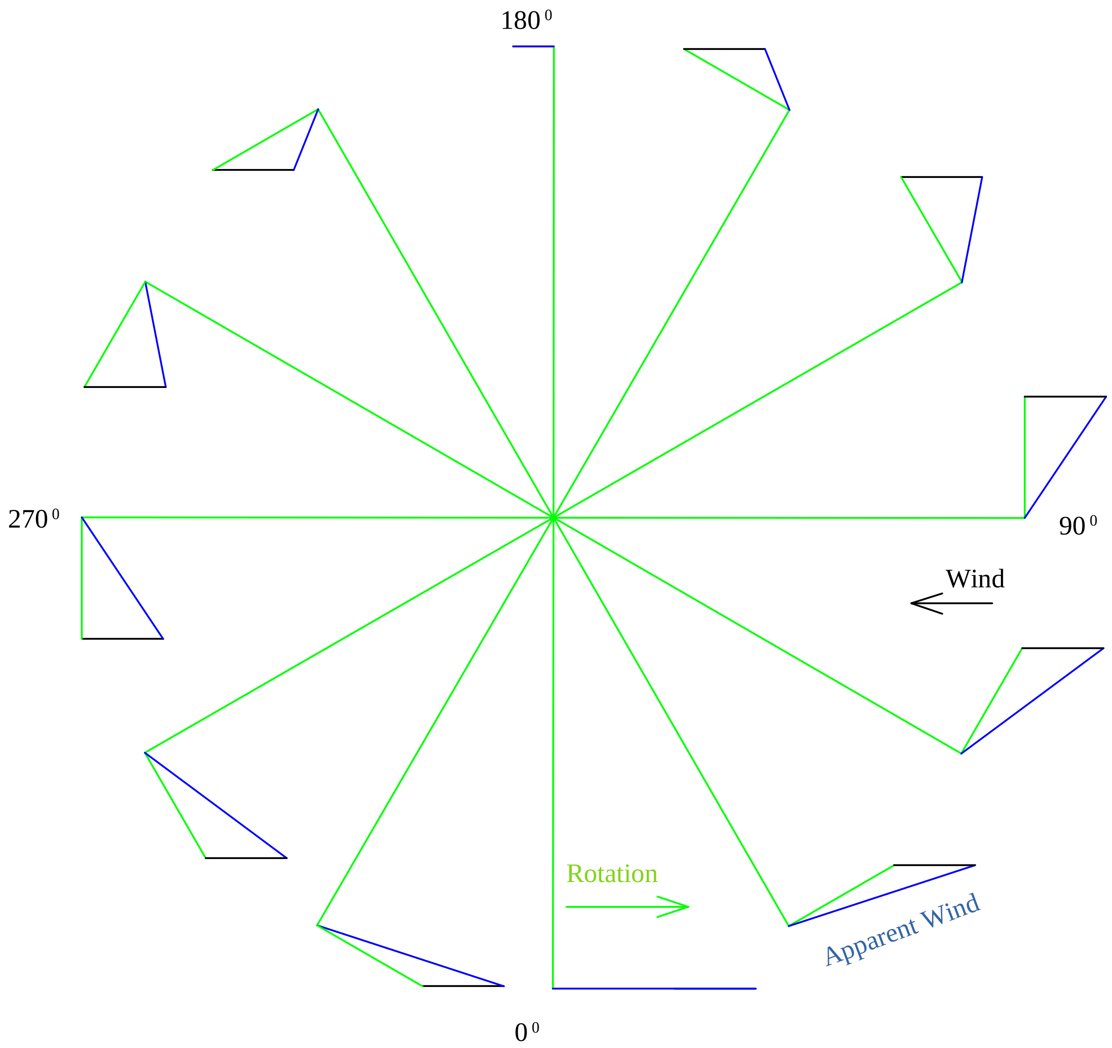
Airflow for vertical axis wind turbines (VAWTs) with aerofoils

The speed and direction of the airflow (apparent wind) for VAWT aerofoils depends on 2 factors:
1 The ratio of the rotational speed (tangential) of the aerofoil and the true wind speed referred to as Tip Speed Ratio (TSR)
2 The azimuthal position of the aerofoil as it rotates around the vertical axis

From the diagram below it can be seen how the apparent wind changes from a maximum velocity parallel to the true wind at the o ^{0} azimuthal position to a minimum value at the 180 ^{0} position. .



Note how the apparent wind diverges from the tangential velocity between these azimuthal positions and that the divergence is on opposite side on the windward and leeward sides.
The apparent wind will then be on alternate sides of the aerofoil as it moves from the windward to leeward section of its rotation.

The lift force on the aerofoil is always 90 degrees to the apparent wind so no torque is produced at the 0 ^{0} and 180 ^{0} azimuthal positions. In order to minimize drag (negative torque) a zero angle of attack (AOA) is needed at these positions.

