EE 559 Homework #3
Due Monday September 26, 2016

A. Using previous relations provided in the "Set 1" slides, derive the following torque expressions:

1. $T_{em} = 3p\,\mathrm{Im}\left\{\underline{\lambda}_s^* \underline{I}_s\right\}$
2. $T_{em} = 3p\,\mathrm{Im}\left\{\underline{\lambda}_r \underline{I}_r^*\right\}$
3. $T_{em} = 3p\dfrac{L_m}{\sigma L_r L_s}\mathrm{Im}\left\{\underline{\lambda}_r^* \underline{\lambda}_s\right\}$ (and identify σ)

B. Use $Q = 3\mathrm{Im}\{\underline{V}\,\underline{I}^*\}$ and the equivalent circuit to derive reactive power expressions, in terms of $\underline{I}_s$ and $\underline{I}_r$ for
   1. The stator, Q_s
   2. The rotor, Q_r

C. For each DFIG condition below, compute P_{airgap} and P_{slip} and draw the power flows similar to slide 30 in the "Set 1" slides.
   1. P_{mech}=-1 MW with s=+0.30 (subsynchronous operation).
   2. P_{mech}=-1MW with s=-0.30 (supersynchronous operation).

D. Complete the table on below (the boxed section) by computing the per-unit values of the indicated five resistances/inductances for the 2 MW machine.

Characteristic	5 kW	15 kW	250 kW	2 MW
Synchronous speed (rev/min)	1500	1500	1500	1500
Rated power (kW)	5	15	250	2000
Rated line-to-line stator voltage (V_{rms})	380	380	400	690
Rated stator current (A_{rms})	8.36	32	370	1760
Rated torque (N·m)	31.8	95.5	1591	12732
Stator connection	Star	Star	Star	Star
p	2	2	2	2
Rated $\underline{V}_r$ (V_{rms})	205	380	400	2070
Rotor connection	Star	Star	Star	Star
u	0.54	1	1	0.34
R_s (mΩ)	720	161	20	2.6
$L_{\sigma s}$ (mH)	5.8	3	0.2	0.087
L_m (mH)	85.8	46.5	4.2	2.5
R'_r (mΩ)	2566	178	20	26.1
$L'_{\sigma r}$ (mH)	19.85	3	0.2	0.783
R_r (mΩ)	750	178	20	2.9
$L_{\sigma r}$ (mH)	6	3	0.2	0.087
L_s (mH)	91.6	49.5	4.4	2.587
L_r (mH)	91.6	49.5	4.4	2.587
V_{base}	220	220	231	398.4
I_{base}	8.36	32	370	1760
r_s	0.027	0.023	0.032	
$l_{\sigma s}$	0.069	0.137	0.1	
l_m	0.976	2.12	2.11	
r_r	0.028	0.025	0.032	
$l_{\sigma r}$	0.071	0.137	0.1	

u (or a)
R_s
$L_{\sigma s}$
L_m
R'_r
$L_{\sigma r}$
R_r
$L_{\sigma r}$
L_s
L_r
V_{base}
I_{base}
r_s
$l_{\sigma s}$
l_m
r_r
$l_{\sigma r}$
Per-unit values