

Instructor: N. Chowdhury  
Time: 3 hours

December 1997

- Notes: (a) This is a closed book examination.  
(b) Formula sheets are attached.  
(c) Record in your answer book(s) all necessary steps and calculations.

Marks

- 15  The open-circuit characteristic data of a dc shunt generator taken at 1400 r.p.m. are shown below:

Field current (A)	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
Term. voltage (V)	92	165	237	303	349	382	415	438	456	469

- Draw the open-circuit characteristic curve of the dc generator at 1400 r.p.m.
- Determine the no-load terminal voltage of the dc generator at 1200 r.p.m. if the field circuit resistance is adjusted to 220 ohms.
- Determine the generated voltage, terminal voltage and power output of the generator at 1200 r.p.m. when it delivers 120 A to a load. The shunt field resistance is 220 ohms and the armature circuit resistance is 0.2 ohm. Neglect armature reaction.
- 16  A wye-connected, three-phase, 60-Hz, 4-pole alternator has 48 slots and 26 conductors per slot. The machine is lap-wound with double-layer. The coils span 11 slots. The alternator has a fundamental flux per pole of 0.06 Wb, a 3<sup>rd</sup> harmonic flux per pole of 0.005 Wb and a 5<sup>th</sup> harmonic flux per pole of 0.002 Wb. Determine the following:
- the pitch factor(s) of the winding,  $K_{p1} = 0.9914$   $K_{p3} = -0.7239$   $K_{p5} = 0.7934$
- the distribution factor(s) of the winding,  $K_{d1} = 0.9577$   $K_{d3} = 0.6533$   $K_{d5} = 0.2053$
- emf per coil,
- the open-circuit phase voltage, and
- the open-circuit line-to-line voltage.
- 8  A three-phase ac synchronous generator is connected to a three-phase system at an infinite bus. With the help of a phasor diagram, explain what would happen if the prime-mover input of the synchronous generator is increased from its previous level while the excitation, the frequency and the terminal voltage are held at their previous levels.
- 15  A three-phase, wye-connected, 480-V, 30-Hp, 60-Hz, four-pole induction motor has the following equivalent circuit constants in ohms per phase referred to the stator:

Marks

$R_1 = 0.2$ ,  $R_2 = 0.3$ ,  $X_1 = 2.5$ ,  $X_2 = 3.3$ , and  $X_\phi = 50$

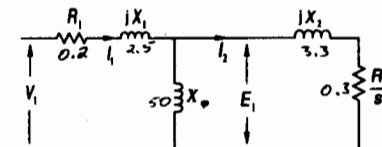


Figure 1. Equivalent circuit of an induction motor.

The motor is connected directly to a three-phase, 60-Hz, 480-V source. Determine the line current and the internal torque during starting.

- A three-phase, 11000-V, 60-Hz, wye-connected, cylindrical-rotor synchronous generator is delivering 2000 kVA at 0.82 lagging power factor when connected to a three-phase, 11000-V, 60-Hz infinite bus. The machine has a resistance of 1.5  $\Omega$  and a synchronous reactance of 14  $\Omega$  per phase.
- 10  (a) Determine the excitation voltage, the power angle and real and reactive power output of the generator. Draw a phasor diagram showing all voltages and the armature current.
- 15  The excitation of the generator is increased by 10 percent while the prime-mover power is held at its previous level. Determine the stator current, the power angle and the reactive power supplied by the generator. [Hint: Do not neglect the stator resistance.]
- 21 6. Mark the following statements as TRUE or FALSE. If you mark a statement as FALSE, briefly mention your reason(s) for doing so.
- The net effect of armature reaction in a dc machine can be considered as a reduction in the armature current.
- In a dc machine, pole face windings are used to neutralize the reactance voltage.
- In dc machines, interpoles are used to improve commutation.
- The speed of a dc shunt motor varies linearly as a function of its field flux.
- Short-pitched coils are used in three-phase alternators to improve the waveform of the voltage.
- Synchronous generators connected to infinite buses usually operate at lagging power factors.
- A synchronous motor connected to an infinite bus can be operated at a leading power factor.
- Synchronous motors are self-starting and, therefore, can be started with a load.

