Among the Airborne Wind Energy concepts Magnus based airborne wind energy systems uses rotating cylinders as aerostat. The rotating cylinder when exposed to wind flow produces a lift force, described as Magnus effect. The Magnus based aerostat have a high lift coefficient which is supplemented by lighter air capabilities, and have a naturally robust design. The aerostat following a predefined trajectory leads to the development of high traction force in the tether which in turn is used to drive the generator and produce electricity.

### Magnus Effect

\[ C_L = \frac{2}{3} C_D \]

\[ F_L = \frac{1}{2} \rho SV^2 C_L \]

\[ T = \frac{1}{2} \rho SV^2 C_T \]

### Control Strategy

**Guidance strategy**

- We apply the guidance strategy given in [5], and another gain \( k_p \) to obtain a constant width trajectory \( \beta_{ref} = \frac{h_0}{\tau} \).

**Control of tether length**

- A PID controller \( K_v \) is used in order to follow the radial position \( r_{ref} \) through \( U_{T} \) acting on the winch actuator.
- The response time for this control loop is set to be faster than the variations of other forces in order to get an efficient production cycle.

- \( \Theta \) : Attitude of Magnus cylinder by ZYZ \( (\alpha, \beta, \gamma) \)
- \( T_{w} \) : Winch Tension
- \( r_{ref} \) : Tether length
- \( \beta_{ref} \) : Yaw angle in ZYX transformation
- \( \beta \) : Reference radial position

### Mathematical Model

**Equation of rate of change of translational velocity**

\[ \begin{align*}
\frac{dv_x}{dt} &= \frac{1}{m} (F_R - \omega \times v_y) \\
\frac{dv_y}{dt} &= \frac{1}{m} (F_R - \omega \times v_x) \\
\frac{dv_z}{dt} &= \frac{1}{m} (F_R - \omega \times v_z)
\end{align*} \]

where,

- \( \omega \times v \) : Cross product of \( \omega \) and \( v \)
- \( F_R \) : Body forces acting on the ABM and is given by

\[ F_R = F_F + F_B + \omega \times F_B + F_L \]

\[ W_B : \text{Weight in Body Frame,} \]

\[ F_B : \text{Bouyant Force,} \]

\[ F_F : \text{Rope Force,} \]

- \( c_y \) : Yaw rate,
- \( c_x \) : Pitch Rate

### Static Model


\[ P_{prod} = \frac{1}{2} \rho S V^2 C_T \frac{V_{Reall}}{\tau} \]

- **Theoretical Power consumed during recovery phase** \((P_{rec})\)

\[ P_{rec} = \frac{1}{2} \rho S V^2 C_T \frac{V_{Reall}}{\tau} \]

- **Estimated Power produced in one complete cycle** \((P_{cycle})\)

\[ P_{cycle} = \frac{P_{prod} \tau_{prod}}{P_{rec} \tau_{rec}} \]

Hence, to maximize the power it is to maximize the ratio \( C_T \), the maximum \( C_T \) for the Magnus cylinder is found to be at spin ratio, \( X = 3.6 \).

### References


