8-10 (Solved Problem) Consider a 5.0MW/950V/50Hz/1170rpm DFIG WECS. Parameters of generator are given in Table B-7 of Appendix B. DFIG WECS is connected to a grid (line-line voltage *VAB*=950V, 50Hz). Generator operates with an MPPT scheme. Neglect rotational & core losses. At a given wind & generator speed, rms fundamental grid current *Ig*, & stator active power *Ps* are found to be 2016.08A & –3261.6 kW respectively. Calculate following assuming unity power factor operation for DFIG WECS:

a) rms stator current,

b) generator mechanical torque & power,

c) rotor mechanical & electrical speeds & slip,

d) net power delivered to grid & rotor active power, &

e) stator & rotor winding losses, & efficiency of DFIG.

Generator Type	**DFIG, 5.0MW/950V/50Hz**	
Rated Mechanical Power	5.0 MW	1.0 pu
Rated Stator Line-to-line Voltage	950 V (rms)	
Rated Stator Phase Voltage	548.48 V (rms)	1.0 pu
Rated Rotor Phase Voltage	381.05 V (rms)	0.6947 pu
Rated Stator Current	2578.4 A (rms)	0.8485 pu
Rated Rotor Current	3188.7 A (rms)	1.0494 pu
Rated Stator Frequency	50 Hz	1.0 pu
Rated Rotor Speed	1170 rpm	1.0 pu
Nominal Rotor Speed Range	670–1170 rpm	0.573–1.0pu
Rated Slip	-0.17	
Number of Pole Pairs	3	
Rated Mechanical Torque	40.809 kN.m	1.0 pu
Stator Winding Resistance R_s	1.552 mΩ	0.0086 pu
Rotor Winding Resistance R_r	1.446 mΩ	0.008 pu
Stator Leakage Inductance L_{ls}	1.2721 mH	2.2141 pu
Rotor Leakage Inductance L_{lr}	1.1194 mH	1.9483 pu
Magnetizing Inductance L_m	5.5182 mH	9.6044 pu
Base Current $I_B = 5\text{MW}/(\sqrt{3}\times 950\text{V})$	3038.7 A (rms)	1.0 pu
Base Flux Linkage Λ_B	1.7459 Wb (rms)	1.0 pu
Base Impedance Z_B	0.1805 Ω	1.0 pu
Base Inductance L_B	0.5746 mH	1.0 pu
Base Capacitance C_B	17634.9 μF	1.0 pu

Solution:

a) The stator can be calculated by

$$I_s = P_s / (3V_s) = -3261.6 \times 10^3 / (3 \times 950/\sqrt{3}) = -1982.2 \text{ A (rms)}$$

b)Generator air-gap power can be given by

$$\frac{\omega_s T_m}{P} = 3(V_s - I_s R_s) I_s$$

from which generator mechanical torque can be obtained as

$$T_m = 3(V_s - I_s R_s) I_s \times (P/\omega_s) = -31320.7 \text{ N.m}$$

Generator mechanical torque can be related to pu rotor speed as

$$T_m = T_{m,R} \times (\omega_{m,\text{pu}})^2 \text{ N.m}$$

from which pu rotor speed can be calculated by

$$\omega_{m,\text{pu}} = \sqrt{\frac{T_m}{T_{m,R}}} = \sqrt{\frac{-31320.7}{-40809}} = 0.8761$$

Rated mechanical power:

$$P_{m,R} = \omega_{m,R} \times T_{m,R} = 1170(2\pi)/60 \times (-40809) = -5000 \times 10^3 \text{ W}$$

Generator mechanical power at 0.8761pu rotor speed:

$$P_m = P_{m,R} \times (\omega_{m,\text{pu}})^3 = -5000 \times 10^3 \times (0.8761)^3 = -3361.9 \times 10^3 \text{ W}$$

c) The rotor mechanical and electrical speeds:

$$\omega_m = \omega_{m,R} \times \omega_{m,\text{pu}} = 1170(2\pi)/60 \times 0.8761 = 107.34 \text{ rad/sec} \quad (1025 \text{ rpm})$$

$$\omega_r = \omega_m \times P = 107.34 \times 3 = 322.02 \text{ rad/sec}$$

The slip can be calculated by:

$$s = (\omega_s - \omega_r) / \omega_s = (314.16 - 322.02) / 314.16 = -0.025$$

d) The net power delivered to the grid:

$$\left|P_g\right| = 3V_g\left|I_g\right| = 3\times 950/\sqrt{3}\times 2016.08 = 3317.3\times 10^3 \ \text{W}$$

The rotor active power:

$$P_r = \left|P_g\right| - \left|P_s\right| = (3317.3 - 3261.6)\times 10^3 = 55.75\times 10^3 \ \text{W}$$

e) The stator winding loss:

$$P_{cu,s} = 3(I_s)^2 R_s = 3 \times 1982.2^2 \times 1.552 \times 10^{-3} = 18.29 \times 10^3 \ \text{W}$$

The difference between *Pm* and *Pg* is the losses on the stator and rotor windings, that is,

$$|P_m| - |P_g| = P_{cu,s} + P_{cu,r} \text{ W}$$

from which the rotor winding loss can be obtained as

$$P_{cu,r} = |P_m| - |P_g| - |P_{cu,s}| = (3361.9 - 3317.3 - 18.294) \times 10^3 = 26.25 \times 10^3 \text{ W}$$

The efficiency of the DFIG neglecting rotational and core losses is then

$$\eta = P_g / \left| P_m \right| = 3317.3 / 3361.9 = 98.68\%$$

8-11 Repeat Problem 8-10 when the fundamental grid current *Ig*, and stator active power *Ps* are 1366.87A and –2517.8 kW respectively.

Answers:

a) $I_s = -1530.2\,\text{A (rms)}$

b) $T_m = -24147\,\text{N.m}\,,\ P_m = -2275.8\times10^3\ \text{W}$

c) $\omega_m = 94.25\,\text{rad/sec}\ \ (900\,\text{rpm}),\ \ \omega_r = 282.75\,\text{rad/sec}\,,\ \ s = 0.1$

d) $\left|P_g\right| = 2249.1\times10^3\ \text{W}\,,\ \ P_r = -268.69\times10^3\ \text{W}$

e) $P_{cu,s} = 10.902\times10^3\ \text{W}\,,\ \ P_{cu,r} = 15.818\times10^3\ \text{W}\,,\ \ \eta = 98.93\%$

8-12 Repeat Problem 8-10 when the fundamental grid current *Ig*, and stator active power *Ps* are 792.42A and –1750.77 kW respectively.

Answers:

a) $I_s = -1064$ A (rms)

b) $T_m = -16769$ N.m, $P_m = -1317.0 \times 10^3$ W

c) $\omega_r = 78.54$ rad/sec (750 rpm), $\omega_r = 235.62$ rad/sec. $s = 0.25$

d) $|P_g| = 1303.9 \times 10^3$ W, $P_r = -446.88 \times 10^3$ W

e) $P_{cu,s} = 5.271 \times 10^3$ W, $P_{cu,r} = 7.873 \times 10^3$ W, $\eta = 99.0\%$