- The flux produced by the stator of an induction motor rotates at synchronous speed.
- The rotor of an induction motor rotates at synchronous speed.
- The frequency of the voltage induced in the rotor of an induction motor would be 60 Hz, if the machine were supplied from a balanced, three-phase, 60 Hz source.
- In an induction motor, the maximum internal torque occurs when the rotor current is at its maximum.
- The magnitude of the maximum internal torque in an induction motor can be increased by increasing the rotor resistance, provided all other parameters remain constant.
- The no-load test of an induction motor is ordinarily taken at a frequency lower than the rated frequency with rated voltage applied to the stator.

THE END

DC MACHINES

EMF, and Electromotive Force:  $e = \bar{v} \times \bar{B}l$ ,  $f = \bar{i} \times \bar{B}l$ ,  $v$  = velocity,  $i$  = current,  $B$  = field,  $l$  = length,  $e$  = EMF,  $f$  = force

Lenz's Law:  $e = -\frac{\delta \lambda}{\delta t} = -\frac{\delta(N\phi)}{\delta t}$ ,  $\lambda$  = flux linkage passed through,  $N$  = #turns,  $\phi$  = flux

Avg. Generated EMF:  $e_g = \frac{P\phi n Z}{60a}$ ,  $e_g$  = generated emf,  $\phi$  = flux per pole,  $P$  = # poles,  $Z$  = # conductors,  $a$  = parallel paths,  $n$  = (RPM).

$$\theta_{ad} = \frac{P}{2} \theta_{mech}$$

	Generators	DC Motor: Shunt	DC Motor: Series
Terminal Voltage	$V_t = E_g - I_a R_a$		
Back EMF		$E_g = V_t - I_a R_a$	$E_g = V_t - I_a R_a - I_a R_f$
Back EMF/Speed	$E_g = K_a \phi \omega_m$	$E_g = K_a \phi \omega_m$	$E_g = K_a \phi \omega_m$
Electromagnetic Power		$P_e = E_g I_a$	$P_e = E_g I_a$
Input Power		$V_t I_t = V_t I_a + V_t I_f$	$V_t I_t = E_g I_a + I_a^2 R_a + I_a^2 R_f$
Output Power	$P_{rated} = V_{t-rated} I_{a-rated}$	$P_{out} = P_e - \text{mech losses}$	$P_{out} = P_e - \text{mech losses}$
Torque/Power		$T_e \omega_m = P_e = E_g I_a$	$T_e \omega_m = P_e = E_g I_a$
Torque/Current		$T_e = K_a \phi I_a$	$T_e = K_a \phi I_a$
Neglecting Saturation and armature reaction		$\phi_d = K_f I_f$ $E_g = K_a I_a \omega_m$ $T_e = K_a I_a^2$	$\phi_d = K_f I_f$ $E_g = K_a I_a \omega_m$ $T_e = K_a I_a^2$

$V_t$  = terminal voltage,  $E_g$  = generated emf,  $I_a$  = Armature current,  $I_f$  = field current,  $I_t$  = Load/Line current,  $R_a$  = armature resistance plus effective brush-commutator contact resistance,  $R_f$  = field resistance,  $\omega_m$  = angular speed (radians) =  $2\pi n/60$  where  $n$  = speed (RPM),  $P_e$  = Electromagnetic Power

Speed Regulation:  $SR = \frac{N_{NL} - N_{FL}}{N_{FL}}$ ,  $N$  = speed

Voltage Regulation:  $VR = \frac{V_{NL} - V_{FL}}{V_{FL}}$ ,  $V_t$  = terminal voltage

SYNCHRONOUS GENERATORS (Round Rotor)

Voltage per coil:  $E_{coil} \text{ (rms)} = (2\pi/\sqrt{2}) f_n N \phi_n = 4.44 f_n N \phi_n$ ,  $f$  = frequency,  $N$  = #turns/coil,  $\phi$  = flux/pole, subscript  $n$  = harmonic

Distribution factor:  $K_{dn} = \frac{\sin(0.5n\alpha)}{n \sin(0.5n\alpha)}$ ,  $n$  = harmonic,  $m$  = # individual coils,  $\alpha$  = slot angle, angle between adjacent slots ( $\theta_{ad}$ )

Pitch factor:  $K_{pn} = \sin\left(\frac{nP}{2}\right)$ ,  $P$  = pitch,  $n$  = harmonic

Voltage Generated:  $E_{gn} \text{ (rms)} = 4.44 K_w n f_n \phi_n N_1$ ,  $K_w$  = winding factor ( $K_p, K_d$ ),  $N_1$  = #turns/phase = (mN) where  $m$  = #coils,  $N$  = #turns/coil,  $\phi_n$  = flux/pole, subscript  $n$  = harmonic

