## 2. Speed control of Induction Motor Using Direct Torque Control

1. Take an SCIM from MATLAB Simulink and use the parameters of the machine as given below,

Power rating	7.457 kW
Rated speed	2900 rpm
Rated voltage	380V

Rated frequency	50 Hz
Poles	2
Stator resistance	2.86 ohm
Rotor resistance	4.99 ohm
Magnetizing reactance	78 ohms
Stator leakage reactance	5.44 ohms
Rotor leakage reactance	5.44 ohms

2. DC bus voltage is 1200V, switching frequency is 300 times fundamental frequency. Assume a load torque which is proportional to speed. Verify the model by running the machine model in open loop V/f scheme and observe the three phase currents and machine speed for different excitation voltages and frequencies, maintaining V/f ratio constant.

3. Implement the direct torque control strategy using stator flux estimation.
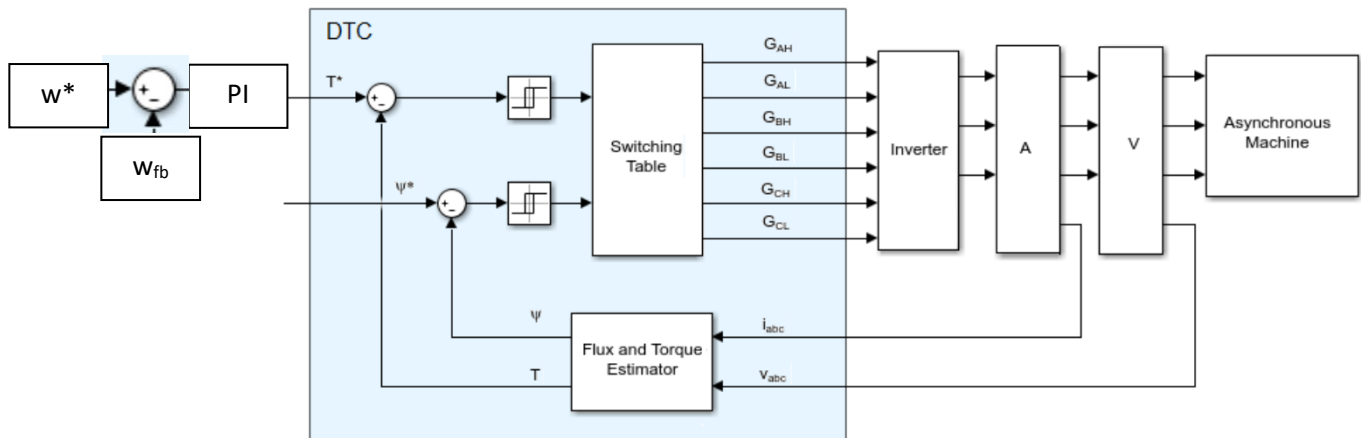
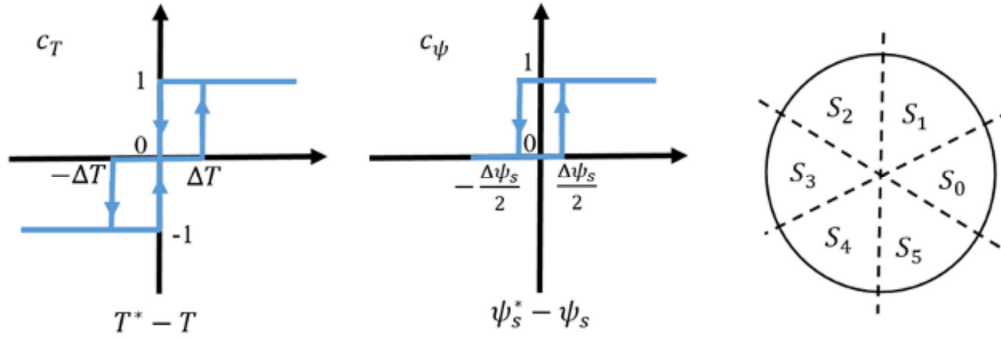$$\Psi_\alpha = (v_\alpha - i_\alpha R_s) \frac{T_s\, z}{z-1}$$

$$\Psi_\beta = (v_\beta - i_\beta R_s) \frac{T_s\, z}{z-1}$$

Torque and flux estimation can be done using equations:

$$T = \frac{3\,p}{2} (\Psi_\alpha i_\beta - \Psi_\beta i_\alpha)$$

$$\Psi_s = \sqrt{\psi_\alpha^2 + \psi_\beta^2}$$

4. Implement flux and torque controllers using hysteresis comparators

Figure labels (top): c_T, 1, 0, $-\Delta T$, ΔT, -1, $T^* - T$; c_ψ, 1, 0, $-\frac{\Delta\psi_s}{2}$, $\frac{\Delta\psi_s}{2}$, $\psi_s^* - \psi_s$; sector diagram with S_2, S_1, S_3, S_0, S_4, S_5.

Assume the reference value of flux to be at the rated value, ψ_s^* of 1.25 Wb, and *flux error band of $\pm 10\%$ for the hysteresis comparator of flux*.

5. Implement the look up table for switching voltage vectors based on the outputs of flux and torque hysteresis comparators, and sector location of stator flux:

c_ψ, c_T $S(\theta)$		S_0	S_1	S_2	S_3	S_4	S_5
$c_\psi = 1$	$c_T = 1$	1,1,0	0,1,0	0,1,1	0,0,1	1,0,1	1,0,0
	$c_T = 0$	1,1,1	0,0,0	1,1,1	0,0,0	1,1,1	0,0,0
	$c_T = -1$	1,0,1	1,0,0	1,1,0	0,1,0	0,1,1	0,0,1
$c_\psi = 0$	$c_T = 1$	0,1,0	0,1,1	0,0,1	1,0,1	1,0,0	1,1,0
	$c_T = 0$	0,0,0	1,1,1	0,0,0	1,1,1	0,0,0	1,1,1
	$c_T = -1$	0,0,1	1,0,1	1,0,0	1,1,0	0,1,0	0,1,1

6. Consider a torque error band of $\pm 10\%$ for the hysteresis comparator of torque. Run the machine under Direct Torque Control with fixed torque reference. Observe (a) reference and estimated torque, (b) actual and estimated stator flux, and (c) three phase currents.

7. Implement the speed control loop. Perform ramping of reference speed from 0 to rated speed in 2 seconds keeping load torque 0. Once speed is reached, half rated load torque step is applied for t=3-3.5s and observe the actual speed, reference and actual load torque and Stator flux trajectory in $\alpha - \beta$ domain (use X-Y plot in Simulink).

8. Repeat task 7 by considering *flux error band of $\pm 5\%$ for the hysteresis comparator of flux*.

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