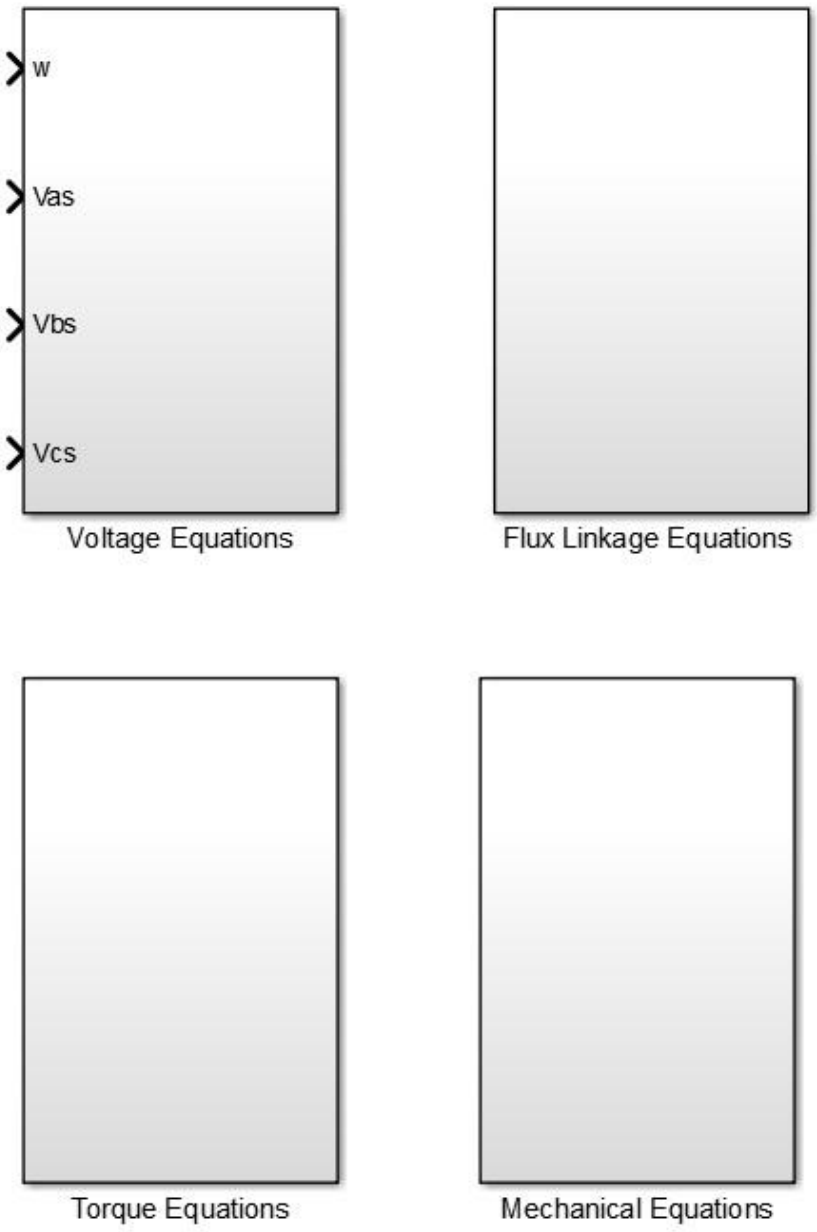
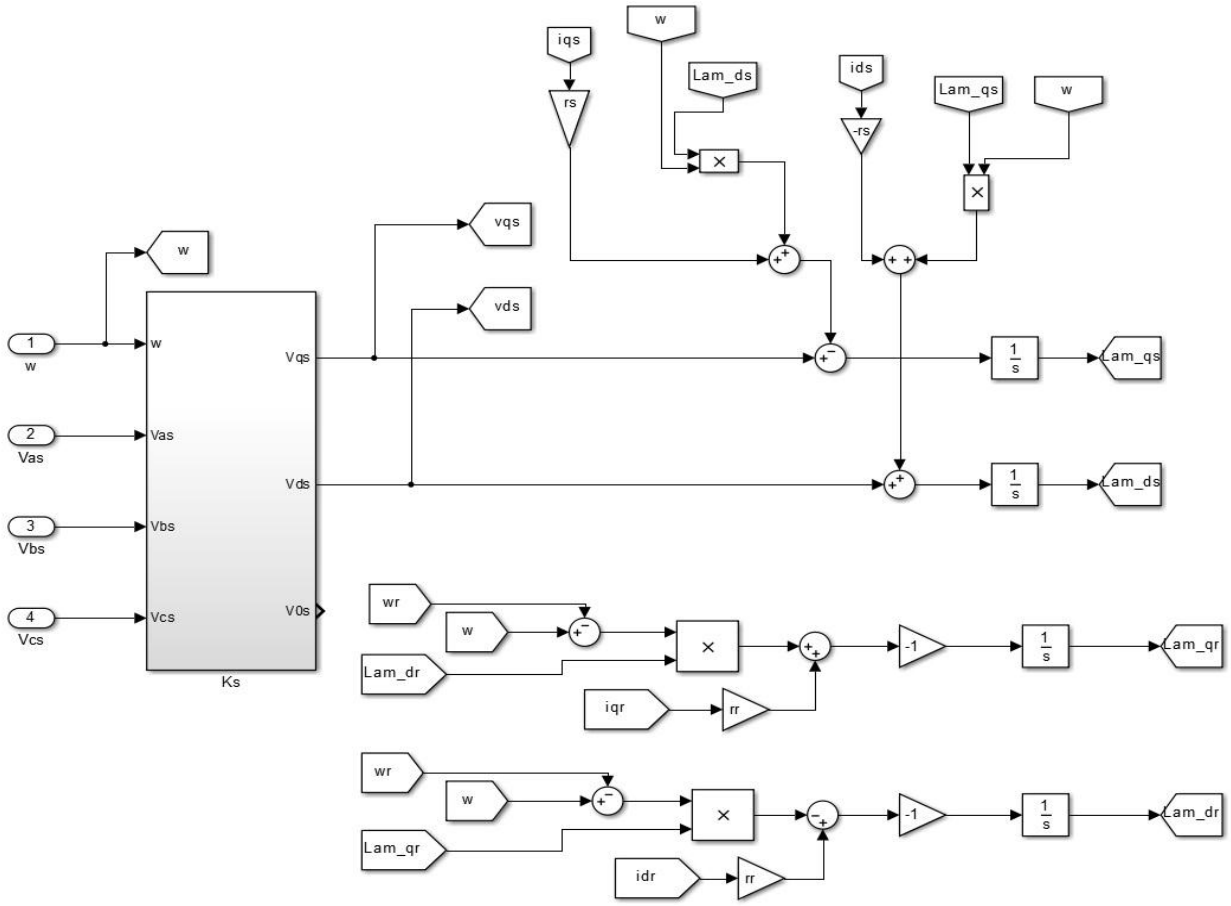
