國 立 臺 北 科 技 大 學

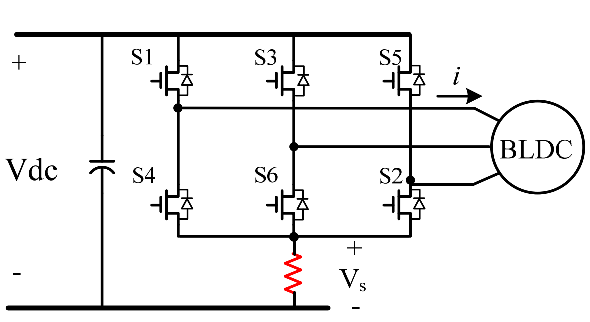
106 學年第二學期電機系博士班資格考試

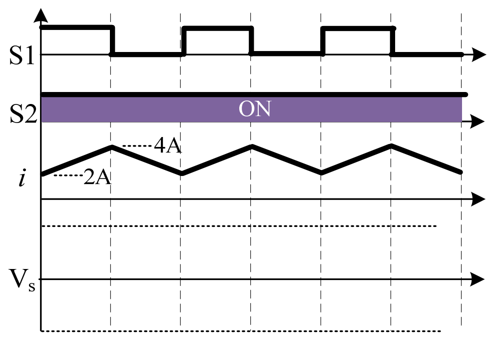
永磁同步電動機之理論與控制試題

注意事項：

1. 本試題共【4】題，配分共 100 分。
2. 請按順序標明題號作答，不必抄題。
3. 全部答案均須答在試卷答案欄內，否則不予計分。
4. 考試時間:二小時。
5. 可以使用計算器。

(1) *(25%)* The driving circuit for a brushless DC motor uses a resistor to sense motor current for control, as shown below. Consider the period when S1 and S2 are the conduction switches, where S2 is always on and S1 is switching to control motor current. Following figure shows the switching waveform and motor current in this period. Let the voltage of the sensing resistor be V_s, and the sensing resistor is 0.1 ohm. Sketch V_s waveform with proper unit and explain your answer.





(2) *(25%)* Consider a vector controlled permanent magnet synchronous motor (PMSM), the motor is running at steady state, and the rotor frame *d*-axis current is -1 A. If the peak value of the motor line current is 3 A, what is the rotor frame *q*-axis current?

(3) (*25%*) A 3-phase, 4-poles IPM-PMSM is stopped at the rotor electrical angle θ_r =120°. If it is to produce a phase voltage vector in the rotor frame: $V_{qds}^r = 10e^{j60^o}$, what phase voltage v_{as}, v_{bs}, v_{cs} should be applied to the motor windings ?

(4) *(25%)* A 4-pole, PMSM is driven by an external load at 2000 rpm. The motor's terminals are open. A voltage meter is used to measure the root-mean-square (rms) line to line voltage between two terminals. If the measured rms voltage is 65 V, use this information to calculate the rotor flux linkage λ_m?

(Refer to the motor model in the following reference equations)

Reference Equations: (参考方程式)

(a) Complex vector transformation:

$$f_{qd}^s = f_q - j\, f_d = f_{abc} = \frac{2}{3}\left(f_a + a \cdot f_b + a^2 \cdot f_c \right), \quad \text{where } a = e^{j120^o}$$

(b) Three-phase and stationary dq frame conversion:

$$\begin{cases} f_{as} = f_{qs} \\ f_{bs} = -\frac{1}{2} f_{qs} - \frac{\sqrt{3}}{2} f_{ds} \\ f_{cs} = -f_{as} - f_{bs} \end{cases} \qquad \begin{cases} f_{qs} = f_{as} \\ f_{ds} = -\frac{1}{\sqrt{3}} f_{as} - \frac{2}{\sqrt{3}} f_{bs} \end{cases}$$

(c) Stationary dq frame and rotor dq frame conversion:

$$f_{qd}^r = e^{-j\theta_r} f_{qd}^s \quad , f_{qd}^s = e^{j\theta_r} f_{qd}^r$$

$$e^{j\theta} = \cos(\theta) + j\sin(\theta)$$

$$\begin{bmatrix} f_{qs}^r \\ f_{ds}^r \end{bmatrix} = \begin{bmatrix} \cos\theta_r & -\sin\theta_r \\ \sin\theta_r & \cos\theta_r \end{bmatrix} \begin{bmatrix} f_{qs}^s \\ f_{ds}^s \end{bmatrix} \quad , \begin{bmatrix} f_{qs}^s \\ f_{ds}^s \end{bmatrix} = \begin{bmatrix} \cos\theta_r & \sin\theta_r \\ -\sin\theta_r & \cos\theta_r \end{bmatrix} \begin{bmatrix} f_{qs}^r \\ f_{ds}^r \end{bmatrix}$$

(d) IPM-PMSM motor equations:

Rotor frame: $$\begin{cases} v_{qs}^r = \left(r_s + L_{qs} p\right) i_{qs}^r + \omega_r L_{ds} \cdot i_{ds}^r + \omega_r \lambda_m \\ v_{ds}^r = \left(r_s + L_{ds} p\right) i_{ds}^r - \omega_r L_{qs} \cdot i_{qs}^r \end{cases}$$

$$T_e = \frac{3}{2}\frac{P}{2}\left[\lambda_m i_{qs}^r + \left(L_{ds} - L_{qs}\right) i_{qs}^r i_{ds}^r \right]$$

For SPM-PMSM, $L_{qs} = L_{ds} = L_s$