

**MIDDLE EAST TECHNICAL UNIVERSITY**

EE564

DESIGN OF ELECTRICAL MACHINES

Project-2 Motor Winding Design & Analysis

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# WINDING DESIGN

In this study, design and analysis of stator winding for a 400V(l-l), 50 Hz, three-phase, squirrel cage, four-pole induction motor built with IEC 63/6-8.55 laminations from Kienle Spiess. Thickness of the laminations is selected to be 0.5 mm and dimensions of the core material are given in Figure 1.1.

## 

(a)

## 

(b) (c)

Figure 1.1 (a) properties of the selected lamination and dimension legend for (b) stator, (c) rotor

As it is given in Figure 1.1, selected stator lamination is constituted by 36 slots(Q*s*), as a starting point an four pole, integral slot, full-pitched, double layer stator winding has been constructed and corresponding winding diagram given with MMF waveforms are given for both Ia=1, Ib= -0.5 Ic=-0.5 and Ia=-0.5, Ib= 1, Ic=-0.5 in Figure 1.2. It shows that the resulting MMF waveform has almost a sinusoid shape with a triangular appearance at the peaks indicating a 5th and/or 7th harmonic content.

As the number of slots per pole per phase (q) and slot angle(α) have already been set and which are given by:

=3

distribution factor(kd) can be calculated by for nth harmonic order

where is the number of pole pairs, m is the number of phases and n is the harmonic order.

Table 1.1 Distribution factors for full-pitched winding

|  |  |
| --- | --- |
| Harmonic order | Distribution factor (kd) |
| Fundemental | 0.9598 |
| 3 | 0.6667 |
| 5 | 0.2176 |
| 7 | -0.1774 |
| 9 | -0.3333 |
| 11 | -0.1774 |
| 13 | 0.2176 |



Figure 1.2 Full pitched, double layer stator winding diagram and corresponding MMF waveform for (top) Ia=1pu, Ib= -0.5pu Ic=-0.5pu, (bottom) Ia=-0.5pu, Ib= 1pu , Ic= -0.5pu

In order to minimize the harmonic content of the induced voltages and resulting harmonics in the current drawn from the supply network, winding factors for low order harmonics can be optimized by adjusting pitch factor

where is the coil pitch (electrical).

Using the software in [3], winding factors for various short pitched alternatives are calculated and depicted in Table 1.2, after evaluating the table 8/9 coil span is found to be optimal choice since it will provide a significant attenuation for low order harmonics of the induced voltages with a small sacrifice in the fundamental voltages. New winding diagram and MMF waveform is given for Ia=1, Ib= -0.5 Ic=-0.5 in Figure 1.2.

Table 1.2 Absolute values of winding factors for different coil spans

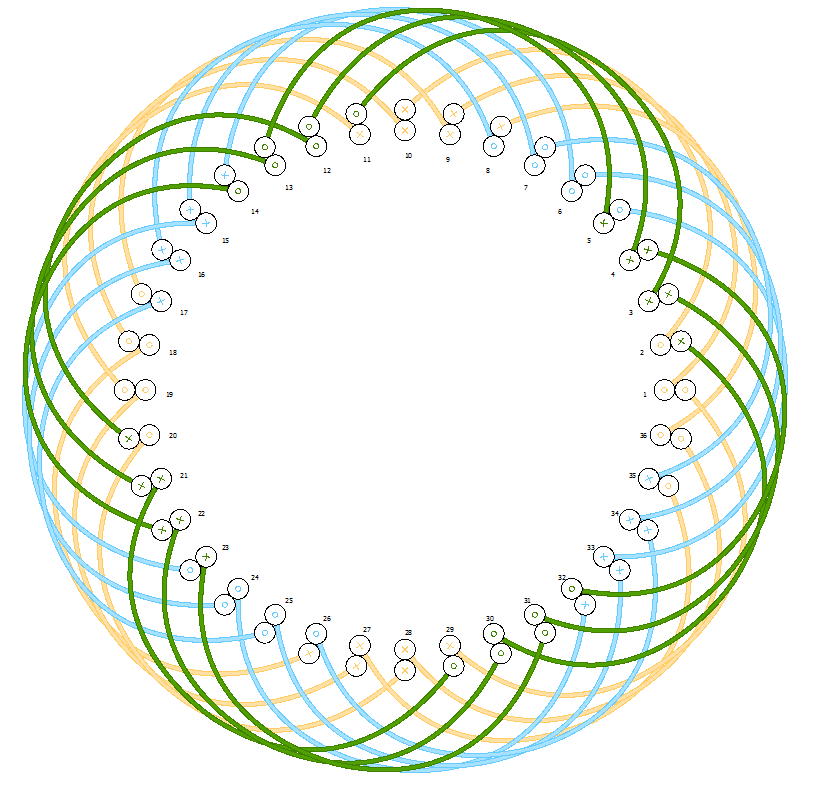
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Winding Factor | Full Pitch | 8/9 | 7/9 | 6/9 |
| kw1 | 0.960 | 0.945 | 0.902 | 0.831 |
| kw5 | 0.217 | 0.140 | 0.038 | 0.188 |
| kw7 | 0.177 | 0.060 | 0.136 | 0.154 |
| kw11 | 0.177 | 0.060 | 0.136 | 0.154 |
| kw13 | 0.217 | 0.140 | 0.038 | 0.189 |

Taking the machine aspect ratio (l’/D) as ~1, and taking kWs/m3

expected mechanical power rating of this machine is found to be

For a four-pole machine at this power range, power factor is around 0.8 [2], taking %80 efficiency at full-load, rated rms current of the machine can be found by

