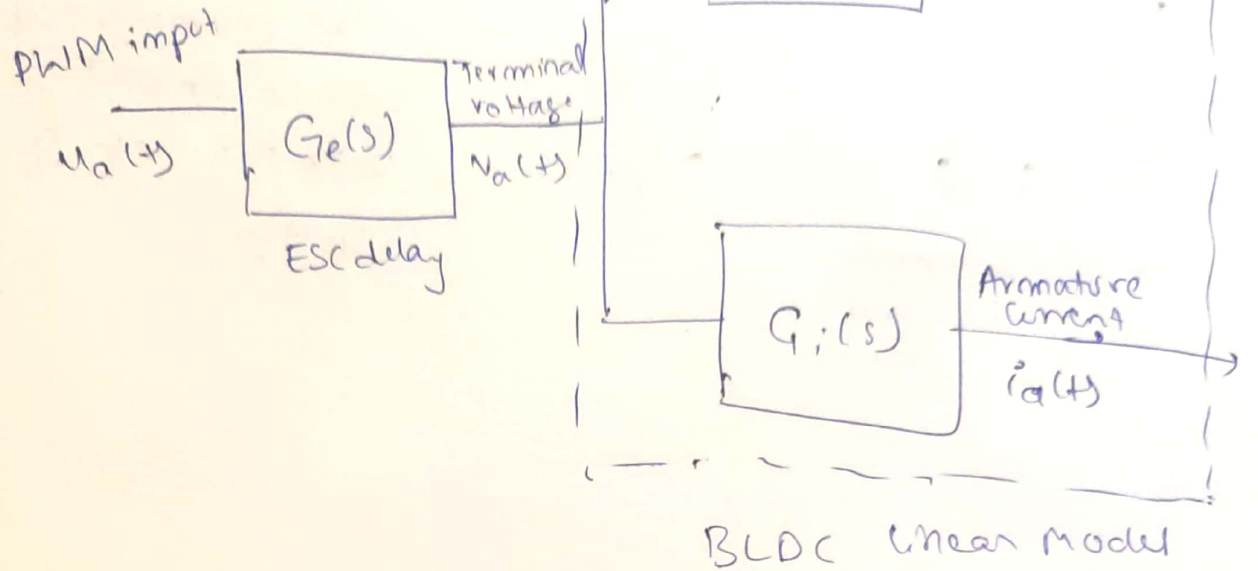


9.) ~~equat~~

# Linear BLDC Motor model



equations

for  $w(t)$

$$J \frac{dw}{dt} + k_f = T$$

$$\frac{dw}{dt} = \left( \frac{T - k_f}{J} \right) \quad \text{--- (1)}$$

for  $i_a(t)$

$$L_a \frac{di_a}{dt} + R_a i_a + e_b = V_a$$

$$\frac{di_a}{dt} = \left( \frac{V_a - e_b - R_a i_a}{L_a} \right) \quad \text{--- (2)}$$

$$e_b = k_e \omega$$

for  $G_e(s)$  [Engine speed control (ESC)]

$$G_e(s) = \frac{0.02187}{Ts + 1}$$

$T \Rightarrow$  time constant of ESC mode

$$= \frac{0.02187}{T} \left( \frac{1}{s + \frac{1}{T}} \right)$$

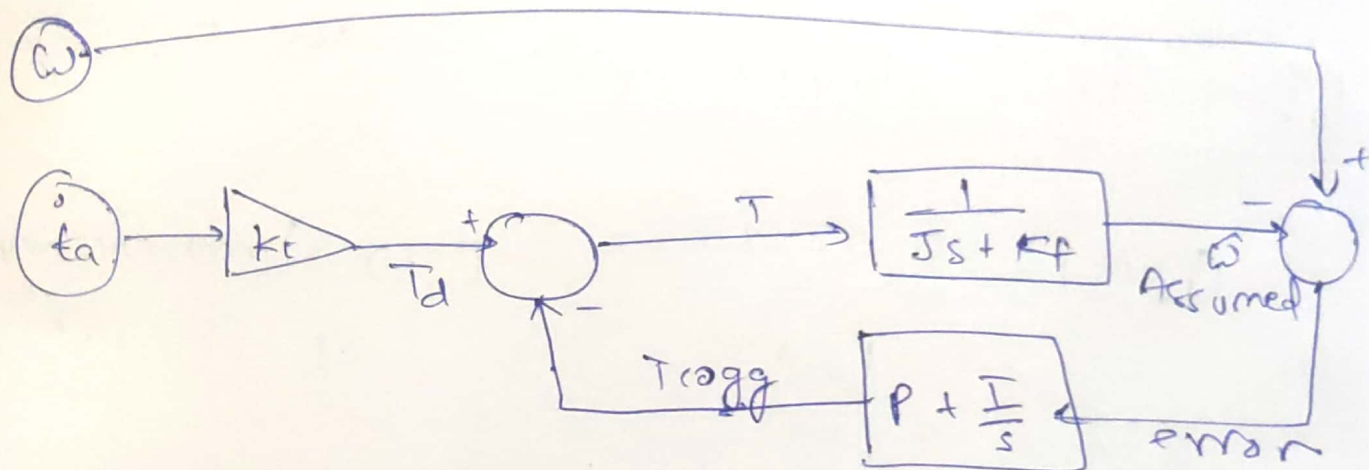
$$\mathcal{L}^{-1}\{G_e(s)\} = G_e(t) = \frac{0.02187}{T} \left( e^{-\frac{t}{T}} \right)$$

