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FLOW FIELD SIMULATION OF WIND TURBINE WITH MORE IMPELLERS (ECCOMAS CFD 2010)

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Abstract. *Our primary aim was to develop a new wind-generator design, which works more efficient therefore can produce more energy in unit turbine area. For this purpose the flow field has been analyzed using a computer fluid simulation to determine the generated power of the wind turbines. The examined two impellers are rotating in the same horizontal plane and their blades turn into the central part of the other one like a gear-gear connection.*

INTRODUCTION

One important question of the wind energy utilization is the conversation efficiency of the theoretical usable energy into productive power. The specific cost of a unit electric power is higher by a single wind generator than that of a whole wind power park. Certain costs of a wind energy park can be distributed during the unique power plants (e.g. electric network, road network, etc.). The specific cost could be more reduced if more then one rotor is installed on a single column. (There are some similar technical solutions, see the next paragraph.) Aerodynamic circumstances were examined around a column with two rotor installed on; furthermore the utilizable power was analyzed through CFD (Computational Fluid Dynamics) simulations. The two rotors are rotating in the aerodynamic field of the other one, but it rotates in the opposite direction however with the same rpm. The developed aerodynamic field around the two impellers was simulated and the utilizable power was calculated along different rotor arrangements.

The CFD gives in the solution for such a task a very good support, because the developed fluid circumstances (fluid field, velocity field, pressure field, etc.) could be represented much better by knowing the geometry of the blade and the impeller. The final control after the design could be made through the on-site measurement of the given wind power plant.

SOME SOLUTION FOR WIND TURBINE DESIGN

There have been developed several inventions for the wind energy utilization even better, like a quick-running (American) wind power plant on Pic. 1. The two rotors are rotating in the opposite direction to avoid the disturbance of each other. Otherwise the confrontating blades would cause large aerodynamic loss because of the identical rotating direction.

A dual wind power plant installed on a single horizontal axle could be seen in Pic. 2 and a more developed version of this one is represented in Pic. 3. Measurement results will be detailed in this article, it is patented [3]. In this technical solution the two rotors on the same shaft. However vortices created by the wind-side rotor of this dual turbine come onto the non-wind-side rotor, which degrades its efficiency. Its value can be exactly determined only by measurements, indeed such results for the already realized wind turbine couldn’t be found in the literature [2, 4]. Number of vortices coming onto the non-wind-side rotor can be reduced by an appropriate placement of the rotors, by the distortion of those, by the distance of the plane of the two rotors or/and by the modification of the quick running factor, etc. The simulation was made by eCon Engineering Ltd.

