Part IB Paper 5: Electrical Engineering
ELECTRICAL POWER

Examples Paper 5 Induction Motors

Straightforward questions are marked †
Tripos standard questions are marked *

Induction Motors

† 1. The following tests are carried out on a three-phase, star-connected, 415 V, 50 Hz, 4-pole induction motor.

	Line voltage	Speed	Input Current	Input Power (total)
(a)	415 V	1500 rpm	6.5 A	1720 W
(b)	65 V	0 rpm	60 A	4860 W

A d.c. measurement reveals the stator resistance to be $R_1 = 0.3\ \Omega$. Assuming that $X_1 = X'_2$, determine the parameters of the per-phase equivalent circuit.

2. A 415 V, star-connected, three-phase 50 Hz, 4-pole induction motor has the following parameters:

Stator resistance R_1 = 0.5 ohm per phase

Referred rotor resistance R'_2 = 0.6 ohm per phase

Combined leakage reactance (i.e. $X_1 + X'_2$) = 2.8 ohms per phase

The magnetising branch impedances are found to be large enough to be ignored in the equivalent circuit. Calculate the peak torque developed by the motor, and the speed at which it is delivered when the machine is star-connected to a 415 V supply.

* 3. An induction motor is rated as follows: Full-load output power, 6000 W; 415V line; 50 Hz; 3-phase; 6-pole; star-connected. The equivalent circuit parameters, referred to the stator are:

Stator resistance	1.52 ohms
Rotor resistance (referred)	0.74 ohms
Stator leakage reactance	2.15 ohms
Rotor leakage reactance (referred)	0.89 ohms
Magnetising reactance	56.5 ohms
Ratio of effective turns (stator/rotor)	1.5
Friction and windage losses	340 watts
Iron losses may be neglected	

Draw an equivalent circuit for the machine, and for a slip of 0.03 calculate:

(i)	Speed;	(vii)	loss torque;
(ii)	stator input impedance;	(viii)	output torque;
(iii)	stator current;	(ix)	output power;
(iv)	referred rotor current;	(x)	input power factor;
(v)	actual rotor current;	(xi)	efficiency.
(vi)	electromagnetic torque;		

* 4. For the machine described in Q3, calculate the slip, speed, and torque at maximum torque, and the slip at maximum output power. What resistance should be connected to the rotor circuit via the slip rings to obtain maximum starting torque ?

(HINT: To determine the slip at maximum output power, resolve the $\frac{R'_2}{s}$ resistor into R'_2 and $R'_2\left(\frac{1-s}{s}\right)$. The power associated with $R'_2\left(\frac{1-s}{s}\right)$ is the output power, and is to be maximised.)

Answers

1. $R_o = 100.1\ \Omega$, $X_o = 39.65\ \Omega$, $R'_2 = 0.15\ \Omega$, $X_1 = X'_2 = 0.217\ \Omega$

2. 163.9 Nm, 1184 rpm

3.

(i)	970 rpm	(vii)	3.35 Nm
(ii)	24.65 Ω	(viii)	51.25 Nm
(iii)	9.72 A	(ix)	5206 W
(iv)	8.79 A	(x)	0.88 (lag)
(v)	13.18 A	(xi)	84.65 %
(vi)	54.6 Nm		

4. 0.2234, 776.6 rpm 161.5 Nm; 0.1671, 1.14 Ω Per phase

Tripos Questions (Paper 5)

Year	Paper 5/3	Paper 5/4	Paper 5/5
2002	3	4	
2003	3	4 (pu)	5
2004	3	4	5
2005	5	3	4
2006	3	4	5
2007	3,4		5
2008	4	3	5
2009	3	4	5

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