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ScienceDirect

Energy Procedia 136 (2017) 330–335

Energy Procedia

www.elsevier.com/locate/procedia

4th International Conference on Energy and Environment Research, ICEER 2017, 17-20 July 2017, Porto, Portugal

Study, design and manufacturing of hybrid vertical axis Savonius wind turbine for urban architecture

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Abstract

This paper presents Study, Design and Manufacturing of a Small Residential Renewable Energy Conversion System mainly based on a local manufactured Savonius-rotor type Vertical Axis Wind Turbine, equipped with Photovoltaic Panel and a Storage System (Battery). This system can be used both for remote area and for building integration. For remote area, this system can be adapted to guarantee uninterruptible electrical power supply, for that, it is recommended to be used in the Algerian East–West Highway for lighting and/or petrol station electrical equipments supply. The advantages of this design are cleanliness, start-up under low wind speed, silent, adaptability in urban architecture.

Peer-review under responsibility of the scientific committee of the 4th International Conference on Energy and Environment Research.

*Keywords:*Vertical Axis Wind Turbine (VAWT); Residential Renewable Energy Conversion System (RRECS); Savonius; Urban architecture

1. Introduction

The simultaneous increase of population and energy demand, turn on natural resources capacity in a real strained situation, and in other hand, utilization of fossil fuel resources of energy is becoming more restricted mainly because of declining in fossil fuel reservoirs, threatening global warming, and the increase of oil prices. Therefore harnessing clean and renewable sources of energy is becoming the main worldwide topic for many researchers. It is more

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1876-6102
Peer-review under responsibility of the scientific committee of the 4th International Conference on Energy and Environment Research.
10.1016/j.egypro.2017.10.389

important than ever to invest in renewable energy; as sustainable and low-energy designs in many countries whose economies are only based on fossil fuel energy like Algeria [1].

In 2015 Algeria adopted update to its Renewable Energy and Energy Efficiency Development Plan until 2030. The review of the Plan puts greater focus on deployment of large-scale solar PV installations and onshore wind due to large technology costs decrease as well as introduction of biomass, cogeneration and geothermal technologies into the mix until 2020. CSP technology will be deployed with a delay due to still high technology costs [2,3]. However, utilizing small wind turbines which incorporate innovative designs and new materials of construction which may provide an attractive prospect of future applications of power production in the urban environment [4,5]. Since the past, Savonius-rotor type vertical axis wind turbines (VAWTs) are still considered as one of the most attractive solutions due to simplicity and ease of manufacturing [6]. Vertical axis wind turbines (VAWT's) are well suited to such environments due to their inherent axi-symmetric design, it offers many advantages over HAWT namely, 1) easy access to facilitate turbine maintenance, 2) reduced loads on the turbine tower to reduce material costs, 3) enabling urban areas with low wind potential to be supplied with clean, silent electric power. These benefits are necessary for the installation and continued operation of cheap small-scale wind turbines [7,8].

Aiming to introduce small wind turbines industry in Algeria, in this work a prototype of a Small-Power Savonius type-vertical axis wind turbine has been studied, designed and manufactured. The system is essentially dedicated to be integrated either into urban areas (buildings, house's roofs, etc.) or for outdoor lighting (gardens, public roads lighting, highways, etc.). It is equipped with photovoltaic (PV) panel and a battery storage aiming to guarantee uninterruptible power supply under any weather conditions. The paper is organized as following: firstly, based on wind energy conversion system basics, the Savonius type-vertical axis wind turbine model and optimal characteristics (Power Coefficient, Tip Speed Ratio) are presented and simulated within *Matlab*/*SIMULINK* environment. Secondly, an aerodynamic simulation in two dimensions (2D) at different wind flows (laminar and turbulent) is presented using *FLUENT* software. Thirdly a design based on *SOLIDWORKS* software of the proposed prototype is fulfilled. Finally the prototype has been manufactured based on Computer Aided Design Machinery.

2. System study

2.1. Mathematical modeling

The key element in the proposed design is the Savonius-rotor (Fig.1); hence as brief theoretical basics of wind energy conversion system, we may introduce the following:

- WindSpeed Model:$\boldsymbol{V_v = V_{mean} + \sum_{i=1}^{n}(a_i\, sin(b_i \omega_v t))}$, ($V_{mean}$: mean value).
- WindTurbinePower:$\boldsymbol{P_{turb} = \frac{1}{2} C_p(\lambda) S\ \rho V_v^3}$($\rho$:airdensity,$S=2RH$:surface,$\boldsymbol{\lambda = \frac{\Omega_r R}{V_v}}$: Tip Speed Ratio, Ω_r: Wind Turbine Speed, *R:* Wind Turbine Radius, *H*: Hight).
- PowerCoefficient: $\boldsymbol{C_p(\lambda) = a\lambda^3 + b\lambda^2 + c\lambda + d}$ (*a*, *b*, *c* and *d* are parameters characterize the designed wind turbine)
- Mechanical equation: $\mathbf{J \frac{d\Omega_r}{dt} = C_{mec} - C'_g}$(*J* : equivalent Inertia, C_{mec}: Wind Turbine Torque, *Cg'*: Generator equivalent Torque)

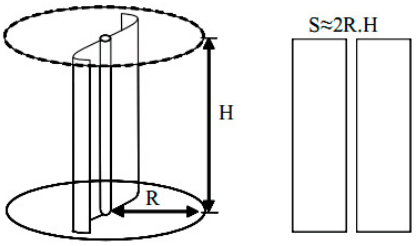

Fig. 1.Savonius-rotor