1) A surface-mount permanent magnet synchronous machine is connected to an inverter that is operated under sine-triangle PWM (no 3rd harmonic term is used in the modulation).

\[ \lambda_{as} = \frac{0.01}{\sqrt{2}}, L_q = L_d = 1 \text{ mH}, r_s = 0.1 \Omega, \lambda_m = 0.1 \text{ Vs}, P = 4, V_{dc} = 200 \text{ V}, \]

\[ \omega_r = 100 \text{ rad/s}. \]

a) Determine \( d \), and \( |\tilde{I}_{as}| \). (21 pts)

b) Neglect core loss and inverter loss. If for the same torque and speed as in a), \( \phi_v = 0 \), the machine efficiency will increase/decrease (circle one). Explain your answer. (12 pts)

2) A 3-phase induction machine is connected to a 376 rad/s utility and is driven mechanically to the operating point shown in the Figure 1. Assume all reference angles used for the machine analysis are defined positive in the counter clockwise direction. For this operating condition shown, complete Table 1 and Table 2. (34 pts)

![Figure 1: Torque/speed curve of induction machine.](image)

Table 1:

<table>
<thead>
<tr>
<th></th>
<th>actual (abc) variables</th>
<th>stationary reference frame ( \omega = 0 )</th>
<th>rotor reference frame ( \omega = \omega_r )</th>
<th>synchronous reference frame ( \omega = \omega_e )</th>
</tr>
</thead>
<tbody>
<tr>
<td>frequency of stator currents</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>frequency of rotor currents</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3) A salient wound-rotor synchronous machine has the following approximate dynamic model

\[
\begin{align*}
    v_{qs}^r &= \omega r \lambda_{qs}^r + p \dot{\lambda}_{qs}^r \\
    v_{ds}^r &= -\omega r \lambda_{qs}^r + p \dot{\lambda}_{ds}^r \\
    v_{fd}^r &= r_{fd}^r i_{fd}^r + p \dot{\lambda}_{fd}^r \\
    v_{kq}^r &= r_{kq}^r i_{kq}^r + p \dot{\lambda}_{kq}^r \\
    \lambda_{qs}^r &= L_{ts} i_{qs}^r + L_{mq} (i_{qs}^r + i_{kq}^r) \\
    \lambda_{ds}^r &= L_{ts} i_{ds}^r + L_{md} (i_{ds}^r + i_{fd}^r) \\
    \lambda_{kq}^r &= L_{kq} i_{kq}^r + L_{mq} (i_{qs}^r + i_{kq}^r) \\
    \lambda_{fd}^r &= L_{fd} i_{fd}^r + L_{md} (i_{ds}^r + i_{fd}^r)
\end{align*}
\]

a) Express the steady-state form of (1)-(8). (13 pts)

b) Using the relation \( \sqrt{2} F_{qs} e^{-j\delta} = F_{qs}^r - j F_{ds}^r \), derive a steady-state phasor equivalent circuit model for the machine. Note the model will include \( i_{ds}^r \). (20 pts)