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DUCTED WIND TURBINES

A potential energy shaper

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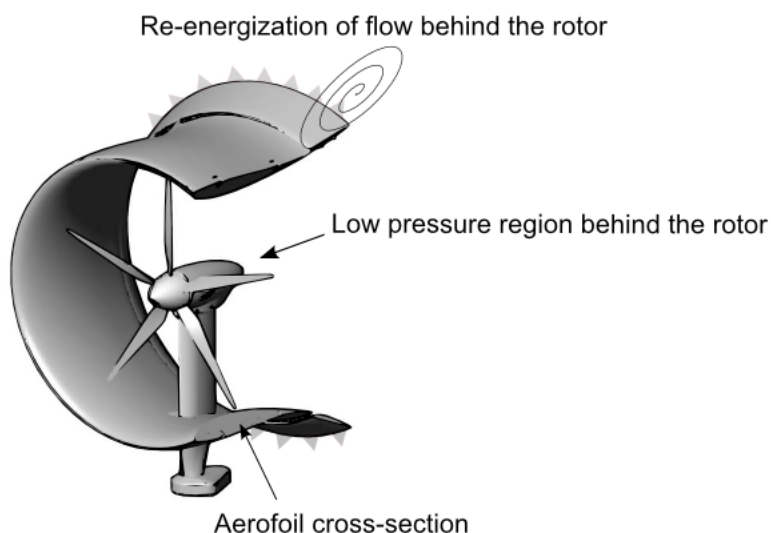
In order to harvest wind resources more efficiently and to the greatest extent possible, unconventional wind turbine designs have been proposed, but never gained any acceptance in the marketplace. A team of researchers from TU Delft plans to revisit the concept of ducted wind turbines, which have been around for decades, and provide some clarity on its potential.

Although we are always inclined to get 100% of everything, it is seldom possible. Sometimes nature has its reasons of confining mankind from achieving its goal. One of the most important inventions was made, way back in 1919 by a German physicist Albert Betz, who demonstrated that we can only extract 59% energy from wind turbines (Burton, 2001). It is quite interesting that a calculation made almost 100 years ago holds true even today and nobody yet has been able to prove otherwise, but many continue to claim that it's false. Intelligent thinkers and engineers have tried almost every possible approach to boost the wind energy captured, with some unique and innovative designs, but never managed to shake the iconic three-bladed horizontal axis wind turbine off its footing. These designs are a testament to the countless brainstorming sessions and ingenuity of today's engineers, which may leave you asking: How exactly is this supposed to work?

Over the past several years, the concept of ducted wind turbines has managed to create some curiosity. This concept, claims to

augment the power production by roughly two times more than any conventional turbine design (Van Bussel, 2007). The technology for ducted wind turbines was first tested by a US company, Grumman Aerospace in

the 1970s as a part of a US Energy Department-funded project (Oman, 1978). The full potential of this research was not realized because of the problems in securing the construction material and therefore redirecting the R&D focus. In 1997, the world's first commercial ducted wind turbine was installed by the developer Vortec Energy Ltd. in New Zealand (Phillips, 1999); its performance was evaluated by researchers from The University of Auckland and from the Crown Re-



DUCT4U

Figure 1 - Schematic of the ducted wind turbine with multi-element duct and trailing edge vortex generator.

search Institute Industrial Research Ltd. The theory and the wind-tunnel investigations behind this concept have delivered some hopeful results, but failed when tested in real outdoor conditions.

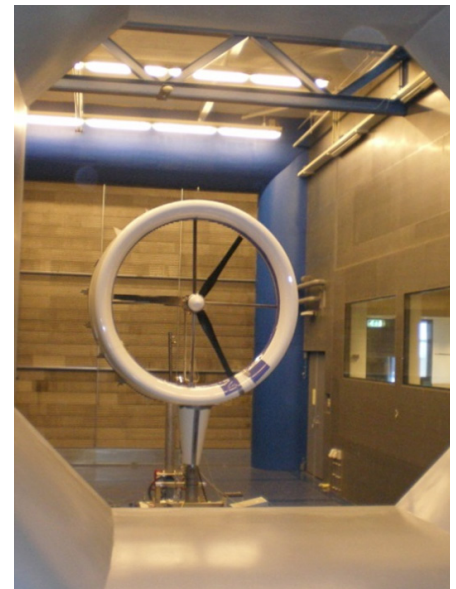
It's an interesting concept that attempts to enclose the turbine blades in a cylindrical shaped casing, as shown in Figure 1; the duct, shroud or diffuser as its denoted, sometimes is designed to accelerate the moving airflow before passing through the blades. Theoretically, the power produced by the wind turbine is directly proportional to the cube of the wind speed. Thus, any increase in the wind speed could result in significant power augmentation. Martin Hansen, in his book on Aerodynamics of Wind Turbines, says quite explicitly: "It is possible to exceed the Betz limit." In the studies dealing with ducted wind turbines, he explains that: "If the cross-section of the diffuser is shaped like an airfoil, a lift force will be generated by the flow through the diffuser. . ." The point here is that the duct geometry creates a low pressure region behind the blades and thus, more air is being drawn by the turbine. Moreover, in the case of a ducted wind turbine, the drag on the duct/diffuser does not contribute to the turbine power. The commenters and few wind energy experts believe the odds are long that this turbine can come even close to delivering the theoretical limits and outweigh performance of the conventional turbine design.