Picture 1: Twin Wind Turbine

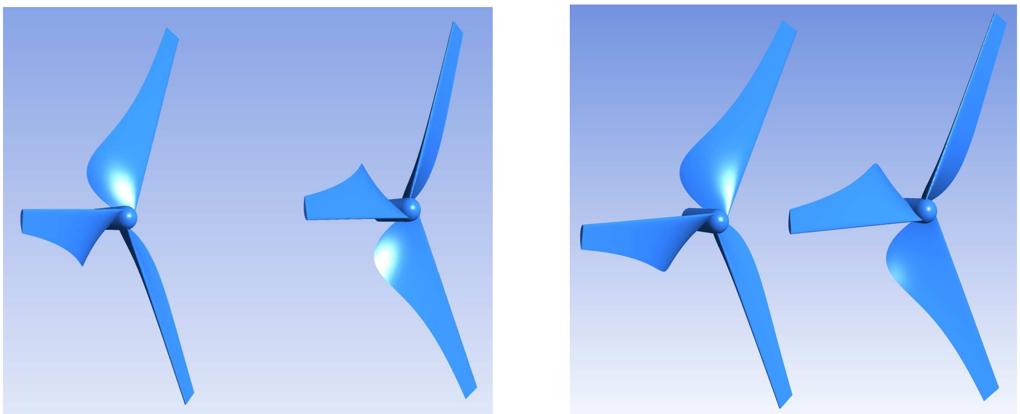
Picture 2: Dual Wind Turbine

Picture 3: Dual Rotor Wind Turbine

MEASUREMENT METHOD AND EXAMINED IMPELLER

A combination of the above detailed two power plant types were examined in this work. The two rotors (Pic. 4.) are rotating against each other where the blades are rotating into each other: blades of one rotor are rotating into the blade space of the other one. In this way the planes of the two rotors are overlapped in this moment. For our research these planes have been shifted from each other to avoid the collision of the blades, henceforth it is expected, that the wind energy can be utilized with better efficiency, than a wind power plant with one single rotor. This solution allows reducing the effect of the interference.

The two examined rotors were designed by the common design process of the wind power plants. The quick tip speed ratio was set at 4 for the sizing and a three-bladed-impeller was chosen for the modeling. The geometry of a blade was developed for optimal variable of pitch angle and variable cord length. The rotation of one rotor is the reflection of the other one to let it rotate in the opposite direction. The rotors does not rotating in the same plane, because one of them is pushed forward with 20% of its tip radius (R) (Pic. 4.). (In this way the rotors will not collide to each other in case of in-phase rotation.)



Picture 4: The analyzed impellers

Suspension and the in-wind-installation of the rotors are not examined in this work, only the possible aerodynamic problem was simulated as the first step of a longer research. A rotor developed with the tipe speed ratio with a value of 4 was simulated with 3.5 and 5 values, as well; therefore the rotor was slowed and accelerated according to the theoretical value, respectively. According to this fact the wind has been more slowed and less slowed than the theoretical, too.

On the other hand the CFD simulation of the above impeller was executed, as well, where the ANSYS V12.1CFX module was applied. In the first step the 3D-Model of the impeller was designed as well as the fluid field. The appropriate mesh has been built-up from tetrahedron elements, where the boundary parameters were set, too. The fluid field consists of about 3.5 million elements. Hexa-mesh was used in the boundary layer along the wall. The SST (Shear Stress Transport) turbulent model was chosen for this purpose. The simulation was carried-out by steady-state setting, and then by transient setting, as well.

