1 Theory

This function implements the multiple streamtubes theory which gives a more accurate prediction of the wind velocity variations across the Darrieus rotor with respect to the single streamtube model.
The multiple streamtubes theory is derived as a generalization of the single stremtube one. The induction a is considered variable with the radius,

$$a = a(r) \tag{1}$$

where

$$r = R\, sin(\phi) \tag{2}$$

The induction comes from the equations of drag force from the differential momentum theory,

$$dD_R = 2\,\rho\,V_\infty^2\,(1-a)\,a\,R\,cos(\phi)\,d\phi \tag{3}$$

end the drag force from the blade element theory.

$$dD_R = \frac{1}{2}\,\rho\,V^2\,c\,Cl\,cos(\phi+\alpha)\,d\phi \tag{4}$$

Matching equations (3) and (4), as in eq. (5), and substituting the working velocity of the airfoil, eq. (6), and the angle of attack expression, eq. (7), the induction is obtained.

$$2\,\rho\,V_\infty^2\,(1-a)\,a\,R\,cos(\phi)\,d\phi = \frac{1}{2}\,\rho\,V^2\,c\,Cl\,cos(\phi+\alpha)\,d\phi \tag{5}$$

$$\frac{V}{V_\infty} = \sqrt{[\lambda +\,(1-a)\,sin(\phi)]^2 + (1-a)^2\,cos(\phi)^2} \tag{6}$$

$$\alpha = arctan\frac{(1-a)\,cos(\phi)}{\lambda +\,(1-a)\,sin(\phi)} \tag{7}$$

Moreover, the C_P and the C_Q coefficients are derived by integrating the forces acting on the blade element during the rotation, as in single streamtube theory.

$$C_P = \frac{N\,c\,\lambda}{4\,\pi\,R}\int_0^{2\pi}\left(\frac{V}{V_\infty}\right)^2\,Cl\,sin(\alpha)\,\left(1-\frac{Cd}{Cl}\,cot(\alpha)\right)\,d\phi \tag{8}$$

$$C_Q = \frac{C_P}{\lambda} \tag{9}$$

The characteristic $\lambda - C_P$ curves obtained through the proposed method is not valid for any λ. It is possible to define a λ_{min} when $\alpha = \alpha_{max}$, at the stall of the airfoil and a λ_{max} by imposing that the turbine must provide power.