THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

FIRST SEMESTER EXAMINATION (2022)

EE313 ELECTRIC MACHINES

BEEP3 & BEEC3

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. State three (3) benefits that a **cylindrical rotor** offers in a synchronous generator.

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

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

D. Define **armature reaction** in synchronous generators?

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

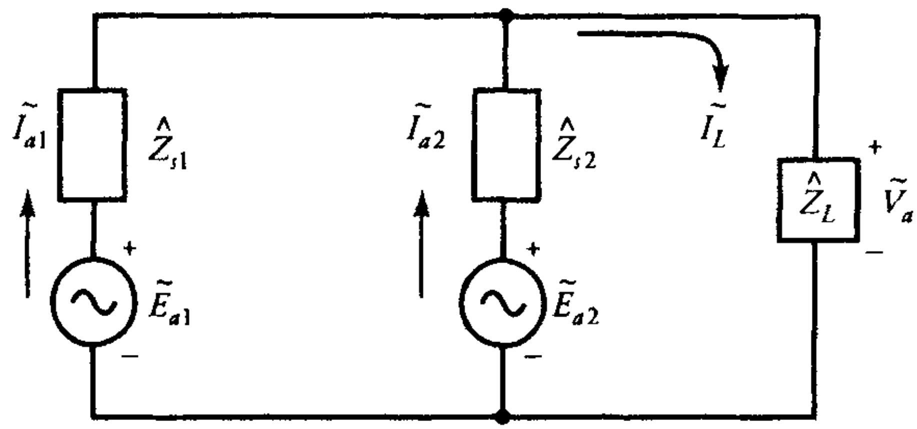
F. What is a ***synchronous reactance*** and how and where does it exist in an alternator?

G. State the requirements that must be satisfied before connecting an alternator to the main grid

Question Two [10+10 = 20 marks]

A. 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.

B. Two three-phase, Y-connected, synchronous generators have per-phase generated voltages of 120 V and 120 V under no load, and reactances of j5 Ω/phase and j8 Ω/phase, respectively. They are connected in parallel to a load impedance of 4 + j3 Ω/phase.



Determine;

I. the per-phase terminal voltage,
II. the armature current of each generator,
III. the power supplied by each generator, and
IV. the total power output.

Question Three [10+10 = 20 marks]

A. 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

B. A 480-V, three-phase, Y-connected, salient-pole, synchronous motor is operating at its full load and draws a current of 50 A at a unity power factor. The d- and q-axis reactances are 3.5 Ω/phase and 2.5 Ω/phase, respectively. The armature winding resistance is 0.5 Ω/phase.
Determine;
I. the excitation voltage of the motor and
II. the power developed by it.

Question Four [6+14 = 20 marks]

A. Why is an induction motor also called an asynchronous motor?

B. State the two main rotor classifications of induction motors

C. Define slip, s in induction motors

D. A 15-hp, 4-pole, 440-V, 60-Hz, Y-connected, three-phase induction motor runs at 1725 rpm on full load. The stator copper loss is 212 W, and the rotational loss is 340 W.
Determine;
   I. the power developed,
   II. the airgap power,
   III. the rotor copper loss,
   IV. the total power input,
   V. the efficiency of the motor and
   VI. the shaft torque

Question Five [10+2+2+6 = marks]

A. Name five (5) single phase motors and briefly describe the construction and operation of each

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

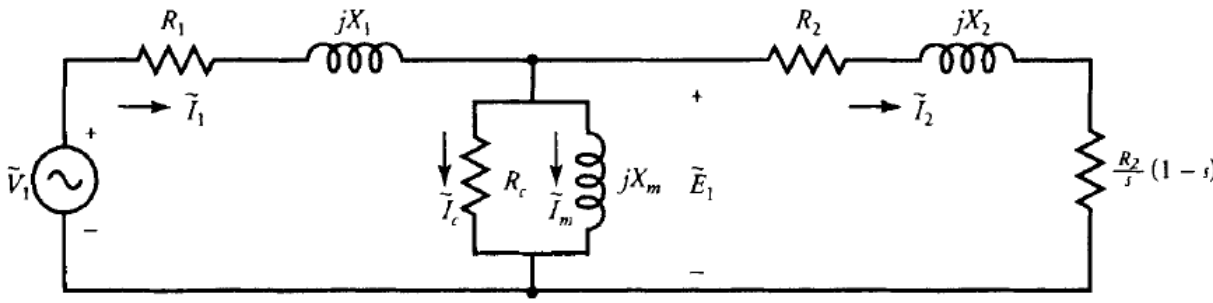


Figure 9.4 The equivalent circuit of Figure 9.3 modified to show the rotor and the load resistances.