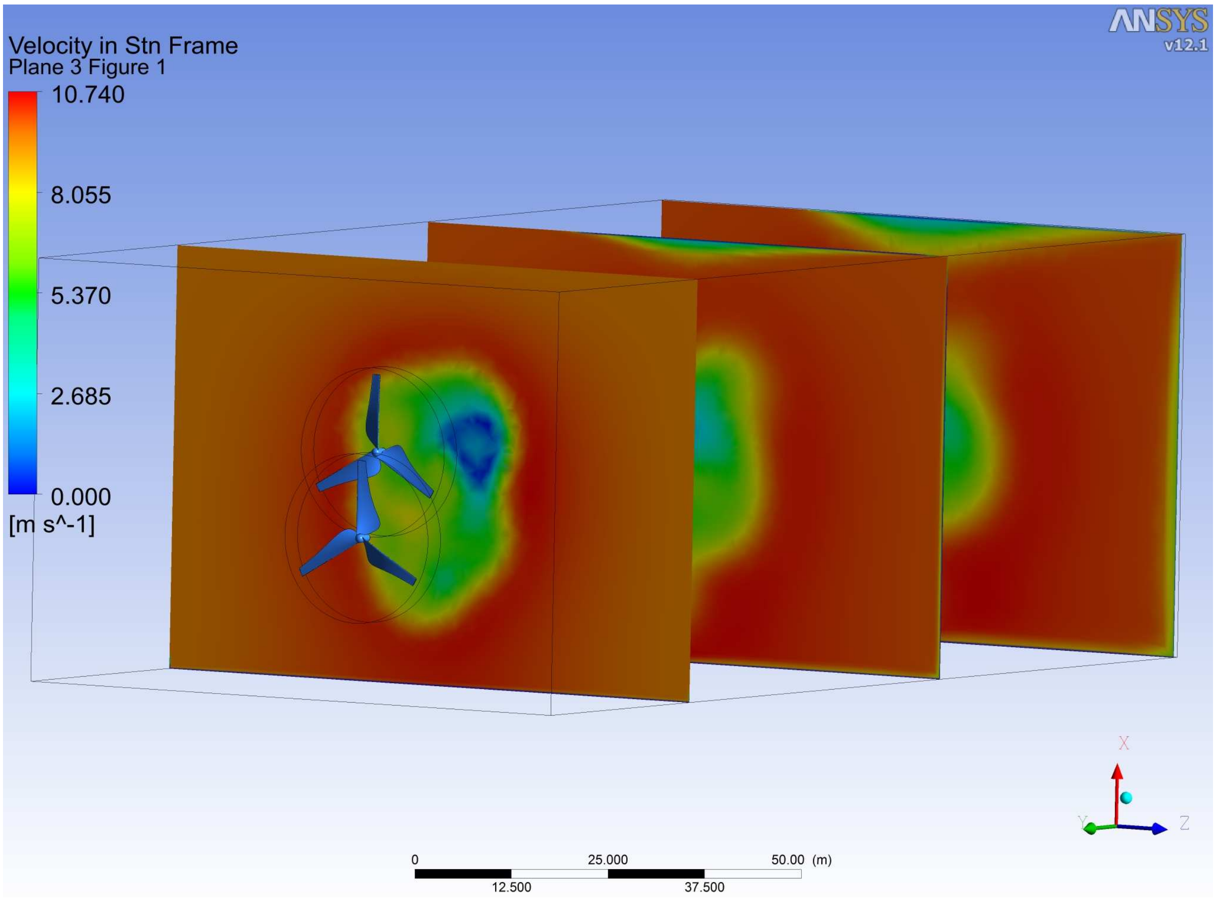
THE RESULTS OF THE CFD SIMULATIONS

The results have been evaluated that way, where the velocity field was analyzed in different distances from the rotor, furthermore the torque developed on the rotor. According to this value the performance could be calculated. The resulted performance values have been summarized in Table 1.

		Torque (Nm)		Performance (W)		Total performance (W)	Specific performance (W/m^2)	Betz-formula (W)
	tipe speed ratio	front rotor	rear rotor	front rotor	rear rotor			
near	3.5	24706	27332	86471	95662	182133	349.4	154441.5
	4	22916	26422	91664	105688	197352	378.6	154441.5
	5	18809	21520	94045	107600	201645	386.8	154441.5
far	3.5	26209	26268	91732	91938	183669.5	292.4	186074.1
	4	24754	24988	99016	99952	198968	316.8	186074.1
	5	20399	21520	101995	107600	209595	333.7	186074.1

Table 1: Summary of the resulted performance values

It can be seen, that the performance of the second wind turbine is always higher. Quite the same performance value is resulted independent from the axle distance along a giventipe speed ratio factor, but in point of the specific performance the shorter axle distance is more favorable.



Picture 5: Air velocity fields behind the impellers

CONCLUSIONS

Simulations were carried-out with two different axle distance and differenttipe speed ratio factor. On the basis of the simulation results the torque values developing on the front and on the rear rotors have been determined, which can be seen in Table 1. The higher tipe speed ratio factor results higher performance of the turbines. It is interesting, but the rear rotor gives always larger performance than the front one. The performance value for the areas sweeping through the blades for 1 quadrate meter has been estimated. If these sweeping areas of the blades overlap each other, the total area will be reduced at about 83 %. In the case of the nearest axes the specific performance for 1 quadrate meter is about 18-20% higher, than that of the farer ones.

On the other hand the maximal output performance has been calculated from the Betz-formula [1] (see Table 1.). The results of the simulation exceed quite in all cases the ones from the Betz-formula: the results of the last solution resulted in about 15-20% lower values than that of the simulation.

The already performed research showed that this problem solution could be resulted in new development directions.

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