Tutorial Sheet 7– Three phase Induction Motor

1. A 3-phase induction motor runs at almost 1,200 rpm at no load and 1,140rpm at full load when supplied with power from a 60 Hz, 3-phase line.
   a) How many poles does the motor have?
   b) What is the per cent slip at full load?
   c) What is the corresponding frequency of the rotor voltages?
   d) What is the corresponding speed (i) of the rotor field with respect to the rotor? (ii) of the rotor field with respect to the stator? (iii) of the rotor field with respect to the stator field?
   e) What speed would the rotor have at a slip of 10 per cent?
   f) What is the rotor frequency at this speed?
   g) Repeat part d for a slip of 10 per cent.

2. A 460-V, four-pole, 50-hp, 60-Hz, Y-connected, three-phase induction motor develops its full-load induced torque at 3.8 percent slip when operating at 60Hz and 460V, The per-phase impedances of the motor are

$r_1 = 0.33\Omega$	$X_m = 30\Omega$
$x_1 = 0.42\Omega$	$x_2^{/} = 0.42\Omega$

   Mechanical, core, and stray losses may be neglected in this problem.

   a) Find the value of the rotor resistance $r_{2.}$
   b) Find $T_{max,}s_{max,}$ and the rotor speed at maximum torque for this motor.
   c) Find the starting torque of this motor. [Ans: (a) 0.171 Ω, 0.0068 Ω, (b) 448 N-m, 0.191, (c) 198 N-m]

3. A 460V, 100hp, four-pole, Δ-connected, 60-Hz, three-phase induction motor has a full-load slip of 5 percent, an efficiency of 92 percent, and a power factor of 0.87 lagging. At start-up the motor develops 1.9 times the full-load torque but draws 8.5 times the rated current at the rated voltage. This motor is to be started with reduced-voltage.
   (a) What should be the reduced supply voltage so that the starting torque is equal to the rated torque of the motor?
   (b) What will the motor starting current at this voltage? [Ans: (a) 333 V, (b) 716 A]

4. An induction motor has an efficiency of 0.9 when the load is 50h.p. At this load, the stator copper and rotor copper loss each equals the iron loss. The mechanical losses are one-third of the no load loss. Calculate the slip. [Ans: 0.03]

5. A 3-phase induction motor has a 4-pole, star-connected stator winding. The motor runs on a 50-c/s supply with 200V between lines. The rotor resistance and standstill reactance per phase are 0.1Ω and 0.9Ω respectively. The ratio of rotor to stator turns is 0.67. Calculate: (a) total torque at 4% slip; (b) total mechanical power at 4% slip; (c) maximum torque; (d) speed at maximum torque; (e) maximum mechanical power. Neglect stator impedance.
   [(a) 40.48 N-m, (b) 6.1 kW, (c) 63 N-m, (d) 1333 rpm; (e) 8.9 kW]

6. A 3-phase induction motor with star-connected rotor has an induced electromotive force of 60V between slip-rings at standstill on open-circuit with normal voltage applied to the stator. The resistance and standstill reactance of each rotor phase are 0.6 Ω and 4Ω respectively. Calculate the current per phase in the rotor
   a) when at standstill and connected to a star-connected rheostat of resistance 5Ω and reactance 2Ω per phase;
   b) when running short-circuited with 4% slip.

   [ans: (a) 4.22A; (b) 2.22A.]

7. The rotor of a 6-pole, 50c/s, slip-ring induction motor has a resistance of 0.2 Ω per phase, and runs at 960 rev per min on full load. Calculate the approximate resistance per phase of a rotor rheostat such that the speed is reduced to 800rev per min for full-load torque. [0.8Ω.]

8. When operated at rated voltage and frequency, a 3-ph squirrel cage induction motor delivers full load at a slip of 5% and develops a maximum torque of 250% of full load torque at a slip of 25%. Neglecting core loss and rotational losses and assuming that the resistances and inductances of the motor are constant, determine the starting torque (at rated voltage and frequency) of the motor expressed as percentage of the full load torque.

   [Ans: 121.67%]

9. A 500-hp wound rotor induction motor, with its slip rings short-circuited has the following properties:
   Full load slip = 1.5%
   Rotor I^2R at full load torque = 5.69 kW
   Slip at maximum torque = 6.0%
   Rotor current at maximum torque = $2.82I_{2fl}$, where I_{2fl} is the full load rotor current
   Torque at 20% slip = $3.95I_{2fl}$
   If the rotor-circuit resistance is increased to $5R_{rotor}$ by connecting non-inductive resistance in series with each rotor slip-ring, determine:
   a) the slip at which the motor will develop the same full-load torque,
   b) the total rotor circuit I^2R loss at full-load torque,
   c) the horse power output at full-load torque,
   d) the slip at maximum torque,
   e) the rotor current at maximum torque,
   f) the starting torque, and
   g) the rotor current at starting. Express the torques and rotor currents in per unit based on the full-load torque values.