THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

FIRST SEMESTER EXAMINATION (2021)

EE313 ELECTRIC MACHINES

BEEL3

TIME ALLOWED: 3 HOURS

INFORMATION FOR STUDENTS:

- You have TEN (10) minutes to read the paper. You must NOT begin writing during this time.
- All answers must be written in the ANSWER BOOK supplied. COMPLETE THE DETAILS REQUIRED ON THE FRONT COVER OF YOUR ANSWER BOOK. DO THIS NOW.
- Drawing instruments and calculators are permitted.
- Answer ALL FIVE (5) questions.
- All questions carry equal marks.
- If you are found cheating in the examination, the penalties specified by the University shall apply.
- Switch OFF all mobile phones.

Question One **[4+2+2+2+2+2+6 = 20 marks]**

A. Define ***voltage regulation*** with regard to an alternator and state the corresponding equation.

B. Mention the use of ***damper winding*** in a synchronous motor

C. Why is the stator core of an alternator ***laminated***?

D. An Alternator is found to have its terminal voltage on load condition more than that on no-load. What is the nature of the load connected?

E. What is ***synchronizing*** in parallel operation of alternators?

F. What is a ***synchronous reactance*** and how and where does it exist in an alternator?

G. Compare salient pole rotor to cylindrical rotor with the given words

No	*Topic*	*Salient Pole*	*Cylindrical*	*Words*
1	Poles	A	B	Projected, non projected
2	Air gap	C	D	Uniform, non uniform
3	Diameter	E	F	Large, small
4	Axial length	G	H	Large, small
5	Damper winding	I	J	Required, not required
6	Speed rating	K	L	High, low

Question Two **[3+3+7+7 = 20 marks]**

A. What is ***hunting*** in synchronous motors?

B. State the difference between ***excitation voltage,*** $\overline{\mathbf{E}}_{\mathbf{a}}$, and ***effective excitation voltage,*** $\overline{\mathbf{E}}_{\mathbf{a}}'$ in a salient pole synchronous motor.

C. A 9-kVA, 208-V, 1200-rpm, three-phase, 60-Hz, Y-connected, synchronous generator has a field winding resistance of 4.5Ω. The armature-winding impedance is 0.3 + j5 Ω/phase. When the generator operates at its full load and 0.8 pf leading, the field winding current is 6 A. The rotational loss is 500 W.
Determine;

I. the voltage regulation
II. the efficiency of the generator
III. the torque applied to the prime mover.

D. Each coil of a double-layer wound, 4-pole, 36-slot, three-phase, Y-connected synchronous generator has 10 turns. The rotor is driven at a speed of 1800 rpm. The flux per pole is 50 mWb and each phase winding is connected in two parallel paths.
Determine;

I. The frequency of the induced emf
II. The phase and line voltage

Question Three [4+6+10 = 20 marks]

A. State four contrasts between a synchronous motor and an induction motor.

B. The rotor speed of a 440-V, 50-Hz, 8-pole, three-phase induction motor is 720 rpm.
Determine;

I. The synchronous speed
II. The slip
III. The rotor frequency

C. A 2-hp, 120-V, 60-Hz, 4-pole, three-phase, Y-connected, salient-pole, synchronous motor delivers the rated power at 0.8 pf lagging. If $X_d = 2.5\Omega$/phase and $X_q = 1.7\ \Omega$ /phase, and $P_r = 80$ W, determine;

I. The excitation voltage
II. The power angle
III. The power developed
IV. The torque developed
V. The efficiency of the motor

Question Four [4+2+14 = 20 marks]

A. The following equation is used to determine the power developed for a round rotor synchronous motor.

$$P_d = \frac{3E_aV_a}{Z_s^2}[R_a cos\,\delta + X_s sin\,\delta] - \frac{3E_a^2R_a}{Z_s^2}$$

Determine the maximum power developed (Show all working).

