

**EE568 – Selected Topics on Electrical Machines**

Project #2: Motor Winding Design & Analysis

by

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# Introduction

# Question 1: Integral-Slot Winding Design

## Winding Diagram

The stator consists of 120 slots, 20 poles and 3 phases. This configuration results in a q value of 2, which states number of slots per pole per phase.

(1)

This slot and pole value results in an electrical angle of 30° degrees between each slot, whose derivation is given in (2).

(2)

Table 1 : Winding Distribution of the Integral Slot Machine

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Slot Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Electrical Angle | 0° | 30° | 60° | 90° | 120° | 150° | 180° | 210° | 240° | 270° | 300° | 330° |
| Coil distribution | A | A | -C | -C | B | B | -A | -A | C | C | -B | -B |

## Distribution factor, Pitch factor, Winding factor calculation for the fundamental

The results of distribution factor, pitch factor and winding factor are provided in (3), (4) & (5) respectively for the fundamental frequency.

(3)

(4)

(5)

## Distribution factor, Pitch factor, Winding factor calculation for the 3rd and 5th harmonic

The results of distribution factor, pitch factor and winding factor are provided in (6), (7) & (8) respectively for the 3rd, (9), (10), (11) for the 5th harmonic.

(6)

(7)

(8)

(9)

(10)

(11)

## Comments

kd1 and kp1 values are close to unity meaning that in this winding distribution the fundamental component’s magnitude is as high as possible.

However, kd3, kp3, kd5, kp5 values are considerably high. These values affect the magnitude of their corresponding harmonics. Even though their flux density magnitudes are low, their induced voltages can be larger due to their higher frequency. Negative value of kw3 states that the 3rd harmonic component will rotate in the reverse direction when compared to fundamental. Due to the high frequency and reverse direction, the magnitude of the voltage induced on the rotor due to the 3rd harmonic will get even larger, causing more losses.

# Question 2: Fractional-Slot Winding Design

In this part, I have chosen a machine which has 24 slots, 20 poles and 3 phases. From [Emetor Winding Design](https://www.emetor.com/windings/) tool, it can be seen that this configuration results in a winding factor of 0.966.

(12)

(13)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Slot Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Electrical Angle | 0° | 150° | 300° | 450° | 600° | 750° | 900° | 1050° | 1200° | 1350° | 1500° | 1650° |
| Electrical Angle (Normalized) | 0° | 150° | 300° | 90° | 240° | 30° | 180° | 330° | 120° | 270° | 60° | 210° |
| Coil distribution | A1 | C1 | -C1 | -B1 | B1 | A3 | -A3 | -C3 | C3 | B3 | -B3 | -A2 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| Slot Number | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Electrical Angle | 1800° | 1950° | 2100° | 2250° | 2400° | 2550° | 2700° | 2850° | 3000° | 3150° | 3300° | 3450° |
| Electrical Angle (Normalized) | 0° | 150° | 300° | 90° | 240° | 30° | 180° | 330° | 120° | 270° | 60° | 210° |
| Coil distribution | A2 | C2 | -C2 | -B2 | B2 | A4 | -A4 | -C4 | C4 | B4 | -B4 | -A1 |

(14)

(concentrated winding) (15)

(16)

(17)

(concentrated winding) (18)

(19)

(20)

(concentrated winding) (21)

(22)