Despite the questions and skepticism, Prof. Gerard van Bussel, a wind energy expert at TU Delft, strongly believes in the idea and says: "One of the most promising concepts for urban wind energy harvesting is the ducted wind turbine." In the past, ducted wind turbines were only considered for large power and ground applications, due to the heavy cost and weight of the duct and of the tower, which posed difficulty in proposing an economically appealing product. For small size and urban wind turbines, the shortcomings associated with the high cost of the duct and of the tower have a minor impact on the overall cost. Prof. van Bussel adds; "Ducted wind turbines are a good candidate: They are aerodynamically more efficient than bare wind turbines, inherently safer, produce less noise and have less visual impact due to the

duct surrounding the rotor blades."

A team of researchers is investigating the idea, further forming a part of a research consortium: Duct4U, which is funded by the STW grant. The consortium consists of the Faculty of Aerospace Engineering - Wind Energy Research Group and the Faculty of Mechanical/Maritime/ Materials Engineering; TU Delft. The consortium will be complemented by industrial partners NPSP BV, FemtoGrid Energy Solutions BV and Windchallenge Holland BV. The project aims towards improvement of the aerodynamics and energy performance of the ducted system for urban applications. The experiments will be conducted partly at the TU Delft Open Jet Facility (OJF) and partly at an outdoor testing site: The Energy Wall. The Energy Wall is a large scale conceptual framework along the entering road to TU Delft. The idea is to combine solar panels, small urban wind turbines, a smart grid (DC operated), fine dust mitigation devices and LED lighting. Twenty five or more small urban wind turbines are planned to be integrated into the Energy Wall. This would prove an excellent test-bed, where the ducted turbines could be tested in real outdoor conditions. In parallel, studies based on combined use of theoretical aerodynamics and computational simulations, mainly CFD, would be carried out. This combination between research and tests would allow a good comprehensive validation of theory and models.

A second aerodynamic phenomenon related to ducted wind turbine that has only been partially explored is based upon the extraction of energy from the air flowing outside the duct. If the reduced wind speed behind the rotor is enhanced, more energy per processed volume of air can be extracted by the turbine blades. Some solutions, mainly based on blowing and swirling of boundary layer flows, have been proposed, but with moderate success. This project will investigate the potential of triangular vortex generators and multi-element ducts to re-energize the reduced wind speed behind the rotor. The combined effect of irregular protrusions (vortex generator) and multi-element ducts would result in a large scale flow separation outside the duct, where a very low and unsteady pressure zone appears. As a result,



Experimental test conducted on the 'DonQi Urban Windmill 1.5' model in the Open Jet Facility, TU Delft.

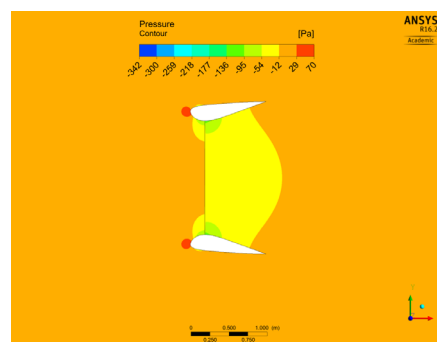
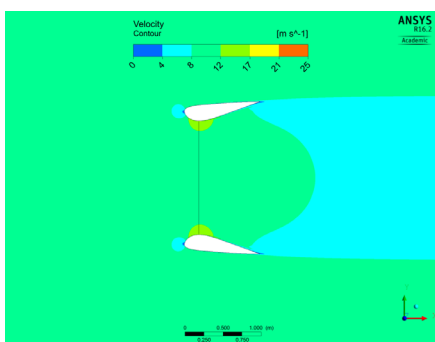
an increased mass flow is swallowed by the rotor and greater power output seems obtainable. Furthermore, the aerodynamics and the integration of ducted wind turbines with the infrastructural elements will be investigated, which may further enhance the performance and cut down the installation costs. In the system optimization process, noise mitigation and enhanced control systems will be taken into consideration.

The current wind turbine technology is already upscaling, and the fact that researchers across the world are exploring different ways to harness this clean energy source should be an encouraging sign to renewable energy's bright future. The ducted turbine research is in active development, and if successful, the product design could offer an improved and efficient energy solution for urban environment. ↑

If you have further ideas or want to contribute to this research as a graduate student, contact the author for further information by email V.V.Dighe@tudelft.nl

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CFD simulation using the simplified 2D duct profile showing velocity contours (left) and static pressure contours (right).