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ELECTROMECHANICAL ENERGY CONVERSION

b. At $s = 0.25$

$$Z_f = 13.5 + j4.8 \text{ ohms} \quad Z_b = 1.98 + j2.73 \text{ ohms}$$

$$V_{mf} = \frac{V}{2} (1 - j/a) = \frac{230 \angle 0}{2} (1 - j/1.54) = 115 - j74.7 \text{ V}$$

$$V_{mb} = \frac{V}{2} (1 + j/a) = 115 + j74.7 \text{ V}$$

$$Z_{1a}/a^2 = \frac{1}{(1.54)^2} (22.2 - j34.4) = 9.36 - j14.5 \text{ ohms}$$

$$Z_{1m} = 2.8 + j2.77 \text{ ohms}$$

$$Z_0 = \frac{1}{2} (Z_{1a}/a^2 + Z_{1m}) = \frac{1}{2} (12.16 - j11.73) = 6.08 - j5.87$$

$$Z_d = \frac{1}{2} (Z_{1a}/a^2 - Z_{1m}) = \frac{1}{2} (6.55 - j17.3) = 3.28 - j8.64$$

$$-Z_d^2 = 64 + j36.8$$

$$Z_f + Z_0 = 19.58 - j1.07 \quad Z_b + Z_0 = 8.06 - j3.14$$

$$I_{mf} = \frac{V_{mf}(Z_0 + Z_b) + V_{mb}Z_d}{(Z_0 + Z_f)(Z_0 + Z_b) - Z_d^2} = 8.31 - j7.33 \text{ A}$$

$$= 11.08 \angle -41.4^\circ \text{ A}$$

$$I_{mb} = \frac{V_{mb}(Z_0 + Z_f) + V_{mf}Z_d}{(Z_0 + Z_f)(Z_0 + Z_b) - Z_d^2} = 9.399 + j1.036 \text{ A}$$

$$I_m = I_{mf} + I_{mb} = 17.7 - j6.29 = 18.8 \angle -19.6^\circ \text{ A}$$

$$jI_{mf}/a = j(8.31 - j7.33)/1.54 = 4.76 + j5.4$$

$$-jI_{mb}/a = -j(9.399 + j1.04)/1.54 = 0.475 - j6.1$$

$$I_a = j(I_{mf} - I_{mb}) = 5.43 - j0.709 = 5.48 \angle -7.45^\circ \text{ A}$$

$$\text{Line current } I = I_m + I_a = 23.14 - j7.0 = 24.2 \angle -16.85^\circ \text{ A}$$

$$\text{Power factor} = \cos(-16.85) = 0.96 \text{ (lag)}$$

$$P_{gf} = 2 I_{mf}^2 R_f = 2 (11.08)^2 (13.5) = 3115 \text{ W}$$

$$P_{gb} = 2 I_{mb}^2 R_b = 2 (9.46)^2 (2.0) = 358 \text{ W}$$

$$P_{gf} - P_{gb} = 2757 \text{ W}$$

$$T = (P_{gf} - P_{gb}) / \omega_s = 2757 / 157 = 17.5 \text{ n-m}$$

$$V_c = I_a Z_c = 5.48 \angle -7.45^\circ \times 53.5 \angle -83.56^\circ = 293 \angle -91.01^\circ \text{ V}$$

c. At $s = 0.04$

$$Z_f/2 = 22.2 + j22.95 \text{ ohms}$$

$$Z_b/2 = 0.882 + j1.36 \text{ ohms}$$

$$Z_{in} = r_{1m} + jx_{1m} + Z_f/2 + Z_b/2 = 26 + j27 = 37.5 \angle 46.1^\circ \text{ ohms}$$

$$I_{1m} = V/Z_{in} = 230 \angle 0 / 37.5 \angle 46.1 = 6.13 \angle -46.1^\circ \text{ A}$$

$$\text{Power factor} = \cos(-46.1) = 0.694 \text{ (lag)}$$

$$\text{Power input} = V I_{1m} \cos \phi_{1m} = 230 \times 6.13 \times 0.694 = 978 \text{ W}$$