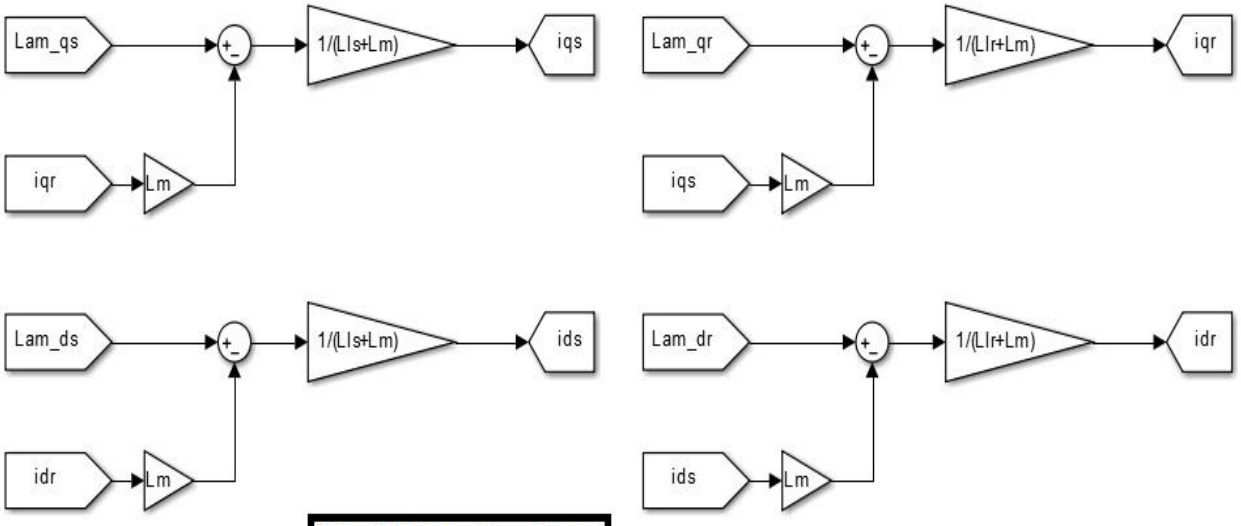
ECE 802, Electric Motor Control, Fall 2013
Exam#2, Induction Machines

