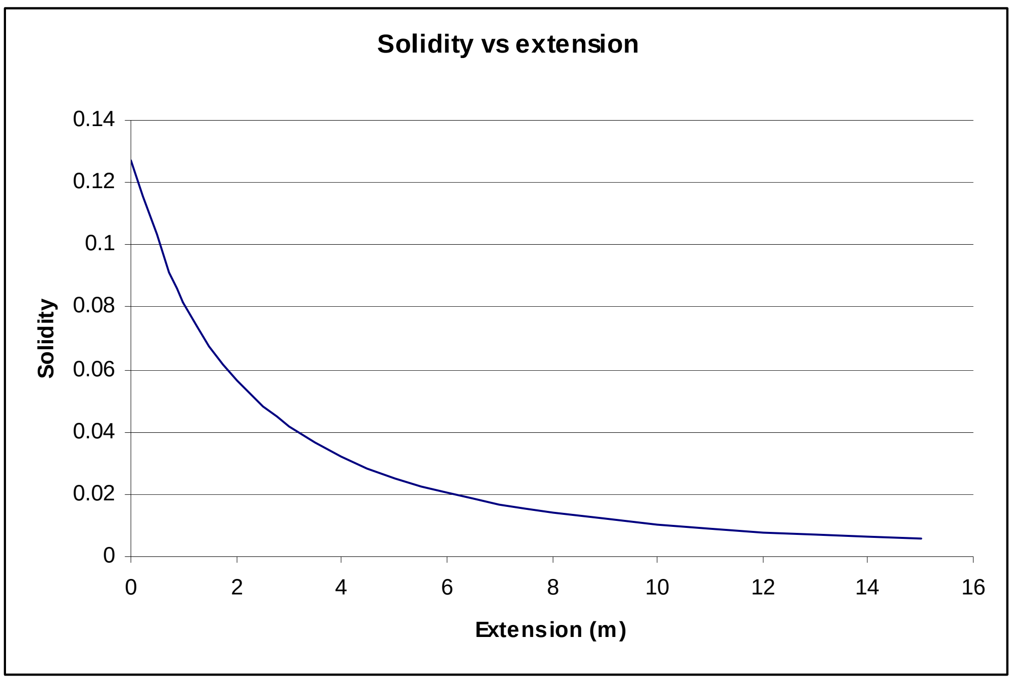
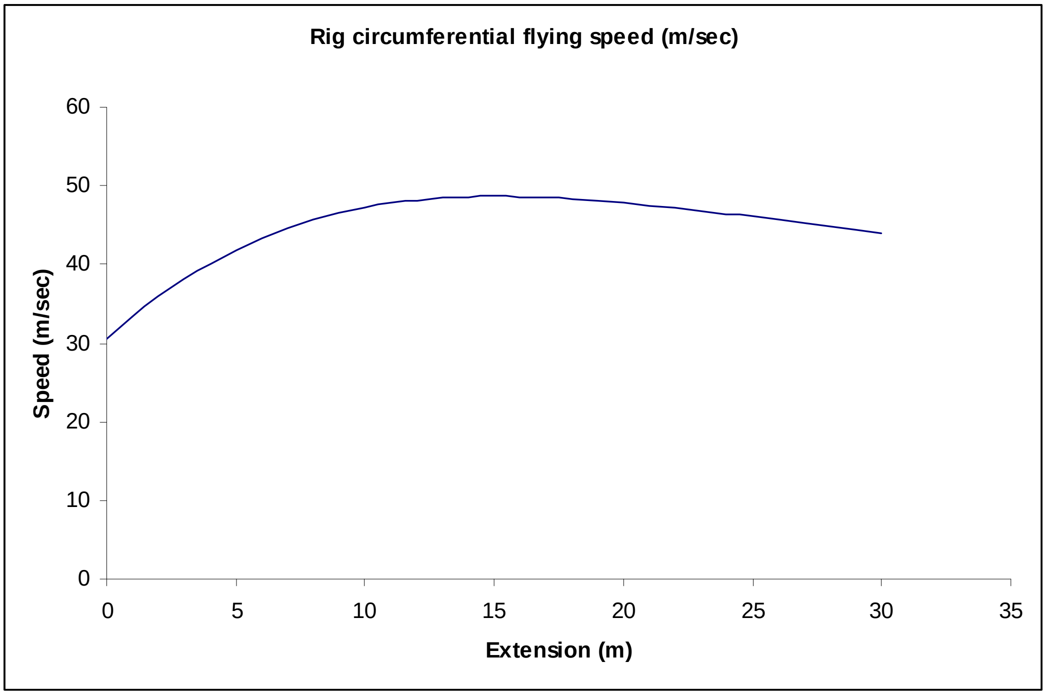
Variable area wind turbine vs conventional horizontal axis turbine.