B. Define a ***synchronous condenser*** with reference to synchronous motor

C. A 20-hp, 480-V, 60-Hz, 12-pole, three-phase, Y-connected, salient-pole, synchronous motor delivers the rated load at a unity power factor. The d- and q-axis reactances are 1.5 Ω/phase and 0.9 Ω/phase, respectively. The rotational power loss is 800 W. The armature winding resistance is negligible.
Determine;

I. The excitation voltage
II. The power angle
III. The power developed due to the field excitation
IV. The power developed due to the saliency of the motor
V. The total power developed
VI. The torque developed
VII. The maximum power developed
VIII. The efficiency of the motor

Question Five [4+2+2+12 = marks]

A. There are two types of rotor construction in induction motors. What are they and when are they required?

B. Why is it necessary to skew the rotor laminations of an induction motor?

C. Explain why the rotor speed of an induction motor is unable to reach synchronous speed of the revolving field.

D. A 12-pole, 208-V, 50-Hz, Y-connected, three-phase induction motor has the following parameters on a per-phase basis: R_1=0.1 Ω, R_2 = 0.06 Ω, X_1 = 0.3 Ω, X_2 = 0.8 Ω, X_m = 750 Ω and R_c = 150 Ω. The friction and winding loss is 2 kW. Determine the efficiency of the motor at its full load slip of 5%.

Data sheet

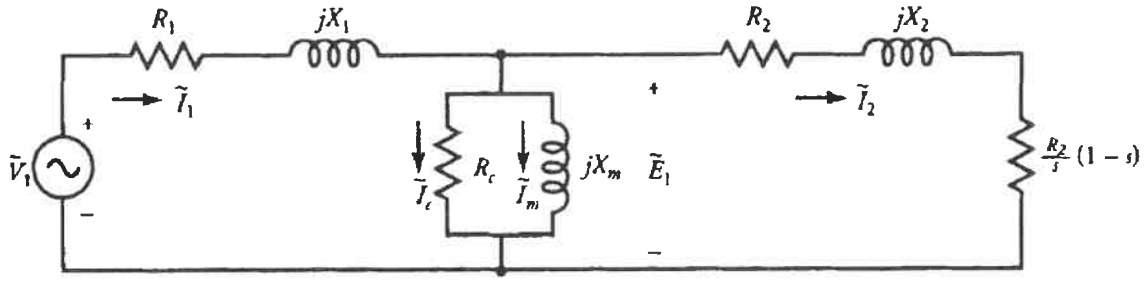


Figure 9.4 The equivalent circuit of Figure 9.3 modified to show the rotor and the load resistances.

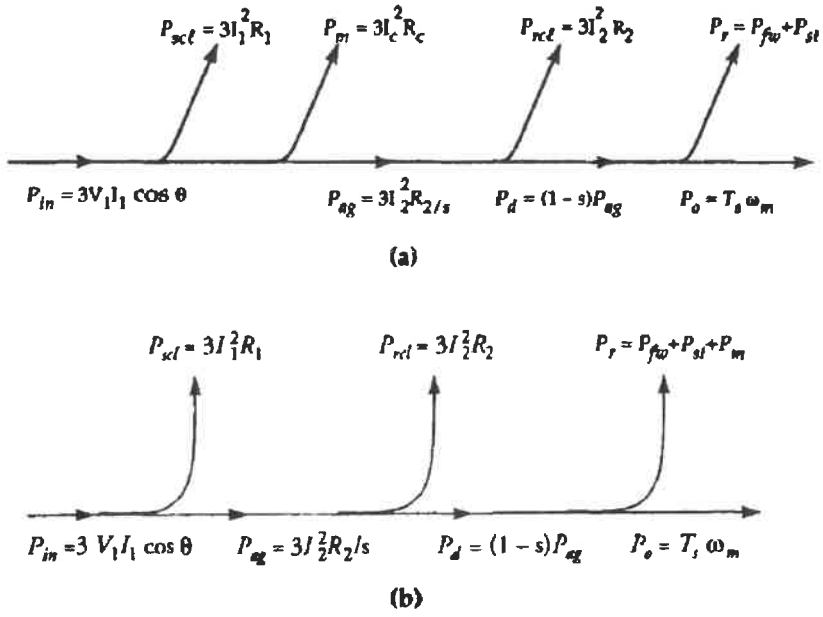


Figure 9.5 Power-flow diagram when the core loss is (a) simulated by R_c, and (b) treated as a part of the rotational loss.