Question 1:

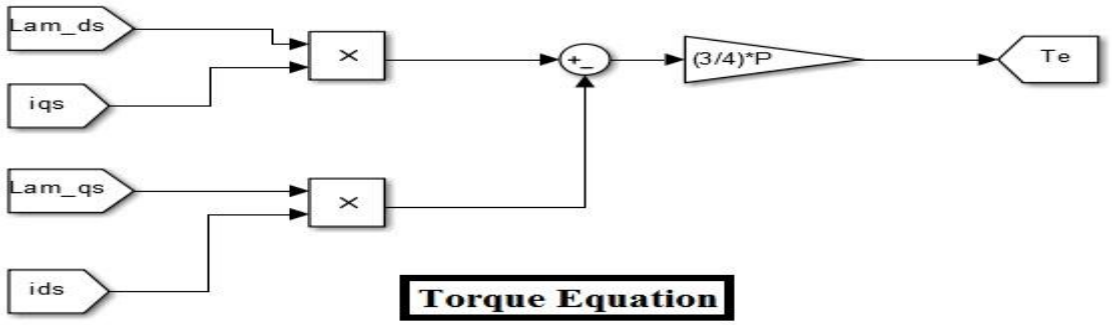




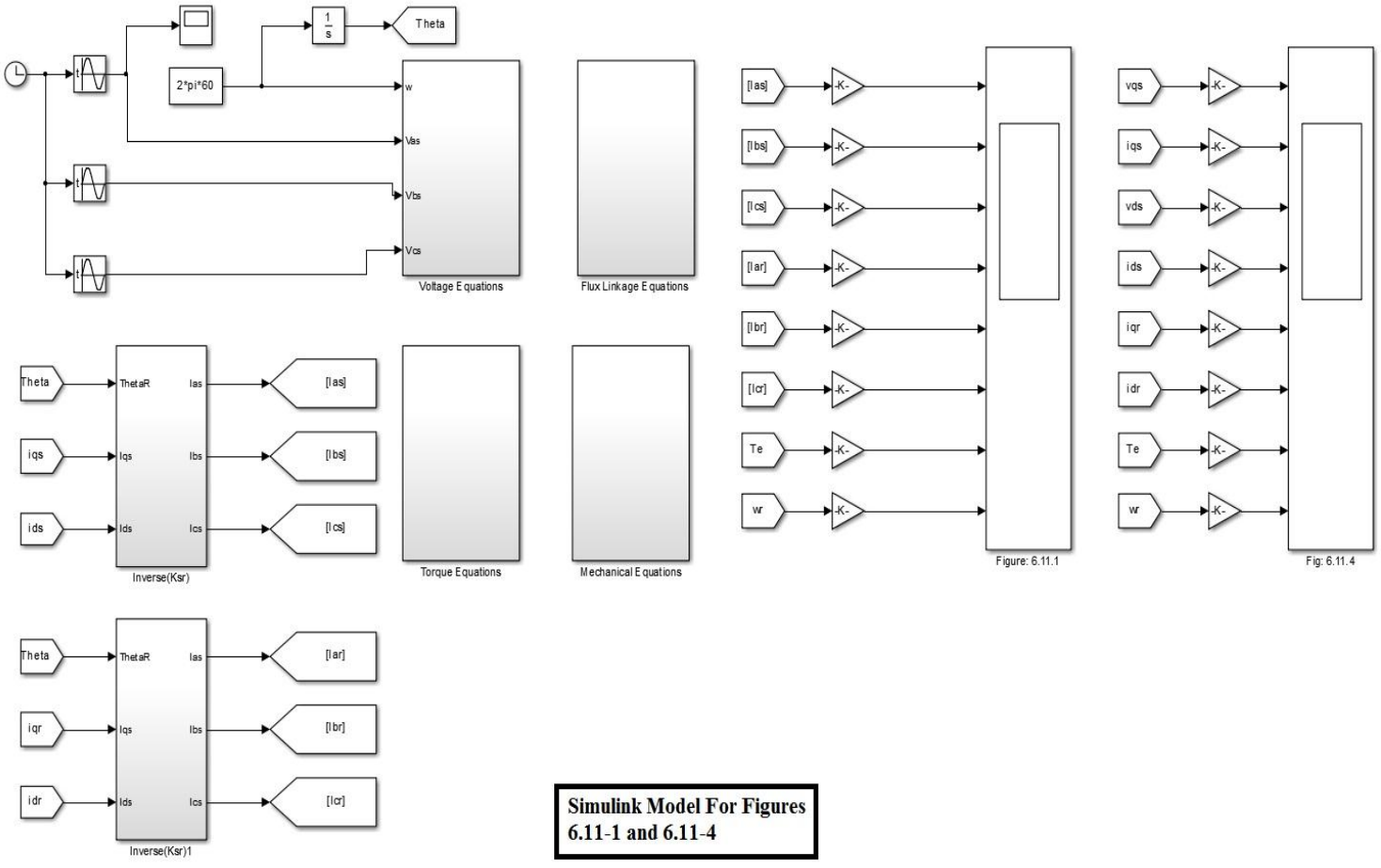
Voltage Equations



Flux Linkage Equations



Torque Equation

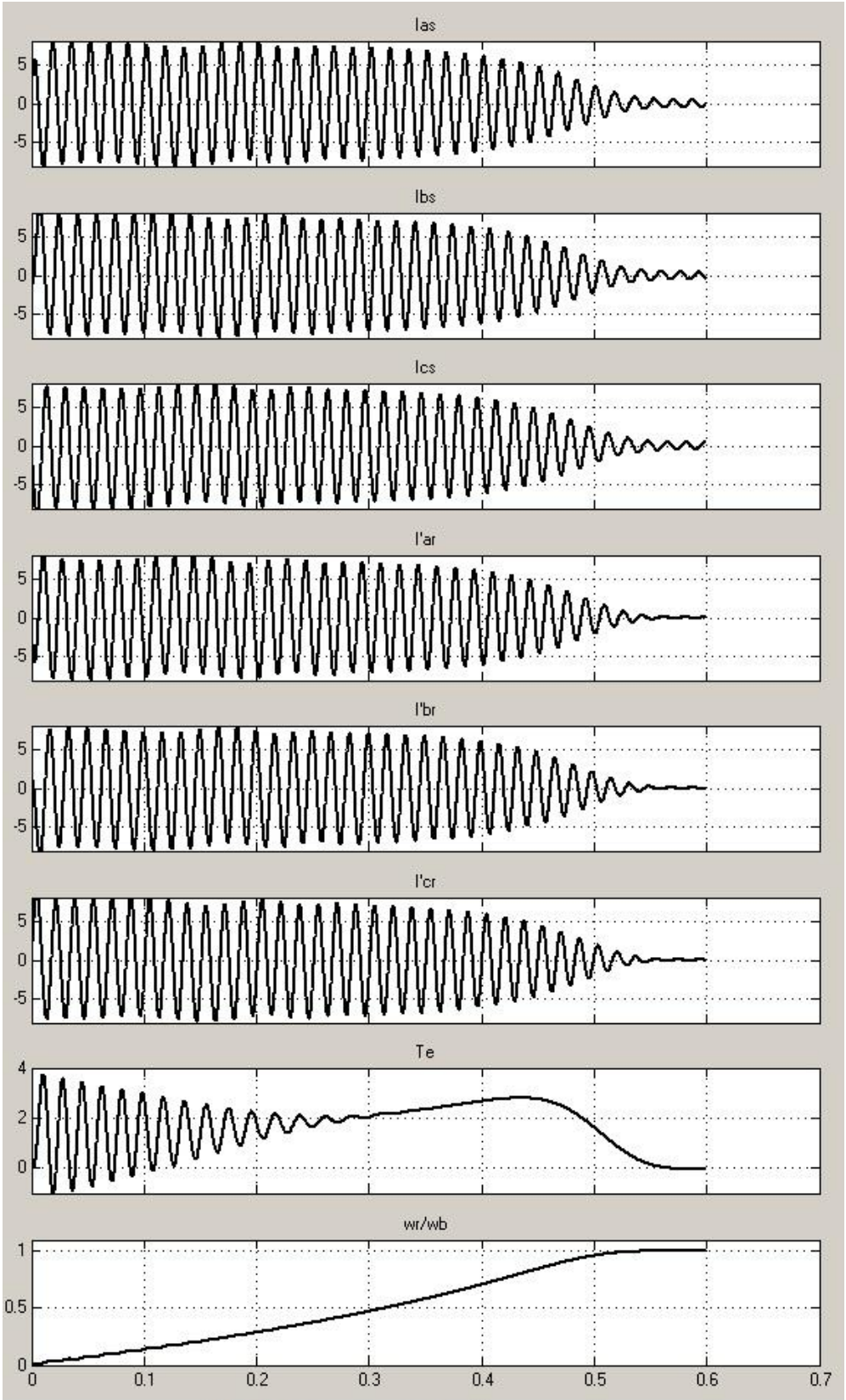