The performance of the variable area wind turbine may be characterised as existing between two limiting conditions. The first of these is the situation with the flying elements resting on the base unit where the two aerodynamic elements are directly analogous to a conventional wind turbine disc and the performance is restricted by the Betz limit. The second limiting condition is where both aerodynamic elements are a significant distance from the base unit and sweep out a ring of large area.

This second condition tends towards a power restriction based only on the isolated performance of the aerodynamic unit as the retardation of the mean free stream flow through the swept ring tends to zero. This arises from the exceptionally low disc solidity and mean disc loading associated with this operational configuration. The following figure illustrates the typical solidity variation for a turbine with two metre wings:

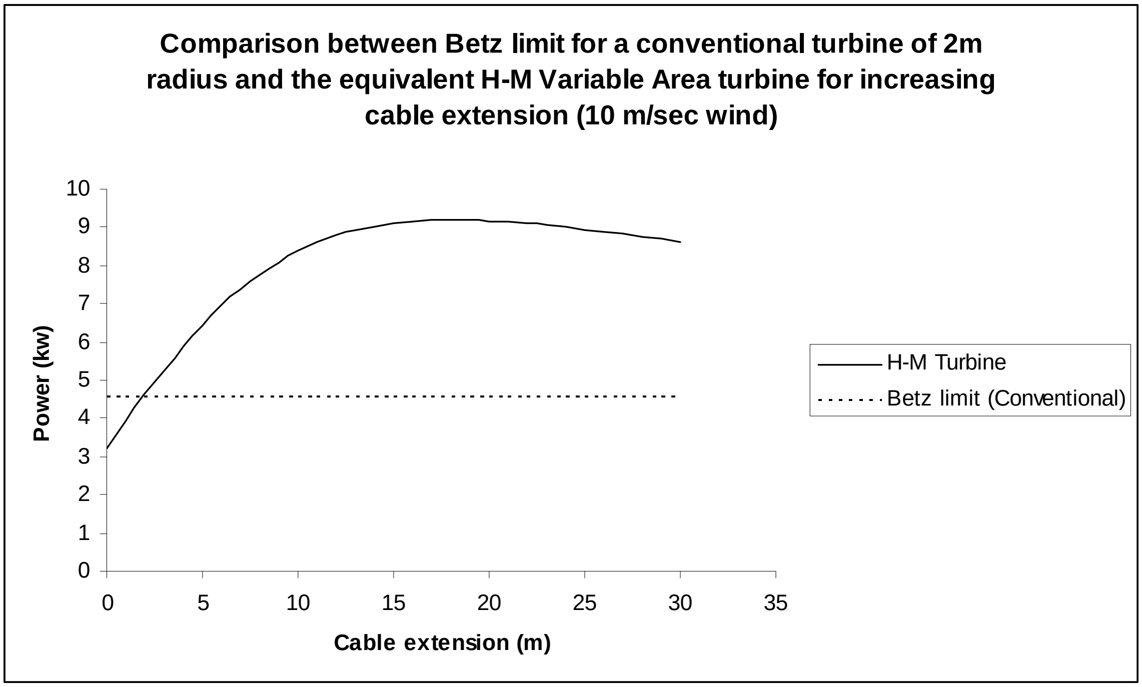


As the rigs are extended the aerodynamic drag of the cables becomes more significant and this results in degradation of the performance of the rigs with greater extension, this is manifested as a reduction in rig flying speed and force and hence an optimum condition will exist where the low retardation of the mean flow achieved by the low disc loading at greater extensions is offset by the increase in rig drag with increasing extension. The rig flying speed variation with extension is shown below for the same two metre wing turbine in a 10 metre/ second wind, this shows the influence of both flow blockage at low extension and increasing cable drag at higher extension:

