# EE3124 Tutorial 7 (Solution)
# Special Machines and Applications

**Name:** **Student No.:**

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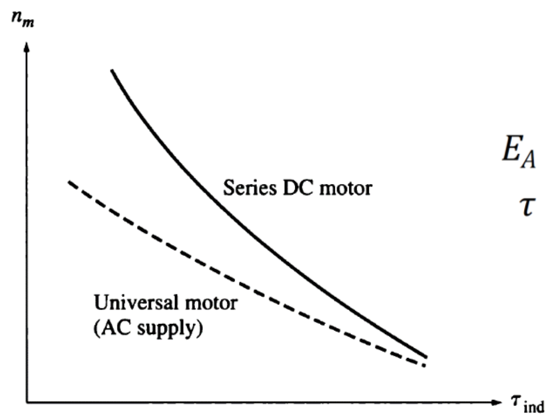
**Q1 -** Why is the torque-speed characteristic of a universal motor on an ac source different from the torque-speed characteristic of the same motor on a dc source?

**Solution**




$$E_A = K_e \phi \omega_m$$
$$\tau = K_e \phi I_A$$

1) The armature and field windings have quite a large reactance at 50 or 60 Hz. A significant part of the input voltage is dropped across these reactances, and therefore $E_A$ is smaller for a given input voltage during AC operation than it is during dc operation. Since the motor is slower for a given armature current and induced torque on alternating current than it would be on direct current.
2) The peak voltage of an ac system is square root 2 its rms value, so magnetic saturation could occur near the peak current in the machine. This saturation could significantly lower the rms flux of the motor for a given current level, tending to reduce the machine’s induced torque.

**Q2 -** Why is a single-phase induction motor unable to start itself without special auxiliary windings?

**Solution**

When single-phase AC supply is given to stator winding. It produces alternating flux.i.e. which alternates along one space axis only. It is not synchronously revolving (or rotating) flux, as in case of 3 phase stator winding, the fed cannot produce rotation. Hence single phase induction motor is not self-starting. To overcome this problem and to make the motor self-starting, it is temporarily converted into two-phase motor during starting. For this purpose, the stator of 1 phase motor is provided with extra winding known as starting winding in addition to the main winding. These two winding are placed across the single phase supply.

**Q3 -** A three-phase P.M. brushless DC motor has a torque constant ($k\Phi$) of 0.12 Nm/A referred to the DC supply. If the armature resistance is 0.150 Ω/phase and the voltage drop across the semiconductor switch is 1 V.

i) what is the no-load speed in r.p.m. when it is connected to a 48 V DC supply.

ii) What is the pullout torque and current of the motor?

iii) What is the maximum power speed in r.p.m.?

**Solution**

i) $$\omega_o = \frac{V'}{k'} = \frac{48-2}{0.12} = 383 rads/\sec$$

$$=3662 \text{rpm}$$

ii) $$I_o = \frac{48-2}{2\times 0.15} = 153A$$

$$T_o = 153 \times 0.12 = 18.4Nm$$

iii) $$P = \tau\omega = \frac{k\phi}{2R_{ph}}(V' - k\phi\omega)\omega$$

$$\frac{dP}{d\omega} = \frac{k\phi}{2R_{ph}}(V' - 2k\phi\omega) = 0$$

$$V' = 2k\phi\omega$$

$$\omega = \frac{V'}{2k\phi} = \frac{46}{2\times 0.12} = 191.67\frac{\text{rads}}{\text{sec}}$$

$$= 1830 \text{ r.p.m.}$$

**Q4** - An universal motor is very similar to a DC series motor in construction, but it is modified slightly to allow the motor to operate properly on AC power. A washing machine is driven by an universal motor, which is powered by single-phase AC source having 110 Vac and 60 Hz. The armature winding of the motor has the resistance and inductance of 0.4 Ω and 3 mH, respectively. The field winding of the motor has the resistance and inductance of 0.8 Ω and 6 mH, respectively. When the washing machine operates at half load torque, the motor draws 10 Aac and runs at 1000 rpm. Calculate the input current and speed of the motor when the washing machine operates at full load torque.

At half load torque,

(i) Calculate impedance of the armature and field windings.

(ii) Calculate the average electromotive force (emf) and average current in the armature.

At full load torque.

(iii) Determine the average and root mean square armature current.

(iv) Determine the average emf in the armature.

(v) Determine the speed of the motor.

**Solution**

(i)

$$Z = \left|(R_a + j\omega L_a) + (R_f + j\omega L_f)\right|$$
$$= \left|(0.4 + j2\times\pi\times 60\times 3\times 10^{-3}) + (0.8 + j2\times\pi\times 60\times 6\times 10^{-3})\right|$$
$$= 3.599\Omega$$

(ii)

When the motor is operated at half load torque, the rms value of the emf in the armature is

$$E_{rms} = V_{rms} - I_{rms}Z$$
$$= 110 - 3.599\times 10$$
$$= 74.01V$$

The average (half-wave) $E_{ave}$ and $I_{ave}$ in the armature become

$$E_{ave} = \frac{2\sqrt{2}E_{rms}}{\pi} = \frac{2\sqrt{2}\times 74.01}{\pi} = 66.632V$$

$$I_{ave} = \frac{2\sqrt{2}I_{rms}}{\pi} = \frac{2\sqrt{2}\times 10}{\pi} = 9A$$

(iii)

When the motor is operated at full load

Since, $T_{ave} = K_a K_f I_{f(ave)} I_{a(ave)} = K_{af} I_{ave}^2$ , While the torque increased two time,

$$2T_{ave} = 2K_{af} I_{ave}^2$$

Therefore, at full-load torque, average armature current is $\sqrt{2I_{ave}^2} = \sqrt{2 \times 9^2} = 12.728A$

The rms current becomes, $I_{rms} = \dfrac{I_{ave\_full} \times \pi}{2\sqrt{2}} = \dfrac{12.728 \times \pi}{2\sqrt{2}} = 14.137A$

(iv)

$$\begin{aligned} E_{rms\_full} &= V_{rms} - I_{rms\_full} Z \\ &= 110 - 14.137 \times 3.599 \\ &= 59.12V \\ E_{ave\_full} &= 53.227V \end{aligned}$$

(v)

We have $E$ in terms of $I$ and ω is

$$E = K_a \phi \omega = K_{af} I \omega$$

$$E \propto I\varpi$$

$$rpm \propto \frac{E}{I}$$

$$rmp_{full} = rpm_{half} \times \frac{I_{ave\_half}}{E_{ave\_half}} \times \frac{E_{ave\_full}}{I_{ave\_full}} = 1000 \times \frac{9}{66.632} \times \frac{53.227}{12.728} = 564.85\ rpm$$