/article/10.1007/s12541-015-0165-3>