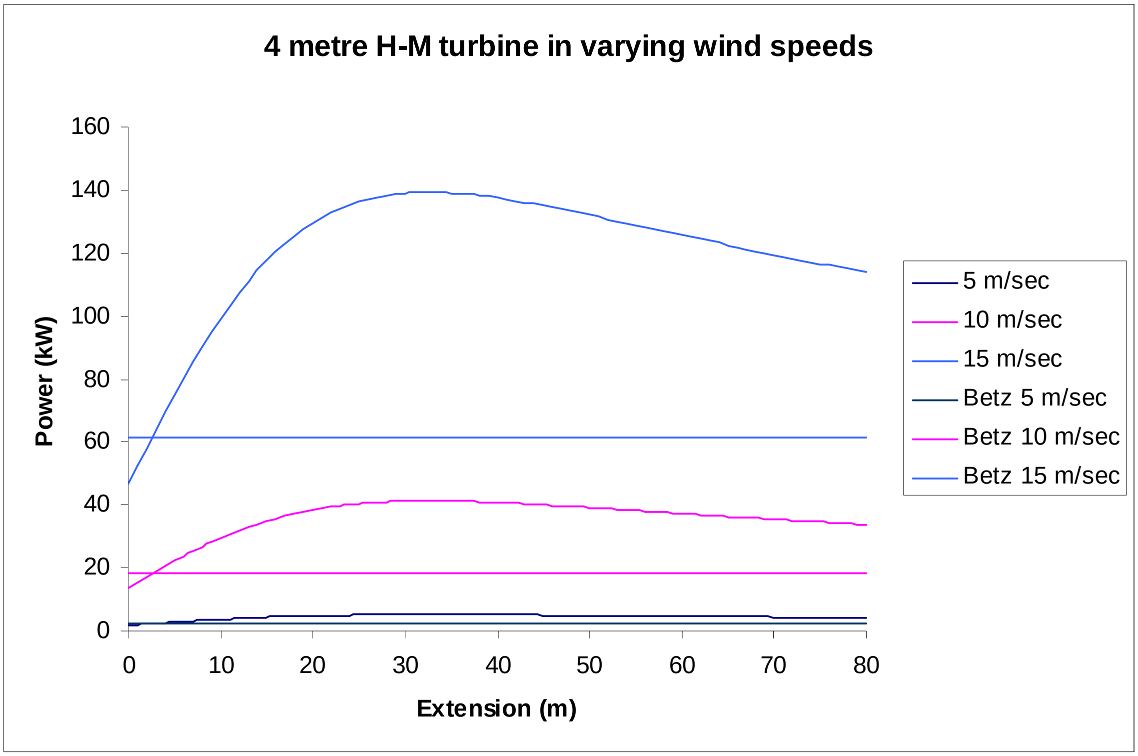


The following figure shows the power variation that would be achieved by the two flying rigs at increasing extension, the model used to develop this curve treats the wake of each rig as a helical vortex pair extending downwind normal to the plane of rotation of the disc. The reality is that the disc plane is swept relative to a normal to the wind direction and hence the flow retardation produced by this model is overly conservative, ie, the real situation will allow higher power generation. Also shown on the figure is a horizontal line representing the Betz limit for a conventional turbine of 2 metre radius. The Betz limit line does not include any allowance for blade drag or other inefficiencies and is purely the theoretical power limitation, in summary, the line for the H-M turbine is conservative, the line for the conventional turbine is optimistic.

Although the difference looks extreme this is less surprising than a first glance would suggest, with a flying rig at a reasonable extension (say 10 metres or so) the entire wing is sweeping at more or less the same speed. With a normal turbine the rate of disc swept varies from zero at the root to a maximum at the tip. The entire flying rig effectively sweeps at close to the tip speed. The reduction in power output at modest extensions is due to the domination of Betz-type limiting effects as the rigs approach each other.



The following figure shows an H-M turbine with two x four metre wings in different wind speeds. This shows that the power variation is simply a function of the cube of the wind speed as for any other turbine. When compared with the previous figure it also shows that the peak power production is proportional to the square of the lineal dimensions, a corollary of this is that the optimum extension of the two metre turbine, at approximately 18 metres, will be half the optimum extension of a four metre turbine which will occur at 36 metres.


4 metre H-M turbine in varying wind speeds
Power (kW)
160
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
Extension (m)
5 m/sec
10 m/sec
15 m/sec
Betz 5 m/sec
Betz 10 m/sec
Betz 15 m/sec