Simulink Model For Figures 6.11-1 and 6.11-4

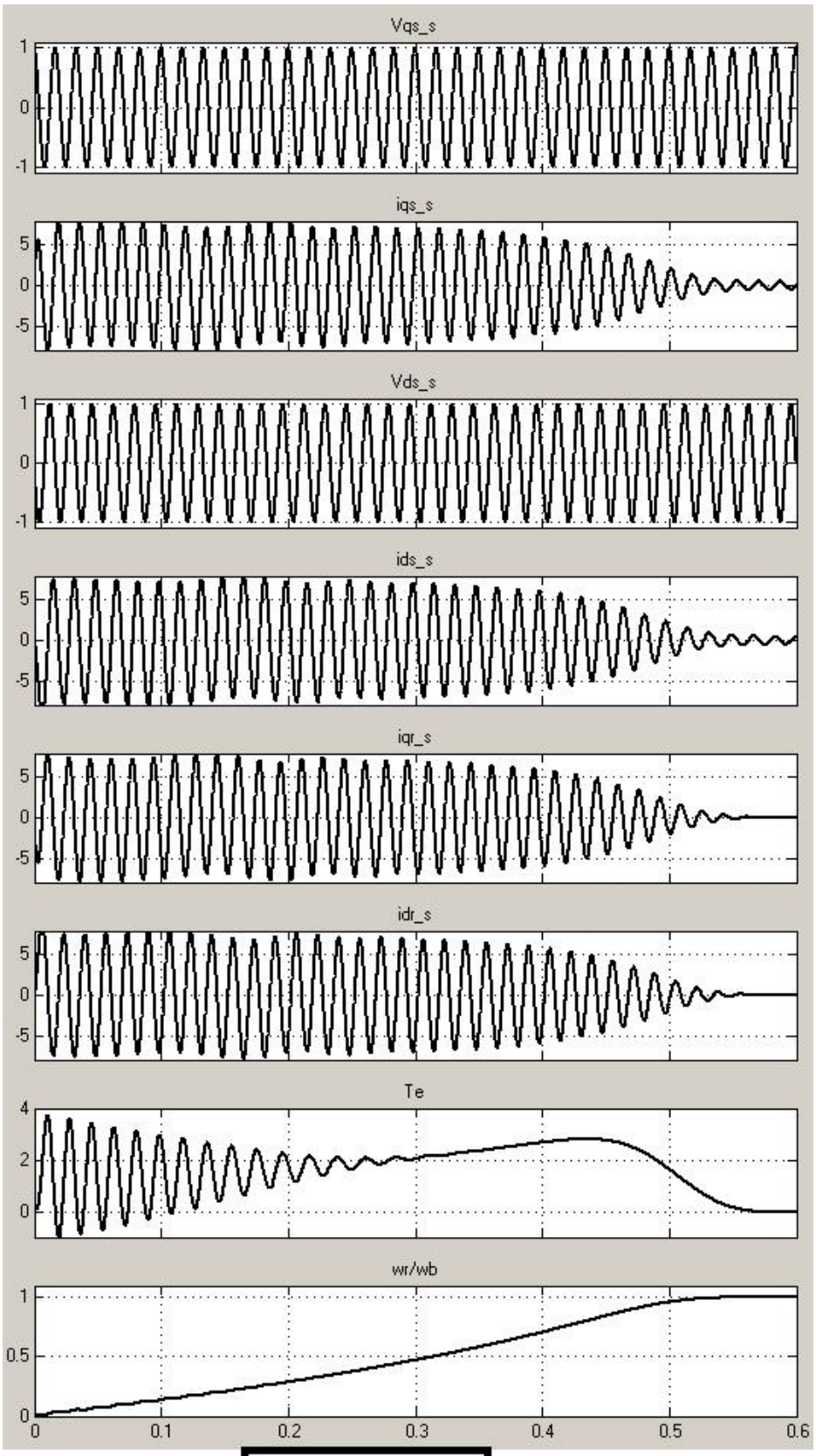
m-file Codes to set up the constants

```
clear all;
P = 6;
wb = 2*pi*60;
Vb = sqrt(2)*220/sqrt(3);
Pb = 10*746;
Zb = (3/2)*Vb*Vb/Pb;
Ib = Pb/((3/2)*Vb);
rs = 0.0453*Zb;
rr = 0.0222*Zb;
Lm = 5.41657e-3*Zb;
Lls = 0.205575e-3*Zb;
Llr = 8.541315e-5*Zb;
Tb = Pb/((2/P)*wb);
H = 10;
```

