Alternative Energy System based on the Vertical Axis Wind Turbine Helical Rotor

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Abstract — **According by roadmap for moving to a low-carbon economy in 2050, ensuring energy security, represent the new imperative and is at the center of the global discussion. The recent scientific researches on the constructive aspects and aerodynamic optimization process related by the new green energy conversion systems offers the possibility to create sustainable development platforms based on the 'smart grid' equipment with high efficiency conversion. The study of the alternative energy systems based on the vertical axis wind turbine helical rotors come in responding to concerns about creation, development and dissemination the new generations high-efficiency capture solutions. The combined helical rotor of vertical axis wind turbine works by using drag-type and lift-type aerodynamically principles, and is adapted for increased conversion efficiency in the geographic areas characterized by low wind energy potential.**

Keywords— vertical axis wind turbines (VAWTs); Darrieus rotor; Savonius rotor; blade design; multiple stream-tube; aerodynamic optimization.

I. INTRODUCTION

In recent decades one of the most important concerns of the government and in the world is the need for energy security. Therefore, alternative energy resources such as wind energy have been rapidly developed. By Global Wind Energy Report there are three important factors which have driven the development of modern wind turbines: firstly related by strong demand of energy; secondly related by the developments advanced of relevant technologies , and thirdly, the political issues related by sustainable development. The recent research in the area of renewable energy is more and more focusing on the development the new efficient solutions and to bring the energy sources near to the final point where they will be used. If we look on the international market, most of the technological solutions for wind energy conversion are with horizontal axis. Broadly speaking is the turbine in which the axis of the rotor rotation is parallel to the wind stream and the ground, and the rotor convert the linear motion of the wind into rotational energy that can be used to drive a generator. The segment of the large wind systems have a lot advantages, related by conversion efficiency and generated power, but the last years trend is characterized by the new phenomenon sometimes called: beyond limits. The primary motivation for this research is to develop an optimal concept, specially adapted to the local possibilities. This is the reason why at the Technical University of Moldova was started a research program which is focused on the study and development a type of wind turbine able to provide high performance in the geographic areas characterized by low wind energy potential. Within the broad context after reviewing the various literature of the wind conversion technology has been proposed the power generation system based on vertical axis wind turbines concept. The main reason for this choice is that vertical axis wind turbines are suitable for low speed and urban environment. From the perspective of urban applications, where the wind is very turbulent and unstable with fast changes in direction and velocity, vertical axis wind turbines have several advantages over the widely used horizontal axis wind turbines.

Advantages of the vertical axis format:

- The generator and the gearbox of a vertical axis wind turbine can be positioned on the ground, therefore reducing the loads on the tower and facilitating the maintenance of the system.
- Good resistance to high wind speeds and doesn’t require a yaw control system because of insensitive to the wind direction capability.
- Low wind speed and higher efficiency.

One of the main problems of lift-type VAWTs is their poor ability to self-start at low wind speeds [1] .

II. THE DEVELOPMENT OF COMBINED VERTICAL AXIS MICRO WIND TURBINE

For our project requirements are: to have the ability to produce electricity at small wind speeds (2.5-5 m/s); to have the optimum dimensions with respect to the energy demand; to cope with turbulence and gusty wind; to produce as less noise as possible and to not produce vibrations.

Based on detailed study and calculation, was proposed the Hybrid designs concept, which are using helical Savonius rotor, together with the Darrieus rotor. The combined helical rotor of vertical axis wind turbine works by using drag-type and lift-type aerodynamically principles. According to the proposed construction, Savonius rotor is used to start a three helical blades Darrieus rotor.

Several parameters should be considered in designing a wind turbine rotor for a particular type of application. These parameters include solidity of the rotor, length, chord and aspect ratio of the blades, diameter of the rotor, number of blades, blade profile, surface roughness of the blade, operational range of Reynolds number, etc.

The choice of the number of blades of a wind rotor is critical parameter for a well operational process. The number of blades has an effect both on the maximum power coefficient as well as on the vibrations and pulsating torque. Hence, a higher number of blades decreases the maximum C_p [2], but in the same time diminishes the torque vibrations. In our case was selected the concept with 3 blade for Darrieus rotor and 2 blade for Savonius rotor.