$$\therefore G_e(t) = \frac{0.02187}{T} \cdot e^{-\frac{t}{T}}$$

$$\rightarrow T = k_t \left( \frac{V - k_b \omega}{R_a} \right)$$

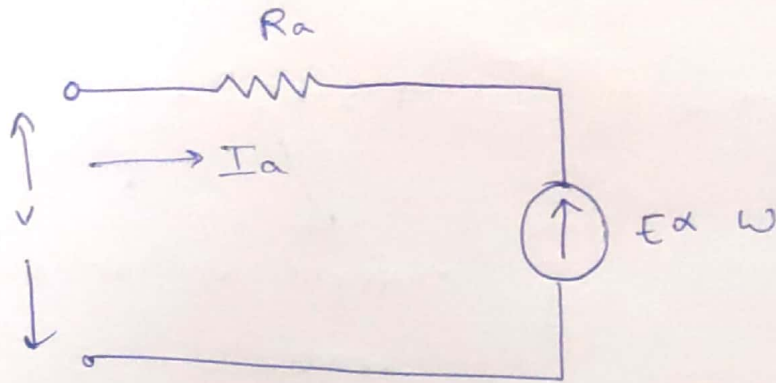
$$\frac{d\omega}{dt} = \frac{k_t}{R_a} (V - k_b \omega) - k_t$$

# Non linear model



## $V \rightarrow I_a$ characteristic

q)



→ BLDC motor has a rotor that is magnetic in nature.

$R_a$  → Resistance due to the winding of the stator

$E$  → Back EMF produced by the BLDC motor is proportional to angular velocity

⇒ Neglecting voltage drop across transistors the voltage equation

$$E \propto \omega \Rightarrow E = K_b \omega$$

↙ back EMF constant

⇒ Applying KVL to the loop.

$$V = I_a R_a + E$$

$$= I_a R_a + K_b \omega$$

$$I_a = \frac{V - E}{R_a} = \frac{V - K_b \omega}{R_a}$$

⇒ Torque is directly proportional to current  $I_a$

$$T \propto I_a \Rightarrow T = k_t I_a$$

↓  
Torque constant of the motor

$$T = \frac{k_t (V - k_b \omega)}{R_a}$$

⇒ Torque equation of a BLDC motor

Inference

↳ as  $\omega$  (speed) increases  $T$  (Torque) decreases.

↳ At a constant speed, as voltage ( $V$ ) increases Torque ( $T$ ) increases

↳ Stalling Torque

↳ at  $\omega = 0$

$$T = \frac{k_t V}{R_a}$$

↳ Maximum speed possible

↳ at  $T = 0$

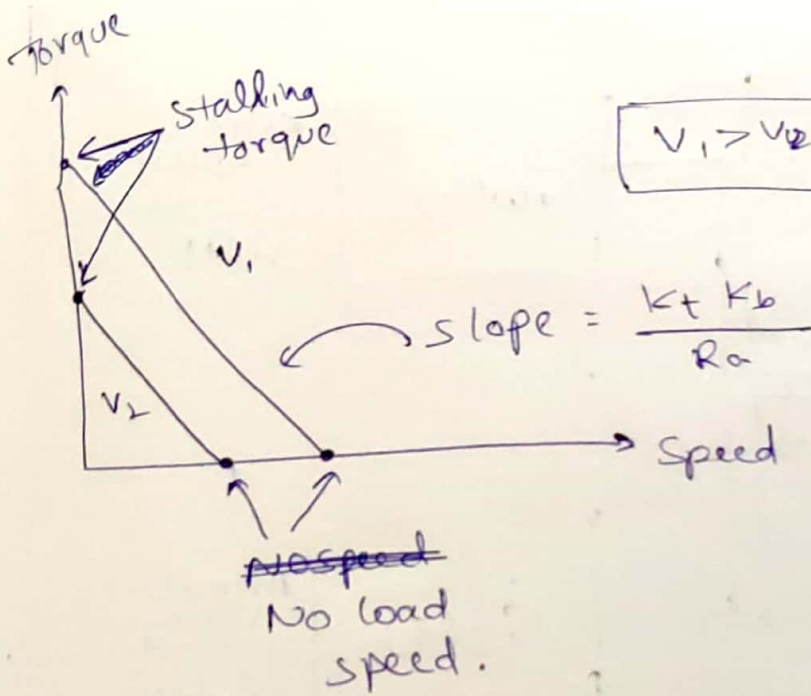
$$\omega_0 = \frac{V}{k_b}$$

↳ Thus overall characteristics is similar to conventional DC motor



## Torque Speed Characteristics

$$T = \frac{K_t (V - K_b \omega)}{R_a}$$



The characteristics can be shifted with the help of Voltage.