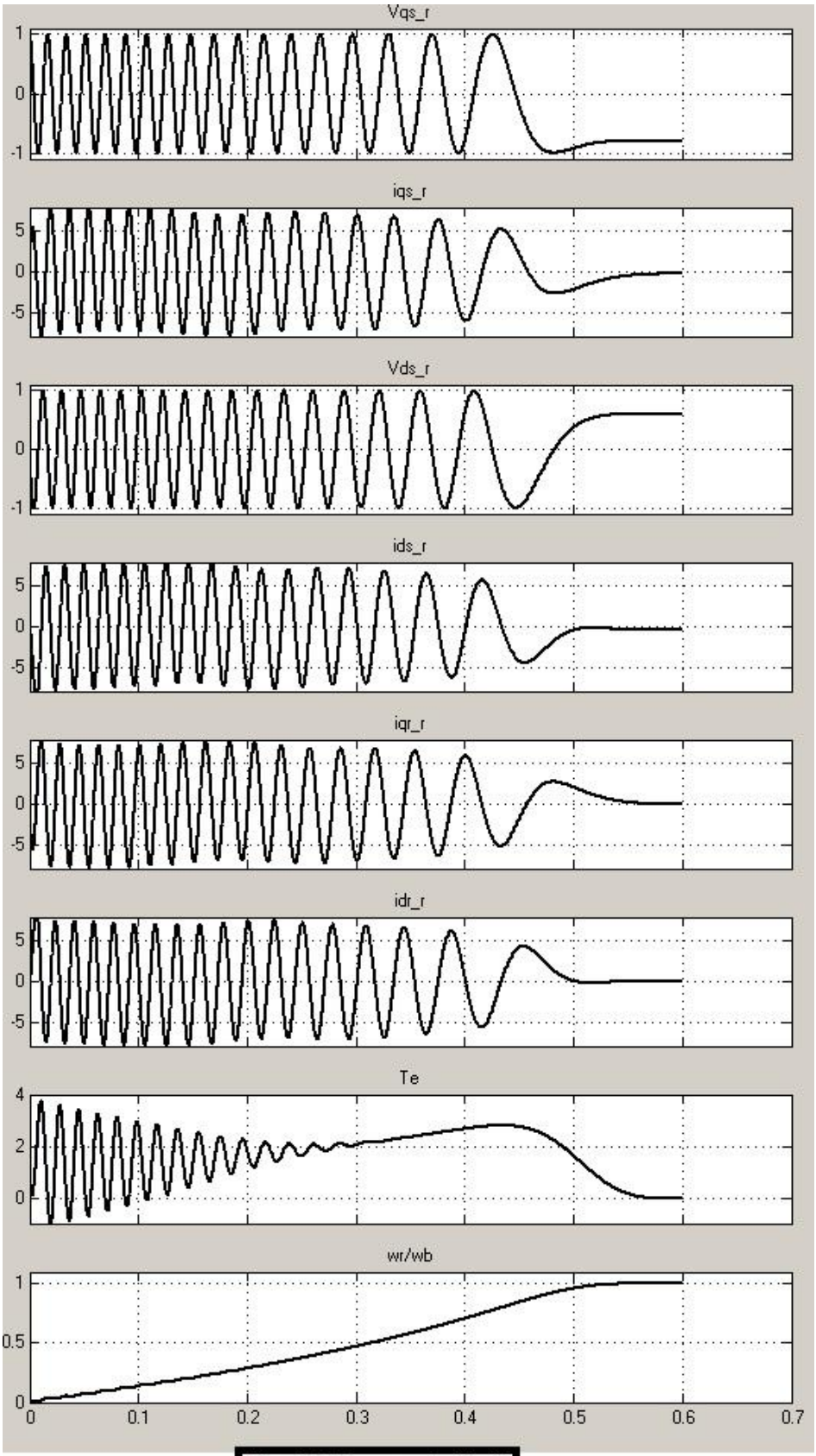
Results



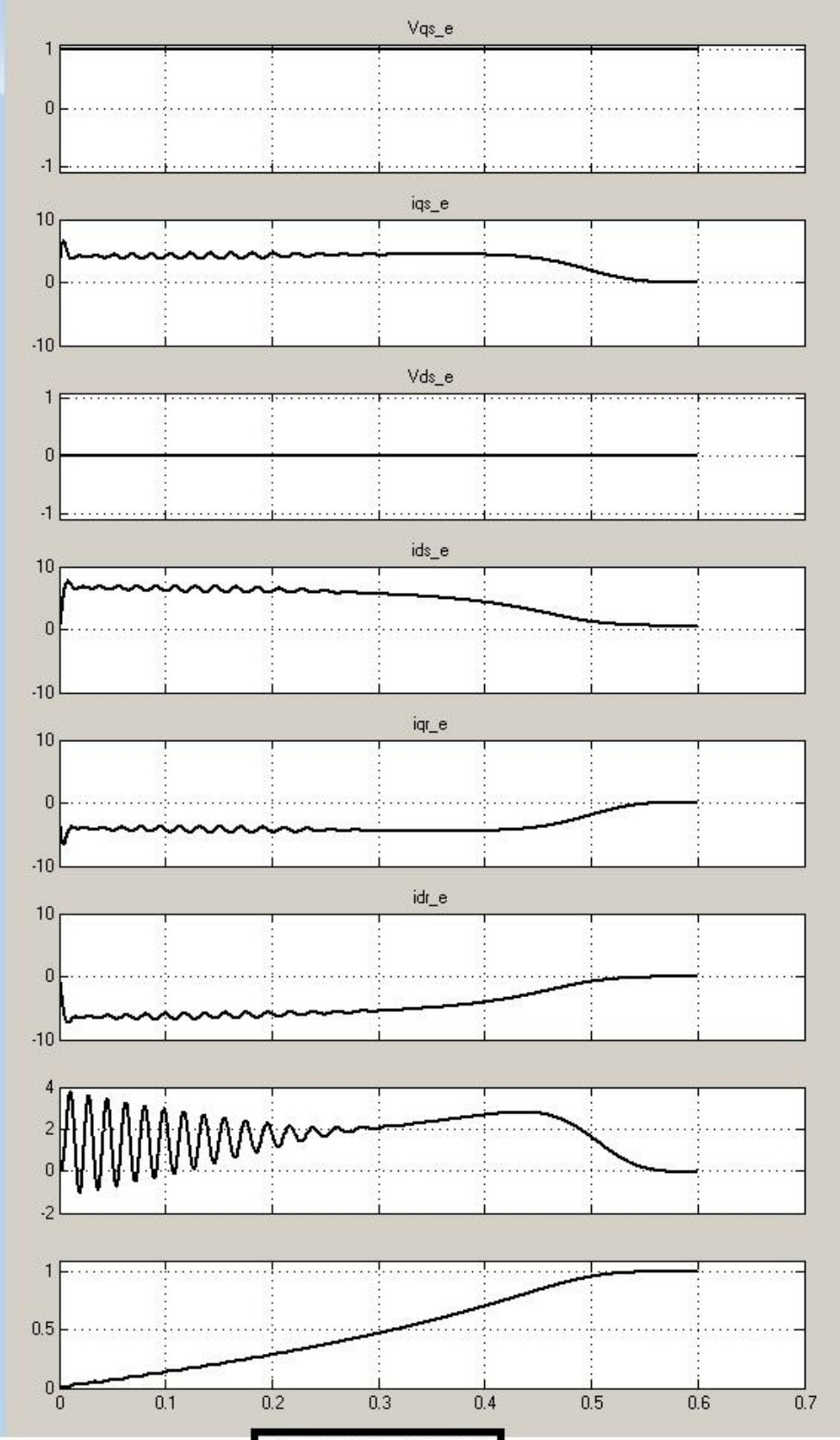
Book Figure 6.11-1



Book Fig 6.11-2



Book Figure 6.11-3



Book Fig: 6.11-4

Question 2:

Calculations for steady-state no-load stator flux

Constants:

$V_s = 127.017$ V
$r_s = 0.2939\ \Omega$
$r_r = 0.1440\Omega$
$L_{ls} = 0.0013$ H
$L_{lr} = 5.5416 \times 10^{-4}$ H
$L_m = 0.0351$ H

$L_{ss} = L_{ls} + L_m = 0.0365$ H
$L_{rr} = L_{lr} + L_m = 0.0357$ H

$f_e = 60$Hz
$w_e = 2.\pi.f_e = 376.9911$rad/s

Since for balanced steady-state conditions the q and d axis variables are sinusoidal in all reference frames except the synchronously rotating reference frame, where they are constants, it has been used for calculating the steady state values.

Since the rotor is accelerating with no load torque and because friction and winding losses have been neglected, the machine accelerates to synchronous speed. i.e.

$w_r = w_e = 376.9911$rad/s

In Synchronous reference frame we have,

$$V_{qs\_e} := \sqrt{2}\cdot V_s \qquad V_{ds\_e} := 0\cdot V \qquad V'_{qr\_e} := 0\cdot V \qquad V'_{dr\_e} := 0\cdot V$$

