Rotating Magnetic Field in AC Machines

1 Introduction

In a DC machine, the stator winding is excited by DC current and hence the field produced by this winding is time invariant in nature. In this machine the conversion of energy from electrical to mechanical form or vice versa is possible by one of the following ways:

1. rotating the rotor in the field produced by the stator
2. feeding external dc current through carbon brushes to the rotor

2 Pre-lab questions

Let, \( \text{XX} = \text{Last two digits of your roll number} \)

\[ g_1(t) = \cos(\omega t) \quad \text{and} \quad g_2(t, \theta) = \cos(\omega t) \cos(\theta) \]

1. Take \( \omega = 2\pi f \), where \( f = \text{XX} \times 50 \). Vary \( \omega t \) from 0 to \( 2\pi \). Plot \( g_1(t) \) vs \( t \) using MATLAB (or any other suitable software)

2. Take \( \omega = 2\pi f \), where \( f = \text{XX} \times 50 \). Vary \( \omega t \) from 0 to \( 2\pi \).
   Take \( \theta = 0 \) to \( 2\pi \). Plot \( g_2(t, \theta) \) vs \( t \); for \( \theta = \text{XX} \)
   Plot \( g_2(t, \theta) \) vs \( \theta \); for \( \omega t = 0, \pi/4, \pi/2, 2\pi/3 \)

3 Theory

Now consider three coils A, B and C of N turns each, displaced in space by \( 120^\circ \) and connected to a balanced 3 phase system as shown in Fig. 1. (Note that the stator winding of 3 phase induction machine is distributed in a large number of slots as shown in Fig. 2). The expressions for the current

![Figure 1: Coil arrangement to produce rotating magnetic field](image-url)
drawn by these coils are given by:

\[ i_a = I \sin(\omega_s t) \]
\[ i_b = I \sin(\omega_s t + 120^\circ) \]
\[ i_c = I \sin(\omega_s t + 240^\circ) \]  
(1)

where \( \omega_s = 2\pi F_1 \) is supply frequency in rad/s and \( F_1 \) is supply frequency in Hertz. When this alternating current flows through the coil it produces a pulsating magnetic field whose amplitude and direction depend on the instantaneous value of the current flowing through the coil. Each phase winding produces a similar magnetic field displaced by 120° degrees in space from each other.

The steps involved in determining the magnitude and position of the resultant field produced by these coils are as follows:

1. Resolve the field produced by individual coil along x and y axes
2. Determine \( \sum x \) and \( \sum y \) components
3. Find the magnitude and angle of the resultant magnetic field with respect to the axis of coil-A

![Figure 2: Distributed coil arrangement for 2 pole 3 phase induction machine](image)

The sum of the x-axis component of the field produced by the three coils is given by:

\[ \sum x = Ni_a + Ni_b \cos 120^\circ + Ni_c \cos 240^\circ \]
\[ = Ni_a - N \frac{i_b + i_c}{2} = \frac{3}{2} Ni_a \]

...as \( i_a + i_b + i_c = 0 \)  
(2)

Similarly,

\[ \sum y = 0 + Ni_b \sin 120^\circ + Ni_c \sin 240^\circ \]
\[ = \frac{\sqrt{3}}{2} N (i_b - i_c) \]  
(3)

The magnitude and angle of the resultant magnetic field are given by

\[ R = \sqrt{ (\sum x)^2 + (\sum y)^2 } \]
\[ \theta = \tan^{-1} \left( \frac{\sum y}{\sum x} \right) \]  
(4)
\[ \omega_{m} = \omega_{s} \frac{2}{P} \text{ radians (mechanical)/sec} \quad \text{... as 1° elec = } \frac{2}{P} \text{ mech} \quad (5) \]

If \( N_{s} \) is the speed of the stator magnetic field in ‘rpm’, then

\[ \frac{2\pi N_{s}}{60} = \frac{2}{P} 2\pi F_{1} \Rightarrow N_{s} = \frac{120F_{1}}{P} \quad (6) \]

4 Procedure

Instructions to TAs/ RAs: There is an opened induction machine in the lab. A sample machine is also there at the FEEDBACK apparatus. Show the setup to students and identify various parts like coil-sides, insulation, laminations etc.

4.1 Demonstration Procedure

1. Connect the three phase winding to a three phase supply.
2. Apply a small fraction (say 10%) of rated voltage.
3. Place magnetic compass needle inside the rotor. The needle should start rotating. This demonstrates that there is rotating magnetic field.

References