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The study consisted in the investigation on a prototype of hybrid turbine characterized by a geometry Darrieus with 4 fixed blades and a Savonius, positioned internally at the Darrenius, constituted by flexible wings which vary in their extension, reducing the extension at the increase of the angular velocity to wrap completely when the angular speed is such high to allow the wing profiles of Darreius to generate a positive torque. In order to characterize the hybrid turbine, the flow field was investigated by means of a bidimensional Particle Image Velocimetry (PIV) technique, measuring velocity and vorticity in two aerodynamic configurations (Savonius blades at the maximum extension and at 2/3 of the maximum extension), for two unperturbed flow conditions of 5 and 10 m/s and for two angular velocity of the turbine which correspond at a tangential maximum velocity of 1 and 1. 7 m/s.

The measurements were performed in a wind tunnel with a measurements test section of 400 x 400 mm and a maximum speed as high as 30 m/s.

Keywords: PIV measurements, Wind Turbine.

Introduction

The need to exploit renewable energy sources has led to a strong development of wind turbines capable of recovering energy from fluid streams naturally present in the atmosphere. This development was based mainly on the development of large wind turbines with rotors that can reach thirty meter in diameter and an elevate aerodynamic efficiency but they can be installed in dedicated fields. Small turbine (mini wind turbine) has been developed in order to utilize the wind energy usually in isolated locations

where is necessary to have a small footprint and a relatively low efficiency is tolerable. In those category must mention the Savonius and Darrenius turbines.

The two types of turbine are both vertical axis, the Savonius is composed of semi-cylindrical shape blades, the Darrieus, instead, is composed of blades having an airfoil such as to generate a thrust on them oblique aerodynamic forces able to generate a rotation torque. Since the “ stalling” operation of the Darrernius turbine it has been the subject of numerous studies, both experimental and numerical as reported by the brief bibliography.

It is well known that these machines with a vertical axis have operating parameters diametrically opposed. In fact the Savonius turbine is a turbine “ on resistance” that can generate power even at low wind speed with a high starting torque. The Darreius turbine, instead, exploits the power generated by the airfoils arranged vertically around the axis of rotation and realize better performance than that obtainable with the Savonius, especially at high angular velocity, but Darrenius turbine has the drawback of not being able to self start because it needs an initial rotational speed to be added vectorially to the wind speed. There are already on the market mini wind turbine in hybrid configurations which seek to combine the positive characteristics of the two types of turbines, i. e. the high torque in the starting phase realized by the Savonius turbine and the good performance at high speed shoved by the Darrenius turbine. Unfortunately this kind of hybrid scheme has the drawback of generating a mutual aerodynamic interference that goes adversely affect the final overall performance. The original idea of

the hybrid turbine under study is therefore to maintain and combine the best features and the strengths of both types of turbine, but reducing the aerodynamic interference phenomena.

The hybrid impeller is composed by four fixed Darrieus blades, and two internal Savonius blades. The Savonius turbine (internal) generate the starting torque and guarantee the operation at low wind speed.

As the wind speed increase and the angular velocity of the hybrid reach the regime necessary for putting the Darrieus turbine in the working condition, the Savonius blades are suddenly rewound in order to reduce the aerodynamic interference with the Darrenius blades.

Experimental Apparatus

Wind tunnel

The study of the hybrid mini wind turbine was made in a low speed wind tunnel specifically designed and installed in the laboratory of Fisica Tecnica Industriale of the University of Basilicata. The tunnel is of the “ open circuit” type and is composed by a 22 KW fan operated with a suitable electronic inverter, by a convergent duct with reduction ratio of the cross-section equal to 2, from a section of useful amount equal to 0. 6 x 0. 6 m, fitted with two openings, the top and sides, transparent rectangular dimensions 0. 5 x 0. 9 m. The maximum attainable speed is 30 m/s with a value of turbulence intensity as less as 3%, obtained thanks to the interposition of a layer of honeycomb between the exit of the convergent and the test section. Fig 1 shows the maximum dimensions of the circuit, while in Figs. 2 and 3 is

respectively possible to observe a typical velocity and turbulence intensity distribution (realized by means of the PIV technique discussed in the next section) obtained for the rated speed of the wind tunnel at 10 m/s.

Velocimetry (PIV)A PIV system has been employed to analyze the instantaneous behavior of the velocity field. The adopted system (whose layout is reported in Fig. 2) is based on two pulsed Nd: YAG lasers firing on the second harmonic (green 532 nm). The beams, properly separated in time, are recombined on the same optical path by a polarized dichroic filter. Then the beams are expanded in one direction, by a combinations of spherical (negative) and cylindrical lens, to obtain a 100 mm wide and 0. 3 mm thick laser sheet in the measuring region. The laser sheet is used to illuminate the airflow around the turbine blade. An air assisted spray has been used to atomize silicon oil in small droplets seeding in wind tunnel upstream the test section. The images have been collected by of a double frame 1024 x 1024 pixels PCO CCD camera synchronized with the two laser beams and with the frame grabber by means of a dedicated electronic synchronizer.