= 0.54A



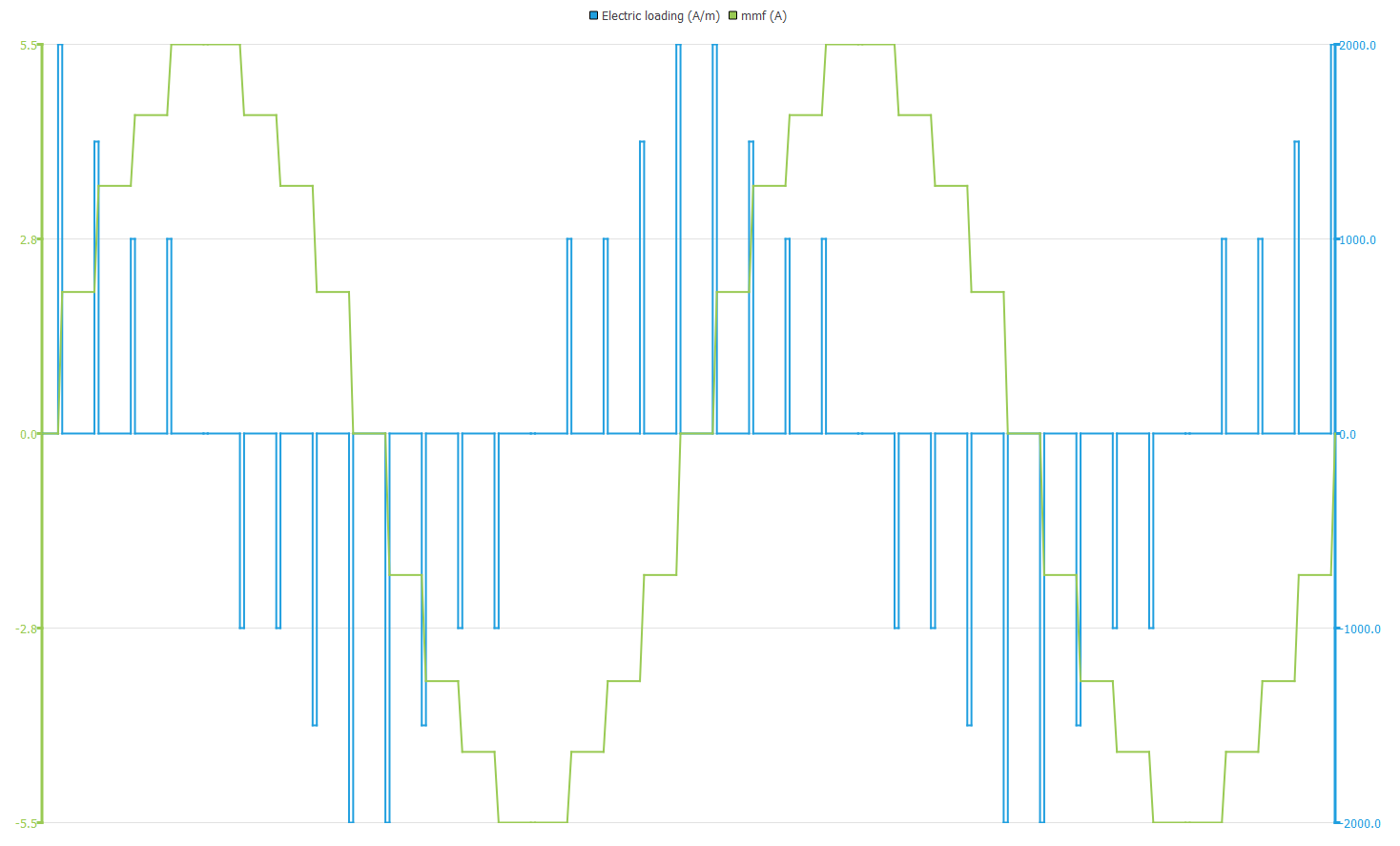


Figure 1.3 Winding diagram and corresponding MMF waveform for 8/9 coil span with Ia=1pu, Ib= -0.5pu Ic=-0.5pu

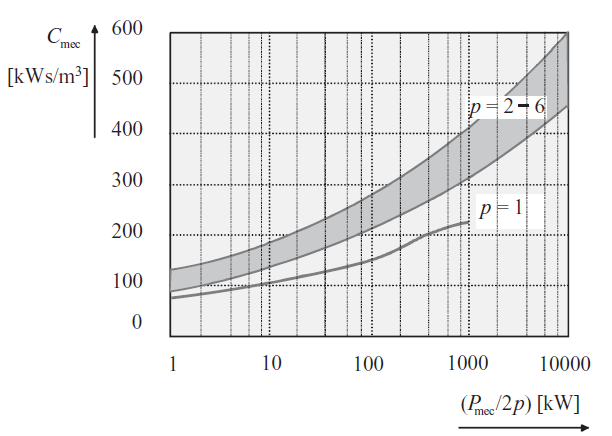


Figure 1.4 Machine constants of totally enclosed asynchronous and synchronous machines as a function of pole power [2]

If Y-connection is chosen, rated current of the coils are equal to the line currents. Then, taking current density, J as 3A/mm 2 (considering AC resistance) wire size (Ac) can be found as

For a double-layer winding, fill factor/space factor of the stator will be limited to 0.6 [2]. Taking fill factor as 0.6, and using slot area As (41mm2 from Figure 1.1)

number of conductors in one slot,

Then using the equality, number of series turns in one phase, is found to be 744

# REFERENCES

## [1] [0079337A7](https://www.mag-inc.com/Media/Magnetics/Datasheets/0079337A7.pdf) datasheet.

## [2] Pyrhonen, J., Jokinen, T., & Hrabovcova, V. (2013). Design of rotating electrical machines. John Wiley & Sons.

## [3] https://sourceforge.net/projects/dolomites/