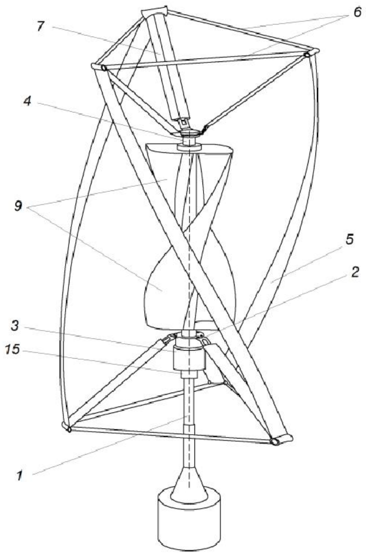

Fig. 1. Combined vertical axis micro wind turbine

The design and construction of the blades are also integral to building a vertical axis wind turbine. It is well known that in urban areas the wind is very turbulent and unstable with fast changes in direction and velocity; therefore it is very important to study a blade design performance, capable of offering the VAWT the ability to self-start. A large number of analytical, numerical, and experimental methods have been used to study the blade profile design modifications and the implications that those modifications bring to the wind turbine performance.

According to the literature for a small scale VAWT, are used symmetrical airfoils. The advantage of the symmetrical airfoils is that symmetrical airfoils produce lift from both side of the airfoil, so these will give a lift during 360o rotating and we are not having a problem to adjust the blades relative to wind direction. By evaluating several symmetrical blade profiles with an aerodynamic multi-criteria shape optimization, reference [1] considered the NACA0018 to have an optimal shape design. This blade presents the best pressure coefficient (C_{pr}) contribution to the tangential force and shows the best drag forces contribution to the forward movement of the wind turbine blades.

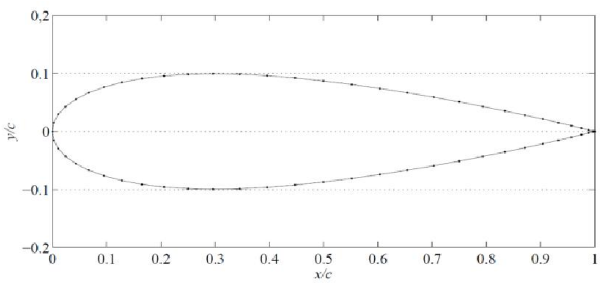

Fig. 2. Segmented NACA0018 blade profile

The next step is focused on determination of computational aerodynamic model. The selected model is based on application of momentum theory and blade element theory to multiple stream-tubes. Within the broad context the most popular stream-tube model is the Double Multiple Stream-tube model (DMST). The stream-tube models are based on BEM (Blade Element Momentum) models that were first introduced by Glauert [3]. The purpose of the numerical simulations of fluid dynamics computer aided (CFD) is to analyze relation between the surface of the blade and the wind flow.

Technical support associated with CFD numerical experiment station consists of Intel graphics (R) Core (TM) i7-4770 CPU 3.40 GHz, operative memory - 8GB, video card - NVIDIA GeForce GT640.

A key step of the calculation process is to define boundary conditions [4]: inlet; outlet; opening and wall areas.

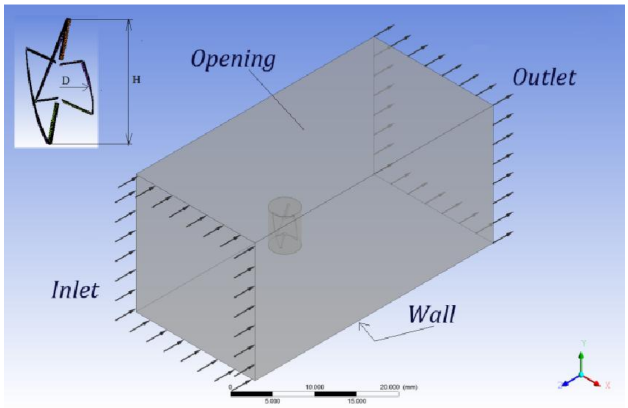

Fig. 3. Defining boundary conditions

The flow-solver is based on the Navier-Stokes equations which formulate the principles of conservation of mass, momentum and energy in the form of partial differential equations. The computational domain is divided into cells and discretization of the Navier-Stokes equations using the finite volume method is carried out on each cell in the domain. The SST (Shear Stress Transport) $k-\omega$ turbulence model was used in the simulation because this model could produce more accurate and reliable results [5]. The SST $k-\omega$ model is also known to have reduced sensitivity to far field values of turbulence frequency, ω, and a more balanced performance for a wide range of flow types compared to other general-purpose two equation models, as demonstrated by Menter et al [5].