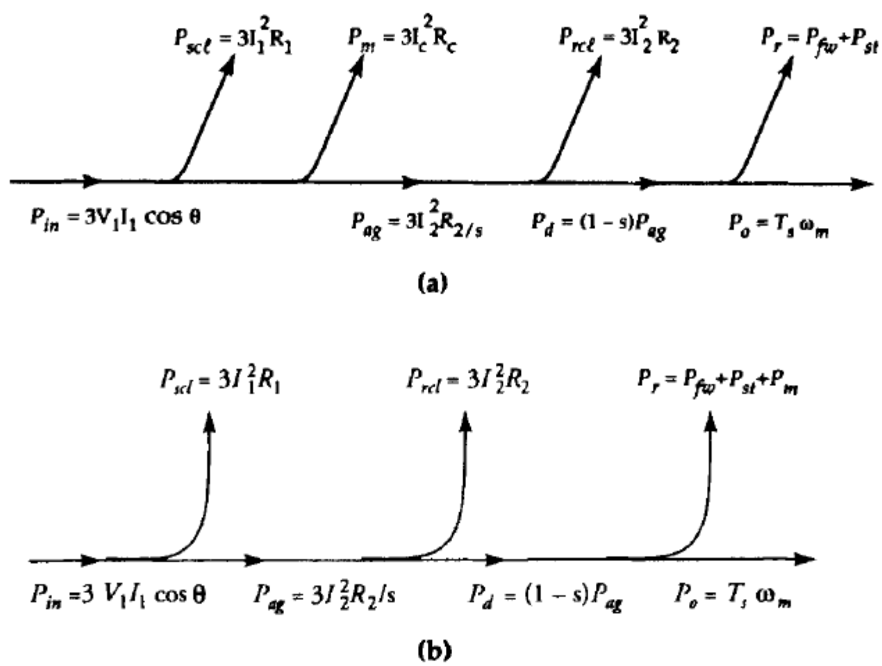


Figure 9.5 Power-flow diagram when the core loss is **(a)** simulated by R_c, and **(b)** treated as a part of the rotational loss.

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

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

$$P_{cu} = 3I_a^2 R_a$$

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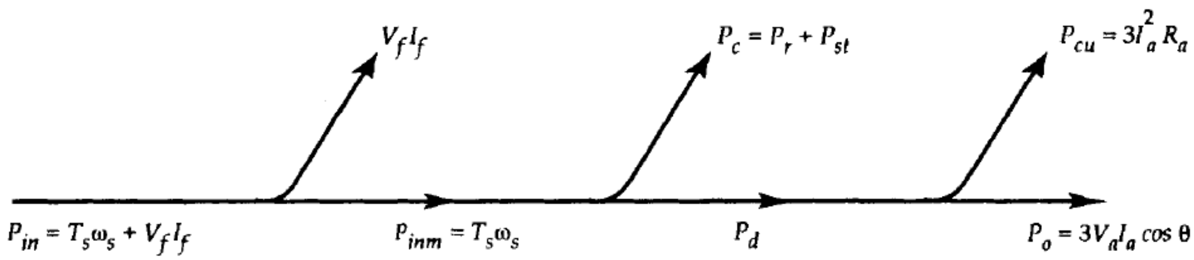
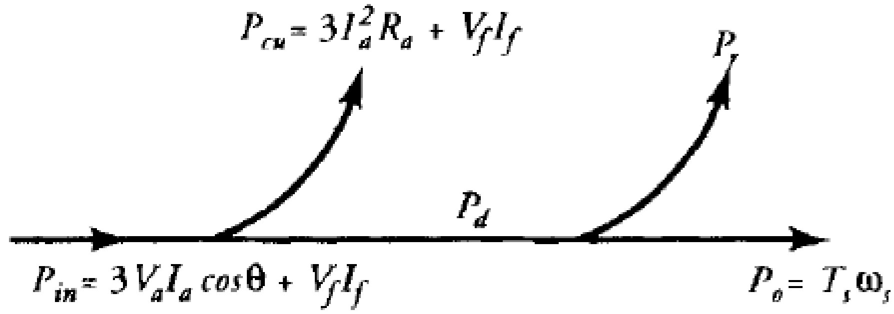


Figure 7.18 Power-flow diagram of a synchronous generator.



Power-flow diagram of a synchronous motor.

$$N_e = \frac{PnN_c k_w}{a}$$

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

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

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

$$\tilde{E}'_a = \tilde{V}_a - \tilde{I}_a R_a - j\tilde{I}_a X_q$$

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

1 hp = 746 W

$$N_r = N_s - N_m$$

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

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

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

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

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