$$P_d = \frac{3V_a E_a \sin\delta}{X_d} + 3V_a^2 \sin 2\delta \left[\frac{X_d - X_q}{2X_d X_q}\right]$$

$$T_d = \frac{3E_a V_a \sin\delta}{X_s \omega_s}$$

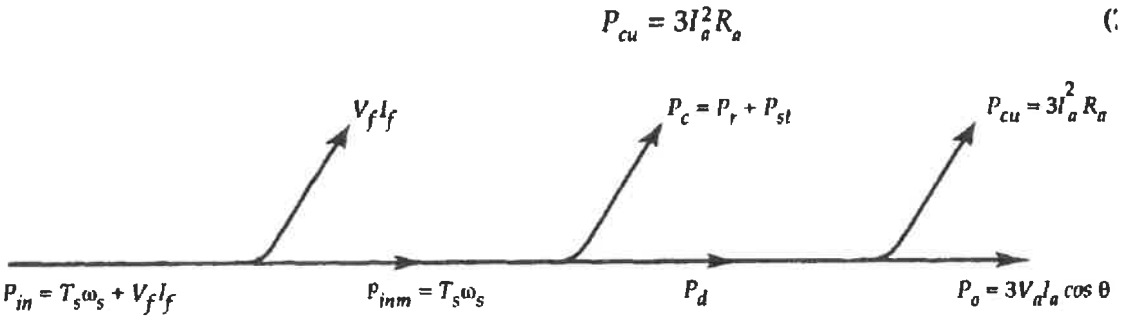
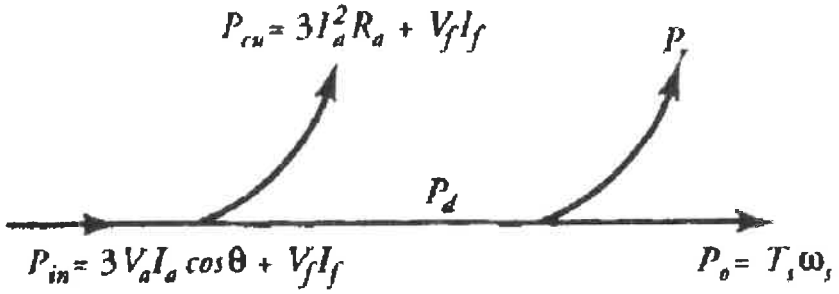


Figure 7.18 Power-flow diagram of a synchronous generator.



Power-flow diagram of a synchronous motor.

$$N_e = \frac{PnN_ck_w}{a}$$

$$E_a = 4.44\, fN_e\Phi_P$$

$$k_d = \frac{\sin(n\gamma/2)}{n\sin(\gamma/2)}$$

$$k_p = \sin(\rho/2)$$

$$\tilde{E}_a' = \tilde{V}_a - \tilde{I}_aR_a - j\tilde{I}_aX_q$$

$$\tilde{E}_a = \tilde{E}_a' - j\tilde{I}_d(X_d - X_q)$$

1 hp = 746 W

$$N_r = N_s - N_m$$

$$\omega_r = \omega_s - \omega_m$$

$$s = \frac{N_r}{N_s} = \frac{\omega_r}{\omega_s}$$

$$s = \frac{N_s - N_m}{N_s} = \frac{\omega_s - \omega_m}{\omega_s}$$

$$\tilde{I}_r = \frac{\tilde{E}_r}{R_r + jX_r} = \frac{s\tilde{E}_b}{R_r + jsX_b}$$

$$= \frac{\tilde{E}_b}{(R_r/s) + jX_b}$$