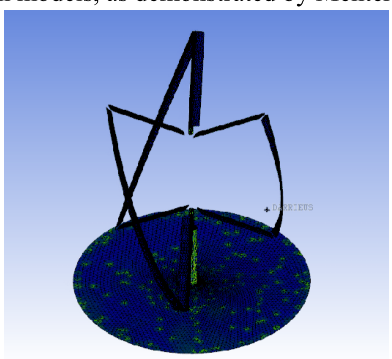

Fig. 4. The aerodynamics mesh of subdomain Darrieus

Using the option Volume Mesh Type: Tetra / Mixed and Tetra / Mixed Mesh Method: Quick (Delaunay), for Savonius rotor with NACA 0017 profile, it was developed a mesh consisting of 3,584,942 finite elements of 0.005 quality value.

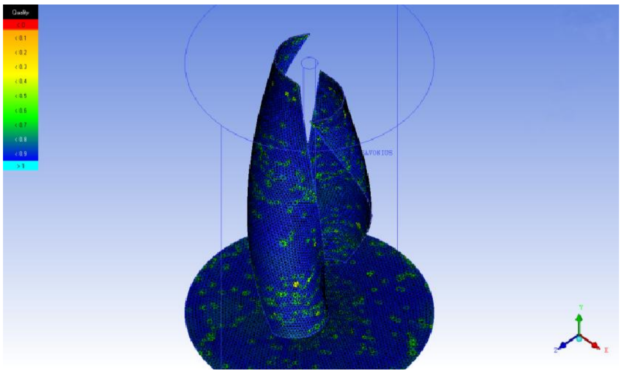

Fig. 5. The aerodynamics mesh of subdomain Savonius

For Savonius rotor was used: Volume Mesh Type: Tetra / Mixed; Tetra / Mixed Mesh Method: Robust (Octree) algorithm. In result were generated 1122723 0102 finite elements.

The following images show the overall picture with the flow interaction around a VAWT blades airfoil.

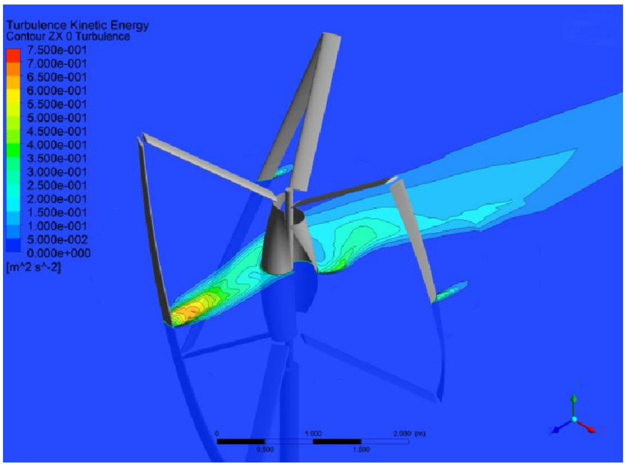

Fig. 6. Turbulence kinetic energy field in the middle of the rotor area (CFX-Post)

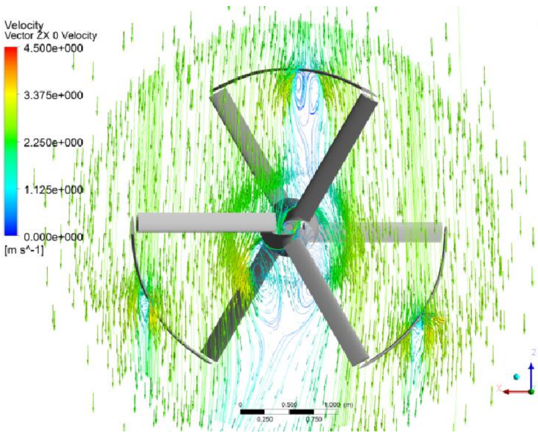

Fig. 7. Velocity vector field in the middle of the rotor area (CFX-Post)

Fig. 8. Alternative energy system based on the vertical axis wind turbine helical rotor

CONCLUSION

This paper focuses on the work process related to the development an optimal concept specially adapted for increased conversion efficiency in the geographic areas characterized by low wind energy potential. Using the proposed CAD rotor models there were performed CFD simulations the rotors and near the blades in order to determine the influence of the constructive and kinematic parameters on the power and performance of the wind turbine. The first results obtained during the validation process are encouraging and allow us to better understand the methodology, and in same time, provides solid information base for further research. If any conclusion can be drawn is that the combined vertical axis micro wind turbine will be definitely a viable and effective solution for our future.

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