$$\begin{pmatrix} I_{qs\_e} \\ I_{ds\_e} \\ I'_{qr\_e} \\ I'_{dr\_e} \end{pmatrix} := \begin{bmatrix} r_s & \omega_e\cdot L_{ss} & 0 & \omega_e\cdot L_M \\ -\omega_e\cdot L_{ss} & r_s & -\omega_e\cdot L_M & 0 \\ 0 & (\omega_e - \omega_r)\cdot L_M & r'_r & (\omega_e - \omega_r)\cdot L'_{rr} \\ -(\omega_e - \omega_r)\cdot L_M & 0 & -(\omega_e - \omega_r)\cdot L'_{rr} & r'_r \end{bmatrix}^{-1} \cdot \begin{pmatrix} V_{qs\_e} \\ V_{ds\_e} \\ V'_{qr\_e} \\ V'_{dr\_e} \end{pmatrix}$$

[I] = [M] . [V]
Then

$$V = \begin{bmatrix} 179.6292 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$M = \begin{bmatrix} 0.2929 & 13.7512 & 0 & 13.2484 \\ -13.7512 & 0.2939 & -13.2484 & 0 \\ 0 & 0 & 0.2939 & 0 \\ 0 & 0 & 0 & 0.2939 \end{bmatrix}^{-1}$$

$$= \begin{bmatrix} 0.0016 & -0.0727 & -3.2766 & -0.0700 \\ 0.0727 & 0.0016 & 0.0700 & -3.2766 \\ 0 & 0 & 3.4025 & 0 \\ 0 & 0 & 0 & 3.4025 \end{bmatrix}$$

$$\gg I = \begin{bmatrix} Iqs \\ Ids \\ Iqr \\ Idr \end{bmatrix} = \begin{bmatrix} 0.2791 \\ 13.0569 \\ 0 \\ 0 \end{bmatrix}$$

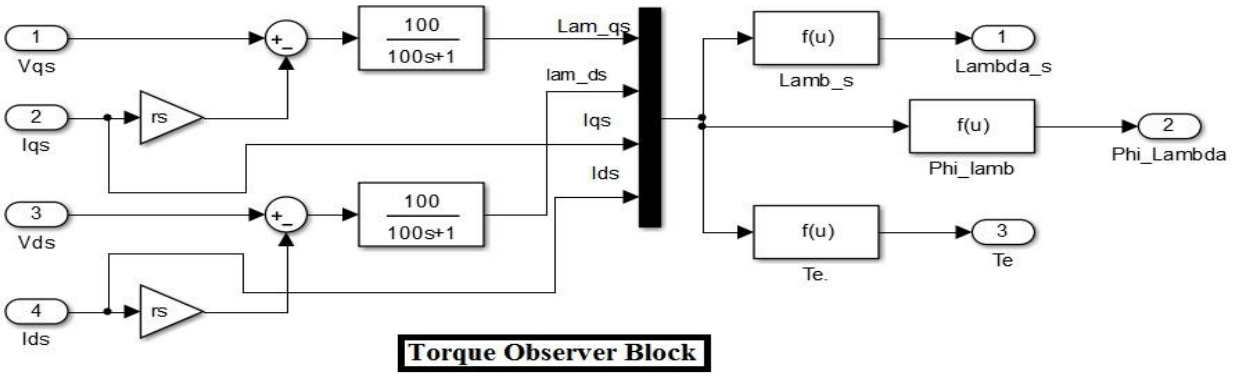
$\lambda_{qs} = L_{ss}.Iqs + L_m.Iqr = 0.0102$