Most Darrieus VAWTs have the aerofoil chords fixed at 90 ^{0} to the radius arm. The AOA on the aerofoils on these machines is the divergence of the apparent wind to the tangential velocity. For fixed aerofoil VAWTs the AOA is small near the 0 ^{0} and 180 ^{0} positions and can be above stall angles near the 90 ^{0} and 270 ^{0} positions unless the TSR is high. The AOA reduces as TSR increases. This results in a narrow band of operational TSRs and wind speeds for good coefficients of performance (Cp around 0.4) and an over speed braking system is needed.

These VAWTs include the Eggbeater shape, and Giromills which may have spiral aerofoils.

Cycloturbines are a varient of VAWT which include a vane to pitch the aerofoils into wind. This can prevent stall conditions at a low TSRs and result in good self starting and more power at lower TSRs but the AOA is reduced resulting in less power at higher TSRs.

Modern electronics have now enabled positive pitch control to be applied which enables the AOA to be optimised over the rotation. This can dramatically increase the potential power of a VAWT over a wider range of TSRs.

Scaling up VAWTs

In existing designs the need to keep aerofoil chords short, due to the relatively small radius of rotation, and to allow for bending loads on the aerofoils results in the selection of thicker sectioned aerofoils, which can also have a section of camber. The aerofoils on the leeward side travel though the wake of the aerofoils on the windward side. It is highly probable that most of the power is generated by the aerofoils on the windward side.

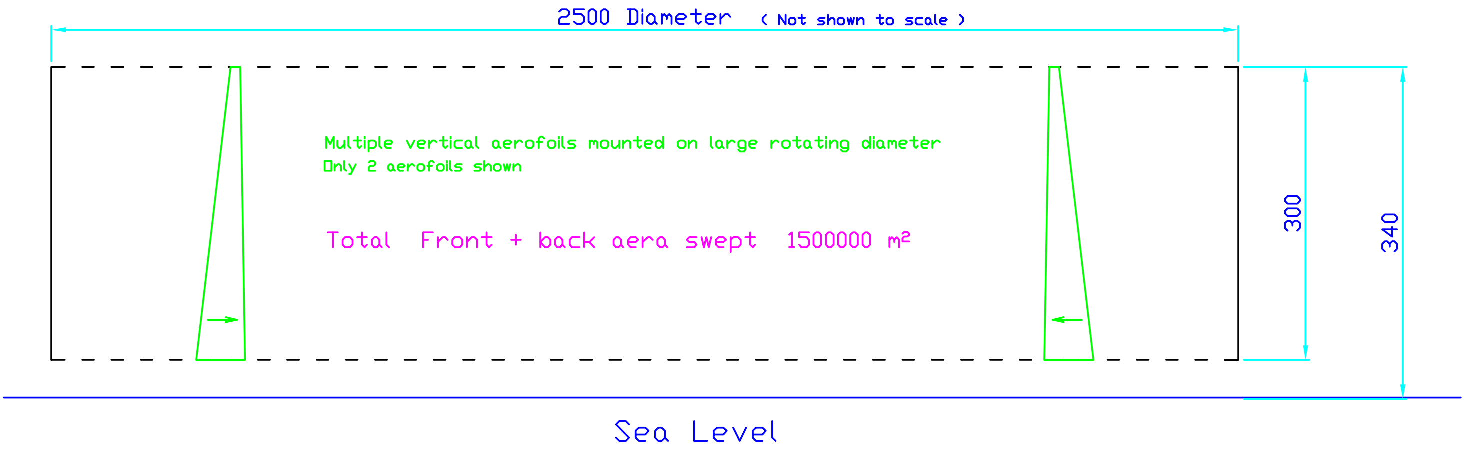
The lift force, which provides the driving torque, also causes compressive loads on the radial arms while in the windward section. These loads are partly offset by centrifugal loads. Long beams under compressive loads can easily bend and tension due to centrifugal loads are lower on a bigger radius of rotation with the same TSR. To increase the compressive loads on longer spans while reducing centrifugal loads would result in failure, which inhibits scaling up of VAWTs of current designs.

To scale up VAWTs and allow for a stopped status (during maintenance) it becomes imperative that the aerofoils can be fully feathered into wind, which means that all the aerofoils must be able to rotate 360^0 about independent axis. This is not possible with VAWTs of current configuration.

An alternative approach to the mounting of the aerofoils allows stayed aerofoils on independent rotating bases, which allows for aerofoils of virtually any height, each of which can rotate 360^0 independently.
It also eliminates the need for a central tower, enabling the use of extremely large diameters resulting in more energy capture on the leeward side. The system does not use radial arms eliminating concerns of bending such arms.

An international patent has been filed ref PCT / GB2018/000134
WIPO publication ref: WO2019/073189 A4

Possible Massive Vertical Axis Wind Turbine using New Design



240 MW @ wind of 11 m/s Cp 0.4
657 MW @ wind of 16.5 m/s Cp 0.325
750 MW @ wind of 20 m/s Cp 0.21

Tip speed aprox 25 m/s

With kinetic energy storage capability