$\lambda_{ds} = L_{ss}.Ids + L_m.Idr = 0.4763$

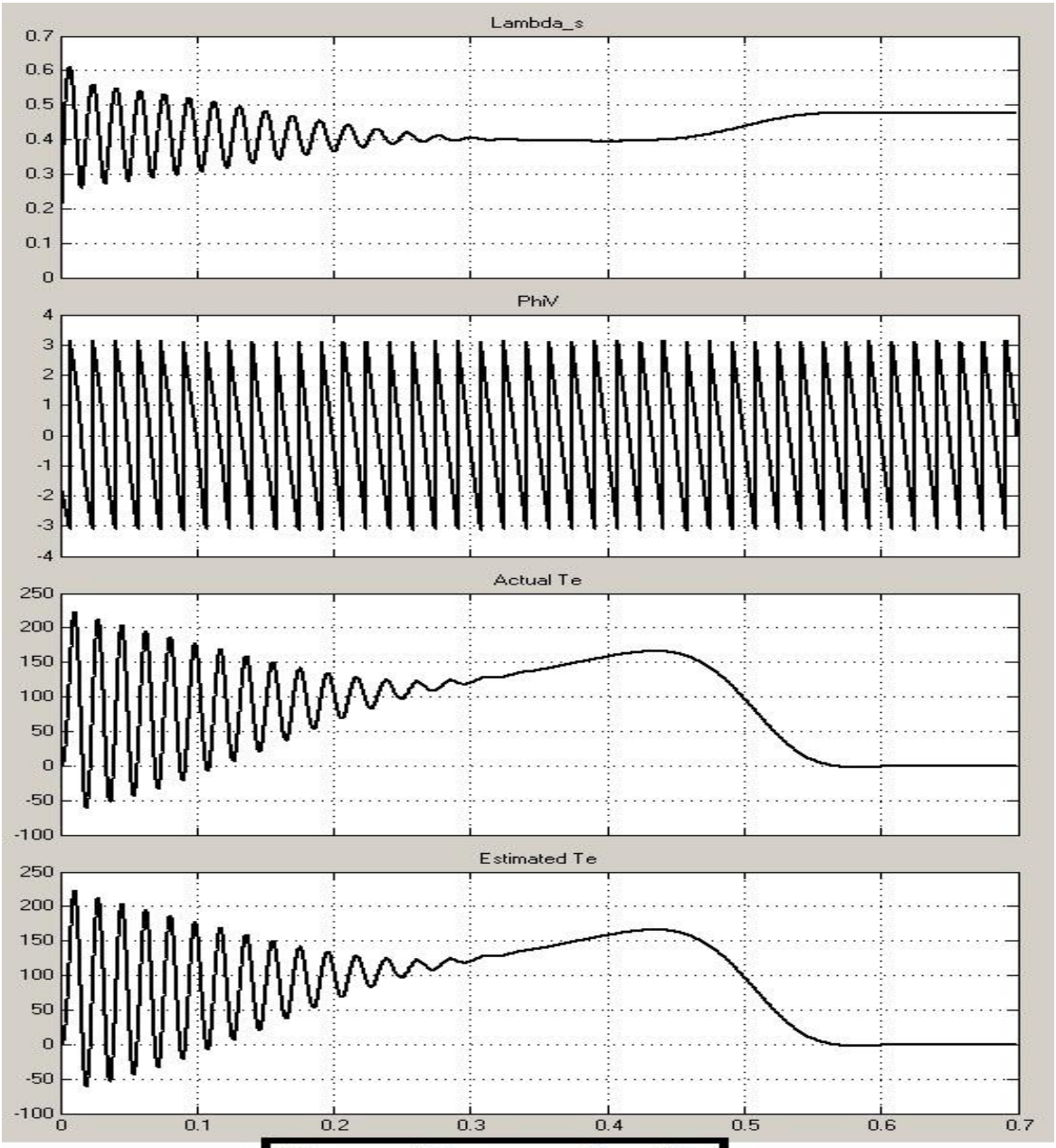
$\lambda_s = \sqrt{\lambda qs^2 + \lambda ds^2} = 0.4764$

The steady-state stator flux value calculated by Torque and Flux Observer model

$= 0.4763 \approx 0.4764.$



Torque Observer Block



Torque Observer Results